Astronomy and astro-physics

THE
SIDEREAL MESSENGER,

A MONTHLY REVIEW OF ASTRONOMY.

VOL. X.

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY.

NORTHFIELD, MINN.
CARLETON COLLEGE OBSERVATORY.
1891.

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KARL LUDWIG HENCKE.

From Himmel und Erde.

THE SIDEREA[illegible] [illegible]ENGER,

CONDUCTED BY WM. [illegible]

DIRECTOR OF CARLETON C[illegible] OBSERV[illegible]

Vol. 10, No. 1. JANUARY, 1891.

THE PROPER MOTION OF THE COMPONENTS [illegible]

S. W. BURNHAM.*

Written for the Messenger.

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* Astronomer, Lick Observatory.

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VOL. 10, NO. 1. JANUARY, 1891. WHOLE NO. 91

THE PROPER MOTION OF THE COMPONENTS OF 61 CYGNI.

S. W. BURNHAM.*

FOR THE MESSENGER.

I have never been able to find in the micrometrical observations of 61 Cygni any evidence of physical connection between these two stars, or rather that they probably form a binary system. The fact that the measures appear to show rectilinear motion only; and the further fact that the two stars have a different proper motion, at least tend to show that each is moving independently through space. At this time 61 Cygni certainly looks like a double star, although even now the distance between the star is much too great to indicate that it is probably binary; but a thousand years ago, taking the proper motions as substantially correct, no double star observer would have thought of looking at it a second time. The stars are now slowly separating, and it is easy to predict what their appearance will be to the observers of a hundred years hence. We have no example of a well recognized binary where the distance between the components is anything like as large as that of 61 Cygni. All of the systems showing sufficient angular motion to make it certain that the stars are revolving about a common center of gravity, have comparatively small apparent distances. This is so well recognized that it has not been considered worth while, so far as the discovery of binaries is concerned, to record new objects where the distances of nearly equal components exceed two or three seconds; and it is equally certain that stars in rapid motion will be found only where the minimum distances are much less than 1″. Just what should be inferred from stars having nearly the same proper motion, and in the same direction, perhaps no one is prepared to say at this time. There are many examples in the

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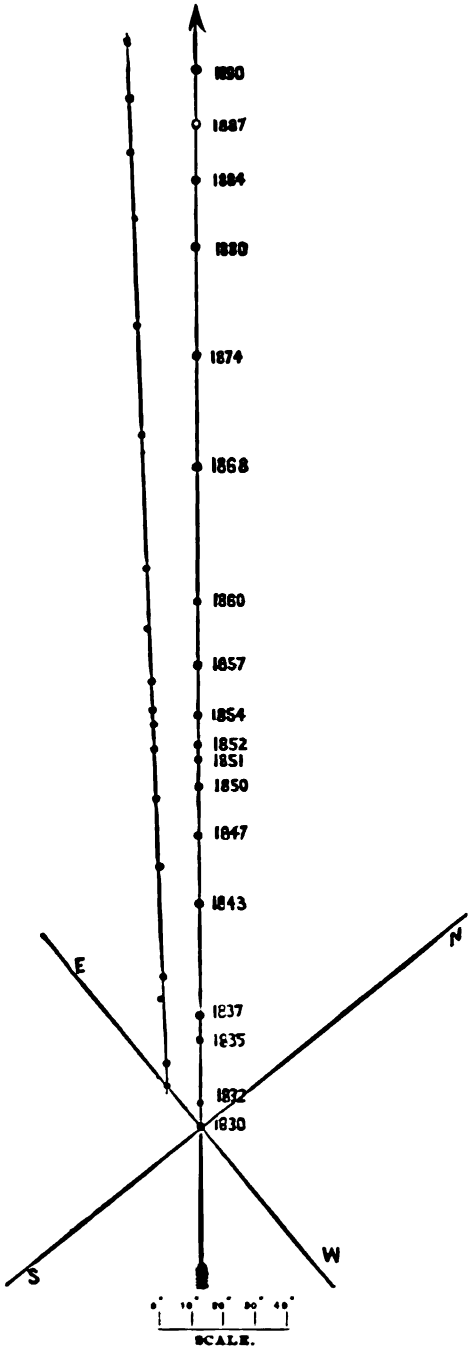
*Astronomer, Lick Observatory.

heavens of this common movement. Some of the stars, like 61 Cygni, are apparently near each other; while others, like those of the Great Dipper, are widely separated, and no one would think of suspecting that they had an orbital motion with reference to each other, although they, and the components of 61 Cygni, may be moving around some common central point.

If the measures of 61 Cygni, commencing with the earliest observations, are carefully platted, they will be found to represent, as nearly as measures can which are more or less in error, rectilinear motion. Of course some of the measures will lie on one side or the other of any line that can be drawn; and if some of the measured distances near either end of the line are a little too small, as is quite likely to be the case, they will give the whole series the appearance of a curve. I have platted in this way scores of stars where there was no suspicion of anything but proper motion, and very rarely, if ever, found an instance where the measures as a whole were so well represented by a straight line. When the relative accuracy of the several measures is taken into account, by considering the times at which the observations were made, the instruments used in the work, the number of nights contributing to the mean results, and particularly the experience of the observers, it is not difficult to draw a line which will represent the motion of the star with all the accuracy attainable from the given data.

Until recently I have never measured 61 Cygni, for the reason that much more time has been given to measures of this pair than its importance as a double star warrants, when so many far more interesting systems have been either very imperfectly followed, or almost wholly neglected. In order to see where the present place of the secondary star would be on the line representing its apparent movement, I have made within the last two or three weeks a set of measures on four nights with the 12-inch telescope. These measures give for the distance 21″.15, and the position-angle 121°.9 (1890.87); and represent as well as could be desired the change due to the proper motions of the two stars.

Two ways may be employed to show graphically from the measures the several positions of the components. The first and the one generally used, is to treat the primary star as



fixed during all the observations, and lay off the angle and distance of the companion at each epoch. In this case the companion, if it has no motion of its own, will have an apparent motion equal to the real proper motion of the principal star and in the opposite direction. The other plan is to plat the measures with the primary shifted along the line of its proper motion by the exact amount of its displacement during the interval between successive observations; in other words giving the two stars the exact places they actually occupy in the heavens at every measure. This method has a great advantage over the other when the proper motion, as in the case of 61 Cygni, is accurately known. I have used both in this case, and give here the latter diagram, which was made on a scale of 20″ = 1 inch. The angles were carefully laid off to the nearest tenth of a degree, and the distance to the nearest tenth of a second. The latest determination of the annual proper motion of the principal star is given as 5″.196 in the direction of 51°.5, and this value was used in platting the measures. The measures from 1830 to 1874 inclusive are by Σ and OΣ; those of 1880 and 1884 are by Hall; 1887 by Schiaparelli; and 1890 my own measures previously referred to. The original diagram when completed was reduced in the camera to the size given here.

It will be seen that these measures give not the least indication of departure from rectilinear motion in the smaller star. Indeed, they could not better represent absolute motion in a right line. We have all sorts of measures of this pair, good, bad and indifferent; and I have no doubt any one having a fair acquaintance with the work of the numerous observers who have measured this pair, could readily select by inspection a series of measures which certainly fail to give rectilinear motion, and probably would give an apparent curve in one direction or the other. In dealing with questions of this kind, it is better to rely altogether upon the observations of the best and most experienced observers, and therefore, I have used the Pulkowa measures for the entire period covered by them. It was impossible to show Bradley's position of 1753 on this diagram without making it on too small a scale when reduced to suit the page of this journal; but this position was used in the diagram made with the principal star considered as fixed, and it is in perfect harmony with the rectilinear motion shown by the other measures.

The diagram given here furnishes an accurate and easy means of determining the relative proper motion of B by measuring the motion of that star along its path during the 60.2 years covered by the measures, and the angle which that line makes with the meridian. The annual movement is thus shown to be 5″.113 in the direction of 53°.5.

On several occasions during the last year or two, I have examined both components with the 36-inch refractor to see if any real double star could be discovered but they appeared to be perfectly round under the highest powers, and as the atmospheric conditions were favorable it was evident there was nothing left for the large telescope to do in this direction.

Professor Newcomb in speaking of the character of the motion of the components of this star, has briefly and forcibly stated the case, and his opinion upon this subject:

"The only conclusion open to us is that each of them describes an immense orbit around their common center of gravity, an orbit which may be several degrees in apparent diameter and in which the time of revolution is counted by thousands of years. Two thousand years hence they will be so far apart that no connection between them would be suspected."

I think this conclusion is fully warranted by all the evidence bearing upon the case; and that all attempts to compute an orbit for this pair must necessarily result in failure.

If this does not sufficiently appear from the measures already made, it will soon be apparent from measures to be made in the near future. A careful set of measures every five years hereafter will be all that is necessary in following 61 Cygni considered as a double star.

CLOSE BINARY STARS.

EDWARD C. PICKERING.*

FOR THE MESSENGER.

At the November meeting of the Royal Astronomical Society Mr. Fowler announced the discovery that the star α Lyræ was a close binary having a period of 24.68 hours. The maximum difference in the velocity of its componets as derived from the doubling of the lines in its spectrum was 370 miles. Confirmation of this discovery is very desirable, since the star would then become one of the most interesting objects in the sky. Accordingly the large collection of photographs of the Henry Draper Memorial has been carefully examined. Seventy photographs of the spectrum of α Lyræ were found, the first one being taken on October 21, 1886. Many of them were taken with 4 prisms of 15° each, and showed excellent definition; a twentieth part of the separation of the lines as observed by Mr. Fowler should be visible. Any given photograph might have been taken when

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* Director of Harvard College Observatory.

the lines were single, but the chances would be thirty to one that this would not be the case. Of course the chances that all could be taken at these times would be infinitely small. Moreover, the interval between the successive photographs is not always a multiple of 12.34 hours. One of the photographs was taken October 12, 1890, four days after the star was seen double by Mr. Fowler, but its lines are single. In some photographs the lines are a little hazy and in two the lines appear closely double, but this often happens when the image is slightly out of focus and there is any spherical aberration in the lens or prisms. Since the news of the discovery reached Cambridge, twenty-two photographs have been obtained on the evenings of December 2, 4, 7, and 9, and on the mornings of December 8 and 10. All of them show the lines single except those taken on December 2, which were out of focus. It may therefore be regarded as proved that the orbit cannot have the simple character announced by Mr. Fowler. The observed doubling of the lines may be accounted for in three ways. First, by an error in the focus. This seems improbable since successive photographs taken November 1 showed a variation in the separation of the lines. Secondly, the orbit may be very elliptical, in which case the lines might be double for a few hours at periastron when the motion is rapid, remaining single for the rest of the time. As the lines were double on October 8 and November 1 the half period might be twenty-four days or any sub-multiple of that time. In this case the lines should be again double on November 25 and December 19, and perhaps on December 7 and 31. With a shorter period the binary character could scarcely have escaped detection. Thirdly, a great variety of appearances might be produced by the presence of a third body. Apparent irregularities in the doubling of the lines in η Ursæ Majoris suggest such an explanation. A circular orbit will not account for the observed changes in this star. On the other hand the variations of β Aurigæ seem to be very regular. An approximate reduction of a series of 130 photographs, extending from November 20, 1886, to December 9, 1890, indicates a period 3*d* 23*h* 36.7*m* and that the lines should be single about Greenwich noon on January 1, 1891.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., Dec. 12, 1890.

STARS HAVING PECULIAR SPECTRA.

New Variable Stars in Perseus, Triangulum and Hydra.

M. FLEMING.

[Communicated by E. C. Pickering, Director of Harvard College Observatory].

A list of interesting objects showing peculiarities in their photographic spectra, and resulting from an examination of the photographs of stellar spectra taken at Cambridge with the 8-inch Draper telescope, and at Chosica, near Peru, with the 8-inch Bache telescope, is given in the following table. The designation of the star is followed by its approximate position for 1900, its magnitude, the date on which the photograph was obtained, the instrument employed, and a brief description of the peculiarity in its spectrum.

Design.	R. A.	Dec.	M.	Date.	Instrument.	Description.
	1900 h m	1900 ° ′				
DM — 20°50	0 16.7	— 20 37	5.5	Oct. 15, 1890	Draper 8-in. tel.	III type.
DM + 54 431	1 53.0	+ 54 20	9.0	Nov. 19, 1889	" "	III type. Hydr. lines bright.
—— —— ——	1 55.1	+ 56 15	....	Nov. 3, 1887	Bache telescope	III type. Hydr. lines bright.
DM — 10 513	2 30.2	— 9 53	8.0	Nov. 5, 1890	Draper 8-in. tel.	IV type.
DM + 33 470	2 31.0	+ 33 50	9.2	Oct. 13, 1890	" "	III type. Hydr. lines bright.
DM + 56 686	2 33.9	+ 56 18	9.1	Nov. 17, 1890	" "	Bright lines.
DM + 56 731	2 44.8	+ 56 31	9.5	Nov. 17, 1890	" "	Bright lines.
A.G.C. 7191	5 59.4	— 6 42	5.8	Feb. 15, 1888	Bache telescope	F line bright.
" 17717	12 56.3	— 70 56	6.6	May 14, 1890	" "	F line bright.
" 18770	13 43.4	— 27 44	7.0	May 16, 1890	" "	III type. Hydr. lines bright.
" 18947	13 51.6	— 55 51	8.0	May 25, 1890	" "	IV type.
" 20554	15 4.8	— 69 42	6.2	May 26, 1890	" "	IV type.
" 22280	16 21.2	— 18 14	4.6	June 18, 1890	" "	F line bright.
H.P. 3321	19 16.0	— 16 8	4.7	Sept. 5, 1888	" "	F line bright.
DM — 10°5057	19 17.7	— 10 54	7.0	Nov. 5, 1890	Draper 8-in. tel.	IV type.
H.P. 3747	20 13.9	+ 34 28	4.4	Oct. 15, 1890	" "	F line bright.
DM + 36°4028	20 17.8	+ 46 36	9.5	Nov. 10, 1890	" "	Bright lines.
A.G.C. 30526	22 16.6	— 46 27	6.7	July 21, 1890	Bache telescope	IV type.

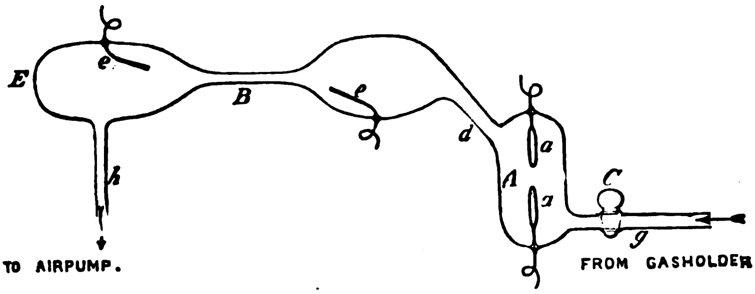
The spectrum of DM — 20° 50 (T Ceti) is that of a well marked III Type star and differs from that usually shown by variables of long period in that the lines due to hydrogen are not bright in its spectrum. DM + 54° 431 [in Perseus] is variable, having the approximate magnitudes 10.6, 11.4, 11.0, 9.1, 9.0, 9.4 and 9.0 on Nov. 3, 1885; Nov. 30, 1887; Dec. 1, 1887; Sept. 29, Oct. 30, Nov. 19 and Nov. 19, 1890 respectively. The last two magnitudes were derived from a spectrum plate and a chart plate taken on the same evening. The star [in Perseus] whose position for 1900 is in R. A. 1^h $55^m.1$, Dec. + 56° 15′ is variable; approximate magnitudes < 15.2, 9.2, 9.3, 9.9, 12.2, 13.5 and 13.4 on Nov. 3, 1885; Nov. 3, 1887; Nov. 30, 1887; Dec. 1, 1887; Sept. 29, 1890; Oct. 30, 1890 and Nov. 19, 1890 respectively. DM + 33° 470 [in Triangulum] is variable. The variability of this star was discovered and measured at this Observatory on Oct. 16, 1890 and the approximate magnitudes 7.5, 9.2, 7.1, 6.8, 7.3, 7.2, and 7.1 obtained for Nov. 7, 1887; Jan. 16, 1888; Dec. 31, 1889; Sept. 25, Oct. 13, Oct. 15, and Oct. 17, 1890. In the Wolsingham Observatory Circular, No. 27, of Nov. 10, 1890, the Rev. T. E. Espin announces his discovery of this star and says that it is "probably variable." DM + 56° 686, + 56° 731 and + 36° 4028 have a spectrum resembling that of the stars discovered by Wolff and Rayet. The first two probably form part of a group similar to the one in Cygnus as several other spectra in the same region appear to show bright lines but are too faint to be seen distinctly. DM + 36° 4026 may be included in the Cygnus group. A. G. C. 7191, 17717, 22280, H. P. 3321, and 3747 have a spectrum similar to that of δ and μ Centauri. Of these A. G. C. 22280 (χ Ophiuchi) and H. P. 3321 (υ Sagittarii) are the most remarkable. χ Ophiuchi has additional bright lines. In υ Sagittarii the hydrogen lines are so fine as to be almost lost, other dark lines equally strong being present. Additional bright lines are also visible. A. G. C. 18770 (in Hydra) is variable; approximate magnitudes 9.7, 9.5, 10.4, 7.4 and 8.1 obtained from photographic charts taken June 14, July 5, July 12, 1889; May 6, and May 28, 1890. The fourth type star, Dunér II, 39 (DM — 5° 4858) has been measured on seven photographic charts giving the approximate magnitudes 8.9, 9.0, 9.1, 8.2, 8.1, 8.2 and 8.1 on June 26, July 20, Aug. 20, Oct. 22, Oct. 28, Nov. 4, and Nov. 18, 1890. Although the range of variability is not great, as seen from the above magnitudes, the variability of this star is undoubted since it appears brighter than adjacent stars on some of the charts and fainter than these stars on others.

In THE SIDEREAL MESSENGER, IX, 379, the star whose spectrum is announced as consisting mainly of bright lines, should be A. G. C. 15220 magnitude 8¼, whose approximate position for 1900 is in right ascension 11^{h} 2.3^{m} — 64° 58′ and not A. G. C. 15177.

Harvard College Observatory,
Cambridge, Mass., Dec. 11, 1890.

THE SPECTROSCOPIC PROPERTIES OF DUST.

The suggestion that the auroral spectrum, the principal ray in the spectrum of nebulæ, and other rays of unknown origin, might be due to meteoric dust induced us to investigate the problem whether solid particles of sufficient minuteness would act like gaseous molecules in an electric discharge and become luminous with their characteristic special radiation. The dust we employed was that thrown off from the surface of various electrodes by a disruptive discharge, and it was carried forward into the tube of observation by a more or less rapid current of air or other gas. The arrangement will be best understood from the annexed diagram, which represents a section of the glass vessel which was the principal part of the apparatus. *A* represents a bulb in which were the electrodes *a*, *a* to give the dust, connected by a widish tube *d* with the tube for observation *B*. The end *E* was blown clear, so that the narrow part of *B* could be observed end-on. The electrodes *e*, *e* were of platinum. The tube *g*, passing from *A* to the supply of gas, was fitted with a glass stopcock *C* for regulating the intake, and the tube *h* led from the distant end of *B* to the air-pump. The air-pump was a large one worked by a gas-engine capable of keeping the pressure down to a few millimetres, even with a considerable leakage. Observations were made of the discharge in *B* at various low pressures, sometimes with, and at other times without, a Leyden jar



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* By G. D. Liveing M.. A., F. R. S., Professor of Chemistry, and J. Dewar M. A., F. R. S., Jacksonian Professor, University of Cambridge. Received August 16, 1890.

in circuit. The sparks in *A* were generally taken with a jar, and there was ample proof, if proof were needed, of the dust derived from the electrodes, since it formed a visible deposit in the tube *d*, in the first bulb of B, and even on the end *E*. The air or other gas passed into *A* was filtered through cotton-wool to remove all dust before admission to the apparatus.

Various metals were used as electrodes in *A*, magnesium, iron, manganese, cadmium, fused calcium chloride, metallic sodium in a little glass cup on a platinum wire, and fragments of the Dhurmsala meteorite; but in no case could the rays of any of the subtances employed be seen in the discharge through *B*, either when a Leyden jar was in circuit or not.

Incidentally, we found that magnesium electrodes were not so good as some of the other metals for these experiments, because the apparatus was never wholly free from traces of air, and lines or bright edges of bands of nitrogen fall very near the most characteristic lines of magnesium, and with small dispersion might easily be mistaken for them.

Air, hydrogen, carbon dioxide, and oxygen, were successively used as the gases passing through the apparatus, and at various pressures from 2mm. up to 20, and, in some cases, up to 40mm., but with the same result; no rays, due to the electrodes in *A*, could be detected in *B*. Even when one of the electrodes in *A* was sodium, and the sodium rays, orange, yellow, citron, green, and blue, were brilliant in the spectrum of *A*, not even the *D* lines could be detected in *B*. We should have expected that some traces of sodium *in the state of vapour* would have been carried by the stream of hydrogen into *B*; but it seems that it was not so; nor could the apparent absence of rays due to the dust, be ascribed to mere faintness in their light, for we took photographs of the spectrum of *B*, and found that even lengthened exposures produced no evidence of rays due to the dust; nor could it be ascribed to the character of the discharge in *B*, for the discharge was varied; sometimes *A* and *B* were in the same circuit; sometimes the discharge in *B* was from a separate coil, and even the powerful discharge from a large coil stimulated by a De Meritens' magneto-electric machine, was tried.

That abundance of dust was formed by the sparking in *A* was proved not only by the deposit in the tube, but by allowing the stream of gas at atmospheric pressure from the tube *h* (of course disconnected from the pump) to inpinge on a flame, when the characteristic flame-spectrum of the electrodes in *A* was at once manifest. When the gas used was hydrogen, and it was burnt in oxygen, the spectrum of the electrodes was particularly well seen; also when the gas was oxygen and led into a hydrogen flame.

That the dust was of extreme fineness and capable of being carried by a stream of gas to a great distance was proved as follows:—A stream of hydrogen, at ordinary pressure, was passed through the sparking tube with magnesium electrodes, and then through more than 100 feet of metal tube in a coil, and, finally, burnt as it issued. Before the sparking began there were no signs of magnesium in the flame; but when sparks had been passing between the magnesium electrodes for a short time, the magnesium spectrum was seen in the flame. It took 55 seconds for the gas to carry the dust through the long pipe, and when the sparking ceased it was again about the same time before the magnesium disappeared from the flame. It always appeared and disappeared sharply in correspondence with the sparking. Similar experiments, but with a shorter tube, were made with other metals, iron, sodium, lithium, etc., always with like results; also a current of oxygen was passed through the sparking tube and into a flame of hydrogen, and produced similar effects. Even aluminum, which does not usually show any part of its spectrum when used as an electrode in a vacuous tube, gave, when sparked in oxygen, dust which, when carried into a hydrogen flame, showed the characteristic bands of alumina.

Considering that a sensible amount of dust was deposited in the bulbs of *B*, we should have expected that some would be deposited on the electrodes *e*, *e* in that tube, and that the discharge from electrodes so coated would give the spectrum of the metal on their surface. There is no doubt that when no discharge was taking place in *B* the electrodes *e*, *e* did receive their share of dust; and, if it had been allowed to accumulate so as to form a coherent crust, it would have given its characteristic spectrum on first passing sparks in

B. But, so long as the dust is loose, the passage of a discharge instantly clears the electrodes of all dust, and seems to dispel all dust from the gas through which the discharge occurs. It is well known that an electric discharge in a vessel of air has the effect of clearing out of the air all the particles that serve as nuclei for the condensation of water; and we made several experiments with a view to determine whether a similar effect was produced on the dust in our tubes. The gas from the sparking tube was carried through a glass globe, and so on to the jet where it was burned; a wire connected with one pole of a Voss or Wimshurst electric machine projected into the interior of the globe, and a patch of tinfoil on the outside of the globe was connected with the other pole of the electric machine. So long as the Voss machine was not worked, the gas carried the dust from the sparking tube through the globe, and it was seen in the spectrum of the flame, or simply in the color of the flame when lithium was one of the electrodes; but, on working the machine so as to produce a silent discharge inside the globe, the flame, in one or two seconds, suddenly ceased to show the spectrum of the dust, and in the case of the lithium lost its red color. When the machine was no longer worked, the spectrum or color speedily reappeared, to vanish again suddenly when the machine was started afresh. When a narrow tube, with a piece of tinfoil outside and wire inside, was substituted for the globe, the like results ensued.

It appears, then, not only that dust, however fine, suspended in a gas will not act like gaseous matter in becoming luminous with its characteristic spectrum in an electric discharge, but that it is driven with extraordinary rapidity out of the course of the discharge. If, then, the spectrum of the aurora be due, not to the ordinary constituents of our atmosphere, but to adventitious matter from planetary space, we conclude that such matter must be in, or must be brought into, the gaseous state, or at least have its properties entirely altered from those it posseses at ordinary temperatures, before it becomes luminus in the electric discharge.

MASS OF 61 CYGNI.

NEWTON. M. MANN.

FOR THE MESSENGER.

In my article in the November MESSENGER on "Three Interesting Binaries," there was an error in the calculation of the mass of 61 Cygni which was not detected in time for correction. The elements there given really make the mass little more than one-half that of our sun. Considering that other stars that have been measured seem, without exception, much more massive—Sirius exceeding the sun at least sixty times, and the other doubles with noticeable parallax going two, three and four times our systen—this small result with 61 Cygni throws some suspicion on the determination of the orbit. In fact I have not pretended to determine it, nor can it be determined at present except within certain limits. Perhaps the matter is of enough interest to be presented somewhat more fully.

The companion star since observed by Bradley in 1753 has passed through 87° of its orbit, and its course for these 137 years is a curve subtended by 26 seconds of arc, showing a deflection of only about 1″.9 from a straight line. Still the curve is unmistakable. From the great mass of observations I deduce the following normal positions (Eq. 1890):

Year.	Angle.	Distance.
1750	31°.27	16″.42
1770	44 .83	15 .43
1790	59 .90	14 .85
1810	75 .40	14 .97
1830	89 .88	15 .84
1850	102 .46	17 .32
1870	113 .04	19 .07
1890	122 .28	21 .14

There is no trouble in completing an ellipse from this curve. The trouble is that it can be made a part of so many different ellipses. In fact it permits of an orbit of any degree of eccentricity. But beside the fact that a low eccentricity is unusual in these objects, and therefore improbable in this case, there is the further consideration that the more the orbit approaches a circle the longer the period and the smaller the mass. Thus if we make the eccentricity so low as 0.185 the semi-major axis becomes 21″.53 and the period amounts to 651 years. Taking parallax at 0″.5 we have the mass of the system, compared with ours: $(21.53 \div .5)^3 \div (651)^2 = .188$—less than ⅕ the sun; which is altogether improbable. If we raise the eccentricity to 0.55 the semimajor axis rises to 25″.8 and the period falls to 446 years. This makes the mass 692 thousandths that of the sun. We must increase the eccentricity to 0.65 to bring the system up to the weight of ours. One of a dozen of possible orbits that I have worked out gives these elements:

Semi-axis major	28″.12
Eccentricity	0.661
Position of Node	163°
Inclination	70° 34′
Period	400.1 years

Mass, 1.11 times the sun.

So great an eccentricity is unlikely to exist, and we may set it down as tolerably sure that here is at any rate one system into which no more material has gone than into our own. It is a feeble boast, but still it is something, to say for the dignity of our luminary that there is one star which is probably inferior to him—a star the nearest to us in all the northern skies, and yet shining only with the fifth magnitude, hardly more than bright enough to be seen with the naked eye. What imagination then shall reach to the massiveness of first magnitude stars which show no sensible parallax! We are not surprised to hear it said that they are 40, 60 or 100 times our sun.

OMAHA, Dec. 1890.

ASTRONOMICAL SOCIETY OF THE PACIFIC.

Meeting Nov. 29, 1890.

The regular meeting was held in the Young Men's Christian Association Hall, the president, E. S. Holden, presiding.

The minutes of the last meeting were approved.

At a meeting of the Directors held prior to the regular meeting the following new members were duly elected:

General John Gibbon, United States army; Herman Schussler, L. Gilson, Dr. E. S. Clark, Fremont Morse, J. J. Gilbert, H. W. Faust, Lieutenant

J. P. Finley, United States army, all of San Francisco; Homer A. Craig and Thomas Prather of Oakland, Cal.; W. B. Hayes, Los Angeles; Maures Horner, F. R. A. S., Somerset, England; C. F. De Landero, Guadalajara, Mexico; Dr. G. Barroeta, San Luis Potosi, Mexico; E. B. Knobel secretary, R. A. S., Braintree, England; P. Noordhoff, Groninger, Holland; Dr. J. Munos Tesar, Caracas, Venezuela; H. F. Newall, Cambridge, England: Professor Martin Kellogg, Berkeley; L. A. Rockwell and Dr. G. A. Wood, Traver; G. J. Hicks, E. M., Staten Island; Professor M. P. Freeman, Tuscon; M. A. Veeder, M. D., Lyons, New York; G. N. Saegmuller, Washington, D. C., Professor B. G. Clapp, Fulton, N. Y.; John A. Parkhurst, Marengo, Ill.; Hon. Demas Strong, Brooklyn, N. Y.; Joseph S. Adam, Canaan, Conn.; James E. Ingraham, Sanford, Fla.; William A. Browne, Newton, Mass.

This brings the total membership to 312.

It was announced that the next meeting (January 31st, 1891) would probably be held in the permanent home of the society, the new building of the California Academy of Sciences, which is almost completed.

The following papers were presented to the meeting, most of which were taken as read:

a. The Law of the Solar Corona, by Professor Frank H. Bigelow, of the Nautical Almanac Office, Washington, D. C.

b. Coronal Extension, by C. M. Charroppin, S. J., University of St. Louis, Missouri.

c. Observations and Drawings of Saturn, 1879 to 1889, by Professor Edward S. Holden, Lick Observatory.

d. The Observatory of Swathmore College, by Miss S. J. Cunningham, Director.

e. The Kenwood Physical Observatory (Chicago), by George E. Hale, Director.

f. Work at the Lick Observatory 1888 to 1890, by Professor Edward S. Holden, Director.

g. An account of an experiment made to determine whether gravitation force, varies with the temperature, by A. E. Kennelly, of Orange, N. J.

h. Index Map of Moon, by Professor C. A. Young.

As the meeting was largely attended by the public and friends of the members Professor Holden gave a popular account of the "Work of the Lick Observatory" since the Observatory had been under his direction.

The meeting then adjourned.

CHARLES BURCKHALTER, *Secretary.*

THE CAUSE OF REFRACTION.

For The Messenger.

At the meeting of the Astronomical Department of the Brooklyn Institute, on Nov. 10, 1890, Henry M. Parkhurst exhibited the following diagrams, to demonstrate that refraction of light is caused solely by the change of the wave lengths in passing into a more or less dense medium.

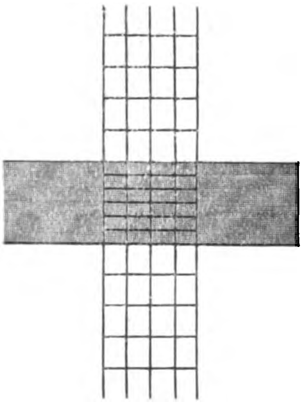

Fig. 1—Retardation of Waves.

In figure 1, a pencil of rays, consisting of successive waves, strikes perpendicularly upon the surface of a denser medium. The effect is to shorten the wave-length in a certain ratio. When the light reaches the rarer medium again, the waves are restored to their original length. That this is so, and that it is the cause of refraction, are shown in the following figures. The pencil is supposed to be magnified at least a thousand times, or each thousandth wave may be supposed to be represented.

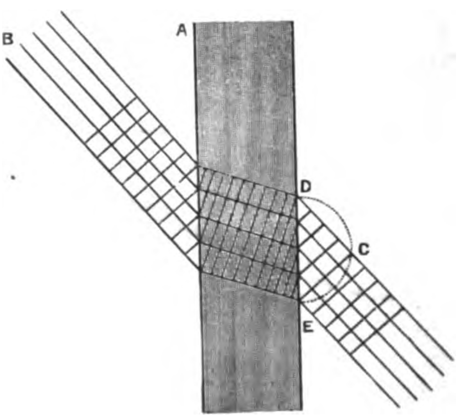

Fig. 2—Refraction of Waves.

In figure 2, the pencil of rays strikes obliquely upon a denser medium. The end of the wave which strikes first is shortened in the same ratio as before. The line of division runs rapidly along the edge, the portion of the waves within the glass being parallel and near together, and the portion outside the glass being parallel and at their original distance. Consequently the wave swings around, as shown. The opposite effect is shown upon emerging from the glass.

In figure 3, the amount of the bending or refraction of the ray is shown to follow the well known law that the sine of refraction is proportional to the sine of incidence. The angle of incidence is represented by I, and making the width of the pencil at the surface of the glass radius, the sine of the incidence is represented by the end of the wave outside the glass, marked sine I, the opposite angle being manifestly equal to I.

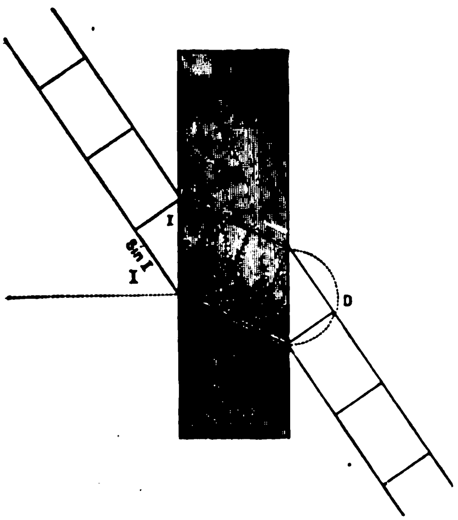

Fig. 3.—Law of Sines.

Again, the angle of refraction is represented by *r*; and employing the same radius as before, the sine of refraction is represented by the end of the wave within the glass, marked sine *r*, the opposite angle being manifestly equal to *r*. Since the shortening of the wave-length evidently produces exactly the observed amount of refraction, and explains the well known law, it is reasonable to conclude that it is the sole cause of refraction. The same principle also applies to the emergence of the ray. Since in emergence the outer angle of the ray must be a right angle, it must be situated in the dotted semicircle shown. See Euclid, Book III., Proposition 31.

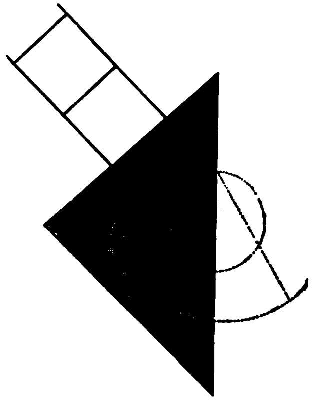

Fig. 4.—Total Reflection.

In passing through a prism, it sometimes happens that the extension of the wave-length carries it outside of this semicircle, as shown in figure 4. The extension of the upper end of the wave not only swings the ray around parallel to the face of the prism, but beyond that; so that the ray is forced back into the prism. In this case there is a total reflection of the light at that surface, it being impossible for a single ray to emerge.

STRANGE ATRONOMICAL COINCIDENCE.

E. E. BARNARD.*

It is very seldom that coincidences of a startling nature occur in the astronomical world. Perhaps this is due in the main to the fact that nearly all things astronomical are subject to exact calculation, and there is nothing more chilling to the ardor of the average fabricator of coincidences than an array of facts and figures. There has very recently occurred, however, a most wonderful coincidence that must startle even the astronomical world, and this, stangely enough, instead of being frowned down by facts and figures, is strongly supported by them.

On the 15th of November last Professor Zona of the Palermo Observatory, in Italy, discovered a comet in the Constellation Auriga. It was moving rapidly to the west and north. On the following night (November 16th), while observing the position of this comet with the great twenty-seven-inch telescope at Vienna, Dr. Spitaler discovered another and fainter comet in the field of view with it; the motion was in the same direction as that of Zona's. Upon the announcement of the discovery of two new comets so close to each other astronomers naturally concluded that they were parts of the same comet and therefore were traveling through space together. It was, however, soon seen that there was no relationship whatever between the two, for Zona's comet rapidly left the other far behind, passing nine hours after Spitaler's discovery within five minutes of arc (one-sixth the apparent diameter of the moon) of the Vienna comet, so that the two must have appeared in the telescope as a double comet. By the night of the 17th, when Zona's comet could first be observed in America, they were some 2 degrees apart, and therefore the fainter one would have escaped discovery. They are now (December 10th) 2 hours apart in right ascension and differ 4 degrees in declination, and while one is moving southwards the other is keeping up its northerly motion.

Anyone familiar with the discovery of comets and the

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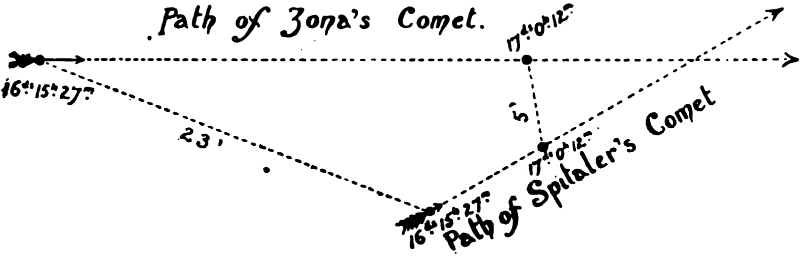
* Astronomer at Lick Observatory.

comparative scarcity of the same, and who can appreciate the vast expanse of the heavens, in which the average comet is the merest speck, will recognize in this discovery of two new comets within a few minutes of each other and in no way physically connected, as one of the most remarkable coincidences ever known. There is no record of any two comets, not physically related, ever having been seen within a degree of each other, and there are many millions of chances against the discovery of two such comets so close together as were Zona's and Spitaler's, and we may safely say that it will never happen again.



I have made a diagram of the paths showing the positions of the two comets at the time of Spitaler's discovery, Nov. 16 days, 15 hours, and 27 minutes, Greenwich mean time, when the two were separated by 23 minutes of arc, and at 24 hours, 12 minutes when the nearest approach (5 minutes of arc) occurred.

These two comets are being regularly observed at the Lick Observatory. Neither is bright. Spitaler's is exceedingly small and faint—the merest speck of haze moving slowly among the stars. Its orbit has not yet been computed, but there is no doubt, from its appearance and slow motion, it must be very distant from us.—*The Examiner, San Francisco, Dec. 14, 1890.*

Mount Hamilton, December 10, 1890.

The Washington Observations for 1884. **Besides the usual observations that receive attention each year at the Naval Observatory, the volume for 1884 contains the second edition of the Yarnall catalogue, the list of stars in which numbers 10,964, and embraces a range of observation from 1845 to 1847. This important piece of work has been previously referred to in this journal.**

DR. KARL LUDWIG HENCKE.

PROFESSOR WILHELM FOERSTER.

Karl Ludwig Hencke was born at Driesen, a small borough in Newmark, April 8, 1793. He died at Merienworder Sept. 21, 1865, at the home of his son-in-law whither he had gone for a visit. His entire life was spent in Driesen and his occupation was post clerk at that place.

In his fourteenth year he became a successful applicant for a position in the post service. A short interruption to his service in this department occurred during the war of 1813 in which he served as a volunteer. But after the battle of Lutzen in which he received mention for his valor, and in which he was wounded, he found it was necessary to return to his position in the post service on account of his wound. Here he remained until 1837 when he received his well merited release with a yearly pension of.225 thalers.

From this time Hencke devoted himself to science. As early as Christmas, 1821, notwithstanding the requirements of his position, he furnished himself with a telescope of the Frauenhofer make, which cost more than 100 thalers, and with the instrument throughout the year, he combined the nightly post service with service to the Urania. Notwithstanding a very small amount of schooling, Hencke obtained a wonderful outlook over the astronomical knowledge of the time, and by his own astronomical activity obtained a place for which was needed great proficiency and stern perseverance and energy, and this the specialist some times loses in the intricacy of the problems and the deep absorption in one object.

The history of knowledge is rich in like peculiar interesting cases, in which the true, strong work of the specialist has furnished the indispensible groundwork for consequent proficiency. Our post clerk now began definite study in the starry heavens. He had the aid of Bode's guidance to the knowledge of the starry heavens, and also soon after furnishing himself with a telescope, which, in a certain way gave him a place among astronomers, he was presented to the Director of the Berlin Observatory and received his counsel.

He soon desired an accurate and full star chart in which might be found all the stars visible in his telescope. A skillful eye, and an unusual degree of accuracy in estimation aided him in establishing the place and magnitudes of the stars which he indicated upon his chart.

Directly after the invention of the telescope (1608), there was a belief that beyond the stars visible to the naked eye, the faintest of which were taken as sixth magnitude, the heavens were filled with innumerable fainter stars, and that especially the fainter cloud-like regions of the sky were composed of these stars crowded close together. With the help of his excellent Frauenhofer telescope, having the use of the existing star-charts,. he constructed an extraordinarily accurate map of the heavens, and the eager zeal with which he searched the sky again and again surpassed what is usually devoted to a single branch of inquiry. Certainly the devotion of many astronomers to their work was not less than that of Hencke, but the separation of work into special departments was not so clearly developed as later, and Hencke stood alone in the concentration of his quiet life. So it happened that the great astronomical world of his day went to the small chamber of Driesen for light.

In a part of the sky which is pointed out on Hencke's chart, and also noted in one of the best academical charts of Berlin, Hencke saw, Dec. 8, 1845, for the first time, a small star which was fainter than the ninth magnitude, and which was mapped in none of the charts. He believed that it was a fixed star on account of its variable light, because having so often swept that part of the heavens, and having noted the variable light of the fixed stars, he believed that the star of Dec. 8 was also a variable star. Hencke sent an account of his discovery to Berlin to the *Vossische News*. A copy of it appeared in the following number on Dec. 13. On the day after Encke sent word from the Observatory of Berlin that the small star had changed its place among the fixed stars and was undoubtedly a planet. This knowledge Encke sent Hencke in a letter beginning with the words, "With the greatest pleasure and the most heartfelt good wishes do I write," etc.

And now recognition came from all sides to the plain man. The great gold Scientific medal was received from King

Frederick William IV; the Red Eagle Order IV. Kl. through the hands of Encke and Humboldt in March, 1846, with a yearly stipend of 300 thalers; the great Scientific medal from the King of Denmark; the title of Doctor of Philsophy from the University of Bonn, through Argelander, as well as praise and congratulations from Paris, London, etc. The earnest expressions of esteem were for Hencke as a man worthy of remark in himself and resulted in a true brotherly regard extended to him from Argelander, Encke, Humboldt and others. Encke was requested by the discoverer to name the new planet. Many names were proposed and finally the name Astræa was chosen.

Hencke was in no wise turned aside from his simple manner of life by the praise he received. He worked zealously, and July 1, 1847, announced the discovery of a second planet which received the name Hebe, and which brought him recognition anew, and a congratulatory letter from Gauss. This was the last of his independent discoveries. During the succeeding weeks in August, 1847, the English astronomer Hind in London, with a much stronger instrument, began to reveal the great belt of planetoids between the orbits of Jupiter and Mars, until now the number of the known planetoids of this group has reached 293* (the last discovered one being of the 12th magnitude). It is clear that Hencke's perseverance and success brought to light the asteroid system. For surely the discovery of the entire mass of the planetoids is not more noteworthy than the discovery of Astræa and Hebe, and these two threw much light on the theory of our planetary system.

Had Hencke possessed a much stronger glass and the special methods and contrivances with which numerous astronomers conduct their discoveries, he would have done more. But he remained to the end of his life busied with the construction of his star-chart and the comparison of the starry fields. It must be repeated that he discovered the planets, but there were soon so many astronomers at work in the field of his success that he was no longer aroused by the priority of discovery. He remained calm and quiet in the knowledge that he would be held worthy through all time on account of his exceedingly accurate star-chart.

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* In December 1890, the number is 300.

Dr. Hencke was, as I have learned, eight years after the discovery of Hebe in the Berlin Observatory, an active man and of quick, merry temperament. He was a strong, independent thinker, almost radical in his tendency. Next to astronomy music and its theory interested him most.

His voice was heard in all the world-moving questions and in his youth he was regarded in the official world as a fearless and sometimes dangerous element. The energetic radicalism of his mind swayed all his opinions in his earlier years.

Rapid progress has followed Dr. Hencke's work. By cooperation and increase of knowledge many astronomical problems of his day have been solved. Photography has aided materially. Millions of faint stars are shown upon thousands of photographic plates. Now not only may we read the great book of the heavens at night, but also even in the day and with what pleasure do we gain therefrom the rich treasures of results and discoveries.—[*Translated from Himmel and Erde.*]

RESEARCHES ON THE MAGNESIA FLUTING IN CONNECTION WITH THE SPECTRA OF THE NEBULÆ.

GEORGE E. HALE.*

FOR THE MESSENGER.

After many years of continued investigation Professor Lockyer has formulated a very comprehensive theory of the universe. The spectroscopic study of meteorites, combined with a knowledge of cometary spectra, has led him to assume that all comets are composed of meteorites in swiftly moving swarms. Considering that these are drawn by the attraction of the sun from the regions of space, through which it is journeying with its attendant planets, he argues that innumerable meteor swarms must exist in space, and, in fact, give rise to the phenomena of stars and nebulæ. In this way it is easy to explain the temporary stars which suddenly shine out with great brilliancy, and as suddenly fade to insignificance. On Professor Lockyer's hypothesis such outbursts of light are caused by the collision of meteor swarms, and the rapid cooling of the stars cannot well be

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* Kenwood Physical Observatory, Chicago.

explained except by assuming them to be composed of such small bodies. On the same theory the nebulæ are sparse swarms of meteorites, the temperature being low owing to the comparatively infrequent collisions of the members. Condensation toward a center is then caused by gravity, and the nebula becomes a star. More and more frequent collisions cause higher and higher temperatures, and finally we have the meteorites completely vaporized, and the hottest stars are the result. A cooling of the vaporous mass follows, the constituent elements are once more returned to the solid state, and a dark, cold body like the earth is the last actor in the stupendous drama of the heavens.

The spectroscope offers us the only means of putting this theory to the test. We must examine and compare the spectra of meteorites in vacuum tubes, in the nebulæ, and in the stars. If we find that a certain fluting of magnesium appears at the lowest temperature in a vacuum tube we should expect to find the same fluting visible in the coolest of the nebulæ. As the temperature in the vacuum tube rises, new lines and flutings become visible, and an increased number of collisions in the nebulæ should show the same lines and flutings. In fact, with the range of temperatures at our command we should be able to find a sequence of spectral changes matching those recorded at the telescope.

Such experiments as these have been carried on by Professor Lockyer. In his work with meteorites he has found a magnesium fluting visible at the lowest temperature of the vacuum tubes. In the nebula of Orion he has seen the brightest line exactly in the position of that in the tube. On this coincidence is based his belief in the meteoric constitution of the nebulæ, and this belief is the groundwork of his entire hypothesis.

In the initial number of the British Astronomical Association's Journal Mr. E. W. Maunder has given an interesting paper on "The Chief Nebular Line." After such a review of the numerous observations of Dr. Huggins, Professor Lockyer, Mr. Keeler and others, it is unnecessary to repeat them here, especially as those of most importance have recently appeared in the pages of THE MESSENGER. It has been shown by Mr. Maunder that the question of coincidence is by no means decided; that more light and even higher dispersion will be needed in future investigations. But while this is probably true there is one direction in which even small instruments can do valuable work. I refer to a study of the character of the nebular line. This, taken in connection with a knowledge of the exact nature of the magnesia fluting, may well lead to conclusions of great weight.

It may be of interest here to mention the opinions of several well-known observers of the nebulæ. In each case the original publication is referred to.

1864. Huggins (*Phil. Trans.* 1864, p. 441). Dumb-bell Nebula. "This line appeared nebulous at the edges.

1866. Huggins (*Phil. Trans.* 1866, p. 385). Dumb-bell Nebula. "When the slit was made as narrow as the intensity of the light would permit, this bright line was not so well defined as the corresponding line in some of the other nebulæ under similar conditions of the slit, but remained nebulous at the edges." . . . H 4572. "The spectrum of this nebula consisted of one bright nebulous line of the same refrangibility as the brightest of the lines of nitrogen." . . . H 4627. "This bright line appeared by glimpses to be double. Possibly this appearance was due to the presence near it of a second line."

1866. Secchi (*Bullettino Meteorologico*, 1866). "The planetary nebula in Andromeda has the line above named, but the principal one is a little diffused."

1868. Huggins (*Phil. Trans.* 1868, p. 542). Orion Nebula. "I expected that I might discern a duplicity in the line in the nebula corresponding to the two component lines of the line of nitrogen, but I was not able, after long and careful scrutiny, to see the lines double. The line in the nebula was narrower than the double line of nitrogen; this latter line may have appeared broader in consequence of irradiation, as it was much brighter than the line in the nebula." . . . "I incline to the belief that it (the line in the nebula) is not double."

1871. Vogel (*Beobachtungen zu Bothkamp*, 1872, p. 59). Dumb-bell Nebula. "But the line here appears broader than in the spectra of the planetary nebulæ, and is in particular very ill-defined toward the violet end of the spectrum."

1872. Huggins (*Proc. R. S.*, v. 20, p. 383) Orion Nebula. "With spectroscope B (two compound prisms) and eye-pieces 1 and 2, (5.5 and 9.2 diameters) the slit being made very narrow, this line was seen to be very narrow, of a width corresponding to the slit, and defined on both edges, and undoubtedly not double. The line of nitrogen when compared with it appeared double, and each component nebulous and broader than the line of the nebula."

1874. Huggins (*Proc. R. S.*, v. 22, p. 252), Orion Nebula. "In the simultaneous observation of the two lines it was found that if the lead line was made rather less bright than the nebular line, the small excess of apparent breadth of this latter line, from its greater brightness, appeared to overlap the lead line to a very small amount on its less refrangible side, so that the two lines appeared to be in a straight line across the spectrum." (With two compound prisms, and eye-piece magnifying 16 diameters.)

1877. Bredichin (*Annals de l'Observatoire de Moscow*, v. 3, p. 120). "In this case (wide slit) the line appeared like a band, a little more defined toward the red."

1884. Maunder (*Greenwich Spectroscopic Results* 1884, p. 5), Orion Nebula. "The line λ 5005 was examined with this latter dispersion, (two prisms) the slit being very narrow, and was seen to be a single line. None of the lines in the spectrum of the nebula, are however, very sharp, λ 5005 showed a faint fringe mainly on the side nearer the blue."

1888. Lockyer (*Meteoric Hypothesis*, p. 317). Orion Nebula. "The image of the nebula being allowed to float slowly over the slit, I distinctly got the impression that the line in question varied in its behavior from the other lines, and that at the points where it was brightest it extended most towards the blue end of the spectrum. The observations were repeated at Kensington by Mr. Fowler, Demonstrator of Astronomy, and by Mr. Baxandall, and they arrived at the conclusion that the chief line had a decidedly fluted appearance."

1888. Taylor (*Monthly Notices*, v. 49, p. 124), Orion Nebula. "The 5001 line is by far the brightest in the spectrum. It is never seen sharp, but, with the narrowest slit, always has a fluffy appearance, this being much more marked on the blue than on the red edge. This was most carefully examined for evidence of structure, but the line was always found to be single, and no decided evidence of fluting structure could be made out.

1880. Lockyer (*Meteoric Hypothesis p.* 317), Orion Nebula "I have more recently observed the spectrum of the nebula in Orion with my 30-inch reflector at Westgate-on-Sea, using an enlarged form of pocket spectroscope with a dispersion which does not split D, and the observation is, to my mind, final. I found that in certain parts of the nebula the lines were knotted, and in others broken; but in the former case, whilst the F line thickened equally on both sides, the chief line thickened only on the more refrangible side . . . This was confirmed by Messrs. Fowler and Baxandall at Kensington, with the 10-inch equatorial on the 31st October and 1st November, 1889, and again by Mr. Fowler, with the 30-inch, on 2d November . . . Messrs. Fowler and Coppen have since made some very careful observations of the Ring nebula in Lyra, and also record the chief line as having a fringe on its more refrangible side. . . . In still more recent observations with a siderostat the chief line was noted by Mr. Fowler and Lieutenant Bacon to have a decided fringe on the more refrangible side."

1889. Huggins (*Proc. R. S.* v. 46, p. 50), Orion Nebula. "My own observations of this line, since my discovery of it in 1864. . . . show the line to become narrow as the slit is made narrow, and to be sharply and perfectly defined at both edges."

1890. Huggins (*Sidereal Messenger*, August 1890, p. 310), Orion nebula. "We come to the conclusion that a marked feature of this line is its sharply defined character on the more refrangible side, we were unable under any of the conditions of observing to detect even a suspicion of any softening of the more refrangible edge of the line; much less the faintest indication of a 'flare' and certainly not the distinctive peculiarity of a 'fluting.'" . . . Liveing (quoted by Huggins, *loc. cit.* p. 311), Orion Nebula. "The line always appeared sharply defined on the more refrangible side, whether the slit were wide or narrow." . . . Copeland (quoted *loc. cit.* p. 313), Orion Nebula. "All the lines were just as broad as the slit; when the slit was wide open they were broad, and when the slit was closed slowly they gradually became narrower and narrower." . . . Young (quoted *loc. cit.* p. 314). Orion Nebula. "With the prism the brightest nebular line seemed absolutely *sharp*, and clearly defined on both sides; with the grating (14,438) the line was fainter, and I could not use so narrow a slit; the dispersion was much higher also; the line therefore was a little hazy, *but equally so on both sides.*"

1890. Keeler (*Publications A. S. P.*, No. 11). Orion Nebula. "With all these different degrees of dispersion (single prism, compound prism, and 14,438 grating) and also with the other spectroscope employed, the nebula lines appear to be perfect monochromatic images of the slit, widening when the slit was widened, and narrowing to excessively fine sharp lines when it was closed up. The brightest line showed no tendency to assume the aspect of a 'remnant of fluting' under any circumstances of observation, but had always the appearance characteristic of light emitted by a gas at low temperature and pressure."

It will be seen from these quotations that great differences of opinion exist as to the appearance of the nebula line. These can partly be accounted for by the different light-gathering power of the telescopes employed, and also by the greater or less dispersion of the spectroscopes. As Professor Lockyer remarks, the fluted appearance could best be seen with small dispersion; but although the fringe would be brighter in this case it would also be narrower, and the second nebular line would be so near the first as to interfere with delicate observation unless hidden by a wire in the eyepiece, as suggested by Dr. Huggins. But mere differences in instrumental equipment are not sufficient to reconcile all the observations. Probably the publication of untouched photographs of the line would be the only means of satisfying the opposing views, but here difficulties of a different nature arise.

It is evidently very desirable to know the precise character of the magnesia fluting, and especially the relative intensities of the maxima. This subject has been studied by Professor Lockyer at Kensington, and by the writer at the Kenwood Observatory. Professors Liveing and Dewar have exhaustively studied the cause of the fluting, but have not given special attention to the relative intensities of the maxima. Professor Lockyer states, "the compound fluting of magnesium near λ 500 is very similar to that of carbon. It consists of a series of bright lines of gradually diminishing brightness and increasing distance apart toward the more refrangible end, and each has a fringe *on the more refrangible side*. The first maximum (the least refrangible) is brighter than the others, and the fringe close to it is brighter than the second maximum."* In all seven maxima were observed, and the wave-length of the first is given as 5006.5. In experimenting on the visibility of the fluting a piece of neutral tint glass was placed between the burning metal and the slit, and the intensity of the light reduced until the fluting was about as bright as the chief line in the Orion nebula. "Under these conditions, the 500 fluting is only faintly visible, and the secondary maxima entirely disappear." Another way of observing this was to hold a piece of magnesia in the oxy-hydrogen flame. With a certain proportion of gases the compound fluting was seen pretty bright. By changing the quantity of hydrogen the fluting was made to fade, and finally only the first maximum and its fringe were seen. Photographs were also made which showed the first maximum brighter than any of the secondary ones.

My own study of the fluting has been made with three different spectroscopes:—a Rowland concave grating of 5-feet focus and 14,438 lines to the inch; a large telespectroscope with telescope of 3 inches aperture, and a 4-inch Rowland 14,438 grating; and a small spectrometer with either a single glass prism, or a small Rowland grating. These instruments, with the exception of the spectrometer, are elsewhere described.† The work was largely photographic, the concave grating being generally employed. In all nearly one hundred photographs of the fluting have been obtained in the first or second order spectrum. Several series of plates were made with different widths of slit, varying from .001 to .04 of an inch. In each series the width of the slit was constant, and pieces of magnesium ribbon of decreasing length were burned before the slit, the plate-holder being moved down between each exposure. Thus seven photographs of the fluting are shown on a single plate, and the exposure of the strips decreases from one side of the plate to the other. If the longest

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* Meteoric Hypothesis, p. 314. † Pub. A. S. P., No. 12.

exposure is just sufficient to show all the lines of the fluting, the fainter lines should disappear as the exposure decreases, and if the first maximum and a portion of the more refrangible shading is brighter than the secondary maxima, we should finally be able to obtain this line and shading alone.

When fully timed the photographs show the seven well known lines of the magnesia fluting and in addition six fainter lines in continuation of the fluting, but evidently distinct from it, as they do not follow the same law of increasing distances. Perhaps these are due to the impurities in the magnesium, but as yet this has not been investigated. Another still more refrangible group of seven faint lines is also well shown, as well as the triplet corresponding to the solar *b* lines. A complete discussion of the spectrum of burning magnesium is reserved for the present; we will only concern ourselves here with the relative intensities of the lines in the principal fluting. The following record of a single plate will show how the lines disappear in a particular case.

Plate No.	Length Mg. Ribbon.	No. Lines Visible.	Width Slit.	Order
E 26	1 inch	6	0.002 in.	1
"	⅞ "	5	"	"
"	¾ "	4	"	"
"	⅝ "	3	"	"

The disappearnace of the fainter lines in this case is seen to be perfectly regular, but it must not be inferred that this regularity continues. On the contrary the first three lines seem to differ materially from the other four, and out of the large number of photographs already made not one shows the head line alone, while the first two lines are shown alone in but a single instance. A number of photographs made by a different method give almost identical results, and show no variations among themselves. During the exposure a screen moved by clock-work slowly rises before the plate, uncovering the lines of the fluting by degrees. Thus the bottom of the spectrum receives an exposure during the whole time that the ribbon is burning, and the exposure gradually decreases toward the top of the plate. This method has proved very successful. The first three lines of the fluting differ so little in height that it is difficult to pick out the longest, while the fourth is much shorter, and the rest of the lines fall off regularly. An examination of a number of plates shows the first lines *very slightly* longer than the second, while the latter exceeds the third by about the same amount. It is not denied that the head line is somewhat brighter than any of the others, but the difference between it and the second line is certainly not great. Moreover the shading on the more refrangible side of the head line is by no means as bright as the brightest part of the second line.

These are the conclusions arrived at by a study of photographs, but it must be added that they are open to possible modifications. The plates used are ordinary, unstained dry plates made by the Seed Co., and their sensitiveness in different regions of the spectrum falls off gradually from the blue into the green. The curve does not fall rapidly at λ 5000, and I cannot think that a slightly decreased sensitiveness at the position of the first maximum can perceptibly effect the results. Even if there were such an effect the first three lines could not differ from the others in so marked a way, as the fall in the curve is perfectly regular. Unfortunately the curve of our plates stained with erythrosin has a minimum in the green at about this point, and no advantage is gained by using them. Moreover, eye observations with the various spectroscopes bear out the same conclusions. When the light from the burning ribbon is cut down by dark wedges etc.,* the first three maxima disappear almost simultaneously, and I have not yet been able to see the head line alone without traces of the rest of the fluting. The bearing of the these experiments upon the spectra of the nebulæ is obvious. It is hardly to be supposed that the light would be such as in all cases to show the chief line more brilliantly than any other line in the spectrum, while at the same time all the secondary maxima are entirely invisible. If the second and perhaps the third lines of the fluting can be found in the spectra of the nebulæ the presence of magnesia will no longer be questioned. In the lack of such observations there is room for reasonable doubt.

KENWOOD PHYSICAL OBSERVATORY,
Chicago, Dec. 20, 1890.

Cheapest Form of Light **is the title of a paper issued by Professor S. P. Langley and F. W. Very, of Allegheny Observatory which is printed in full in the *American Journal of Science*. The object of the paper is to show by the study of the radiation of the firefly that it is possible to produce light without heat other than in the light itself.**

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at inferior conjunction with the sun Jan. 13 at $11^h 31^m$ A. M. central time. He will be at greatest western elongation, 25° 40′ west from the sun, on the morning of Feb. 6. He will be visible to the unaided eye on several mornings about that date. To see him at that time one must look toward the southeast about an hour before sunrise.

Venus will be at her greatest brilliancy for the present season on Jan. 8, when she is also at perihelion. At that time the phase will be crescent, one-fourth of her apparent disk being illuminated. She may be seen toward the southeast in the morning about three hours before sunrise.

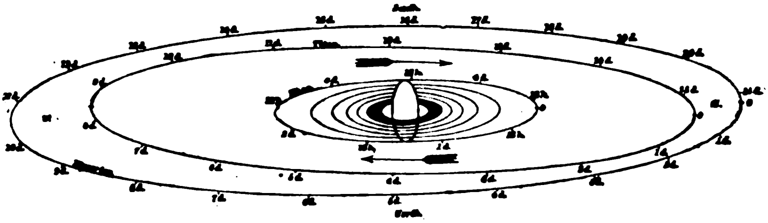
The only observer who, so far as reported, was successful in observing Venus near the time of inferior conjunction Dec. 3 and 4, was E. E. Barnard, astronomer at Lick Observatory, the account of whose observations are given on another page. At Northfield we were unable, on account of cloudy weather, to see the planet until December 6, when the cusps of the crescent could be traced but little, if any, beyond the semicircle.

In the *Journal of the British Astronomical Association*, Vol. 1, No. 1, Oct. 1890, Miss A. M. Clerke gives an interesting review of Professor Schiaparelli's papers on the "Rotation Periods of Mercury and Venus." *L'Astronomie*, Dec. 1890, contains an article by Professor Perrotin, director of the Observatory at Nice, in which he gives the results of his recent observtions of Venus with the great equatorial at Nice. These observations were made in the daytime on 74 days between May 15 and Oct. 4, 1890. Sixty. one drawings were made during these observations, six of which are reproduced in *L'Astronomie* by wood engravings. They all show a dusky marking extending from north to south lying in the first drawings along the terminator, in the later ones gradually moving toward the west. In the later drawings there are several branches to the main dark area. The conclusions derived by Perrotin are entirely confirmatory of those reached by Schiaparelli, namely that Venus rotates upon her axis in the same time that she revolves in her orbit about the sun. The period may be anywhere between 195 and 225 days. The axis is very nearly perpendicular to the orbit.

Mars will be in the same position with reference to the sun in which he has been during the past month. His daily motion eastward and northward is just sufficient to make the time of his setting almost constant. The disk of Mars is now so small that but little of detail can be seen upon his surface.

Jupiter is too nearly in line with the sun to be well seen. He will be at superior conjunction Feb. 13. C. Duprat, at Tebessa, Algeria, reports that on Sept. 26 and the following day he was able to see Jupiter with the naked eye, 20 *minutes before sunset* (*L'Astronomie*, Dec. 1890.)

Saturn is in good position for observation after midnight. He may be readily recognized in the eastern part of the constellation Leo, by his brightness and his steady yellow light. The *Monthly Notices* for November, 1890, has not yet arrived so that we cannot give our readers data concerning the satellites from Mr. Marth's ephemerides. We give this month a diagram showing the apparent orbits of the seven inner satellites as they are seen in an interesting telescope. By the aid of this diagram the observer can easily find the positions of the satellites on each day between the dates of eastern elangation.



Apparent Orbits of the Seven Inner Satellites of Saturn, May 17, 1891, as Seen in an Inverting Telescope.
(The Vertical Scale is Twice the Horizontal One.)

Uranus will be at quadrature with the sun Jan. 21, and stationary in right ascension Feb. 4. He may be best observed from four to six in the morning. He is near the foot of Virgo, about 10° east from Spica and 2°.5 southwest from ϰ Virginis. A telescope of very moderate power will enable one to recognize this planet by its greenish-hued disk.

Neptune is now in his most favorable position for amateur observers, coming to the meridian a little after nine o'clock in the evening. It may be found in Taurus between the well known groups of the Pleiades and Hyades. It is about 3° west and ½° north of ε Tauri, the uppermost star in the V-shaped group of the Hyades. During this month it will be in the same field of view with two eighth-magnitude stars, from which it will be difficult to distinguish the planet except by its relative motion from night to night. Large telescopes will, of course, show the disk of the planet. On Jan. 1 Neptune will be almost directly north of the eastern star. Its motion will carry the planet almost directly toward the western star, by which it will pass on Jan. 9.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Jan. 24	19 01.2	− 19 48	6 05 A. M.	10 46.1 A. M.	3 27 P. M.
Feb. 3	19 22.1	− 20 58	5 52 "	10 28.0 "	3 04 "
13	20 09.4	− 20 37	5 59 "	10 35.8 "	3 13 "
			VENUS.		
Jan. 24	17 15.3	− 18 28	4 14 A. M.	9 00.8 A. M.	1 48 P. M.
Feb. 3	17 52.3	− 19 23	4 15 "	8 58.2 "	1 41 "
13	18 33.6	− 19 52	4 20 "	9 00.2 "	1 41 "
			MARS.		
Jan. 24	23 57.0	− 0 46	9 41 A. M.	3 41.3 P. M.	9 42 P. M.
Feb. 3	0 23.9	+ 2 18	9 16 "	3 28.8 "	9 41 "
13	0 50.6	+ 5 18	8 52 "	3 16.2 "	9 41 "
			JUPITER.		
Jan. 24	21 30.3	− 15 35	8 15 A. M.	1 15.0 P. M.	6 15 P. M.
Feb. 3	21 39.6	− 14 49	7 42 "	12 45.0 "	5 48 "
13	21 49.0	− 14 02	7 08 "	12 15.0 "	5 22 "

Date. 1890.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			SATURN.		
Jan. 24	11 13.4	+ 7 15	8 27 P. M.	2 55.8 A. M.	9 31 A. M.
Feb. 3	11 11.4	+ 7 30	7 41 "	2 14.5 "	8 48 "
13	11 08.9	+ 7 48	6 58 "	1 32.7 "	8 07 "
			URANUS.		
Jan. 24	13 57.6	− 11 26	12 26 A. M.	5 43.5 A. M.	11 01 P. M.
Feb. 3	13 57.8	− 11 27	11 43 P. M.	5 00.5 "	10 18 "
13	13 57.6	− 11 26	11 03 "	4 21.0 "	9 39 A. M.
			NEPTUNE.		
Jan. 24	4 09.7	+ 19 22	12 31 P. M.	7 53.3 P. M.	3 16 A. M.
Feb. 3	4 09.4	+ 19 22	11 51 A. M.	7 13.7 "	2 36 "
13	4 09.3	+ 19 22	11 12 "	6 34.2 "	1 57 "
			THE SUN.		
Jan. 19	20 06.4	− 20 07	7 30 A. M.	12 11.0 P. M.	4 52 P. M.
24	20 27.5	− 19 09	7 27 "	12 12.4 "	4 58 "
29	20 48.2	− 17 51	7 22 "	12 13.4 "	5 04 "
Feb. 3	21 08.6	− 16 26	7 17 "	12 14.1 "	5 11 "
8	21 28.7	− 14 54	7 10 "	12 14.4 "	5 18 "
13	21 48.4	− 13 16	7 04 "	12 14.4 "	5 25 "
			THE MOON.		
Jan. 25	9 47.9	+ 19 10	5 36 P. M.	1 16.2 A. M.	9 02 A. M.
29	12 49.7	+ 0 32	9 46 "	4 03.8 "	10 32 "
Feb. 5	18 07.5	− 24 52	4 28 A. M.	8 53.0 "	1 15 P. M.
10	23 31.4	− 9 49	8 29 "	1 57.4 P. M.	7 38 "
15	4 03.3	+ 19 11	10 39 "	6 09.9 "	1 52 A. M.

Saturn's Satellites.

[Central Time; E = eastern elongation; I = inferior conjunction; W = western elongation; S = superior conjunction.]

JAPETUS.

Jan. 16 11.2 A. M. I.
Feb. 4 8.8 W.

TITAN.

Jan. 17 10.9 P. M. E.
21 5.8 " I.
25 7.7 " W
Jan. 29 11.1 P. M. S.
Feb. 2 9.6 " E.
6 4.5 " I.
Feb. 10 6.2 P. M. W.
14 9.4 " S.

RHEA.

Jan. 18 2.0 P. M. E.
23 2.3 A. M. E.
27 2.7 P. M. E.
Feb. 1 3.1 A. M. E.
5 3.4 P. M. E.
10 3.8 A. M. E.
Feb. 14 4.1 P. M. E.

DIONE.

Jan. 17 4.4 A. M. E.
19 10.2 P. M. E.
22 3.7 P. M. E.
25 9.4 A. M. E.
28 3.1 A. M. E.
Jan. 30 8.7 P. M. E.
Feb. 2 2.4 P. M. E.
5 8.0 A. M. E.
8 1.9 A. M. E.
10 7.4 P. M. E.
Feb. 13 1.0 P. M. E.

TETHYS.

Jan. 17 2.1 A. M. E.
18 11.4 P. M. E.
20 8.7 P. M. E.
22 6.0 P. M. E.
24 3.3 P. M. E.
26 12.6 P. M. E.
Jan. 28 9.9 A. M. E.
30 7.2 A. M. E.
Feb. 1 3.5 A. M. E.
3 1.8 A. M. E.
4 11.1 P. M. E.
6 8.4 P. M. E.
Feb. 8 5.7 P. M. E.
10 3.0 P. M. E.
12 12.3 P. M. E.
14 9.6 A. M. E.

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N.P't. °	Duration. h m.
Jan. 17	...B.A.C. 755	6.5	5 11	83	6 23.2	207	1 12
19	...ω^1 Tauri	6.0	4 45	27	5 45.9	278	1 01
21	...5 Geminorum	6.7	13 37	148	14 19.5	220	0 43
26	...*i* Leonis	5.7	15 46	99	16 56.7	326	1 11
30	...65 Virginis	6.1	12 04	197	12 18.8	222	0 15
30	...P^3 Virginis	5.1	18 21	139	19 39.7	289	1 19
31	...$\varkappa$ Virginis	4.2	14 10	104	15 21.5	327	1 12
Feb. 12	...*f* Piscium	5.1	5 47	28	6 49.8	265	1 03
15	...ω^1 Tauri	6.0	13 01	127	13 38.0	215	0 37

Minima of Variable Stars of theAlgol Type.

[The times are given, to the nearest hour of Central Time, of only those minima which can be observed in the United States.]

U CEPHEI.

R. A..............0^h 52^m 32^s
Decl................+81° 17′
Period.........2*d* 11^h 50^m

Jan. 19	2 A. M.
24	1 "
29	1 "
Feb. 3	1 "
7	midn.
12	"

ALGOL.

R. A..............3^h 10^m 01^s
Decl...............+ 40° 32′
Period.........2*d* 20^h 49^m

Jan. 19	midn.
23	9 P. M.
25	6 "
Feb. 11	11 "
14	8 "

λ TAURI

R. A..............3^h 54^m 35^s
Decl...............+ 12° 11′
Period.........3*d* 22^h 52^m

Feb. 2	midn.
6	11 P. M.
10	10 "
14	9 "

R CANIS MAJ.

R. A..............7^h 14^m 30^s
Decl...............— 16° 11′
Period...........1*d* 3^h 16^m

Jan. 19	8 P. M.
20	11 "
22	2 A. M.
27	7 P. M.
28	10 "
30	1 A. M.

R CANIS MAJ. *Cont.*

Feb. 4	6 P. M.
5	9 "
6	midn.
8	3 A. M.
13	8 P. M.
14	11 "

S. CANCRI.

R. A..............8^h 37^m 39^s
Decl...............+ 19° 26′
Period.........9*d* 11^h 38^m

Jan. 13	10 P. M
Feb. 1	10 "

S ANTLIÆ.

R. A..............9^h 27^m 30^s
Decl...............— 28° 09′
Period...............7^h 47^m

Jan. 16	11 P. M.
17	10 "
18	9 "
21	3 A. M.
22	3 "
23	2 "
24	2 "
25	1 "
25	midn.
26	"
27	11 P. M.
28	11 "
29	10 "
30	9 "
Feb. 3	3 A. M.
4	2 "
5	2 "
6	1 "
6	midn.
7	"
Feb. 8	11 P. M.

S ANTLIAE. *Cont.*

Feb. 9	10 P. M.
10	10 "
11	9 "
15	3 A. M.

δ LIBRÆ.

R.A..............14^h 55^m 06^s
Decl..................— 8° 05′
Period.........2*d* 07^h 51^m

Jan. 18	3 A. M.
24	3 "
Feb. 1	3 "
7	2 "
15	2 "

U CORONÆ.

R. A............15^h 13^m 43^s
Decl................+32° 03′
Period.........3*d* 10^h 51^m

Jan. 13	3 A. M.
20	2 "
26	midn.
Feb. 5	3 A. M.
12	midn.

Y CYGNI.

R. A............20^h 47^m 40^s
Decl................+34° 15′
Period.........1*d* 11^h 57^m

Jan. 15	8 P. M.
18	8 "
21	8 "
24	8 "
27	8 "
30	8 "
Feb. 2	8 "
5	8 "
8	8 "
11	7 "
14	7 "

Phases and Aspects of the Moon.

			Central Time. d	h	m	
First Quarter	1891	Jan.	17	12	18	A. M.
Full Moon	"	"	24	6	25	P. M.
Apogee	"	"	27	9	48	A. M.
Last Quarter	"	Feb.	1	10	42	P. M.
New Moon	"	"	8	8	12	"
Perigee	"	"	9	6	18	A. M.

COMET NOTES.

Comet 1889 V. Mr. Dayton C. Miller, now instructor in mathematics in the Case School of Applied Science, at Cleveland, Ohio, has computed the following elliptic elements of this comet, from observations made by himself with the 23-inch equatorial and square bar micrometer of the Halsted Observatory, Princeton, from Nov. 14, 1889, to March 8, 1890. Three normal places, Nov, 15.5, Dec. 15.5 and Jan. 14.5, were used in computing the elements. The investigation of the orbit and historical sketch of the comet, on the supposition of its identity with Lexell's comet of 1770, were presented as a thesis for the degree of Doctor of Science to the Faculty of the college of New Jersey, Princeton, in 1890.

$$T = 1889 \text{ Sept. } 28.27186 \text{ G. M. T.}$$
$$\left.\begin{aligned} \pi &= 0^\circ\ 44'\ 02''.77 \\ \Omega &= 18\ \ 05\ \ 55\ .67 \\ i &= 6\ \ 04\ \ 02\ .23 \end{aligned}\right\} 1890.0$$
$$\varphi = 27\ \ 15\ \ 38\ .18$$
$$\log a = 0.5537124$$
$$\log \mu = 2.7194381$$
$$P = 6.7697 \text{ yrs.}$$

Middle place, Obs.—Calc.

$d\lambda \cos\beta = +0''.19 \qquad d\beta = +0''.05$

Comet f 1890 (Spitaler) has been looked for at many places but seen at very few. Professor Lewis Swift saw on Dec. 8 an object which on Dec. 14 was not in the same place. Professor Barnard at Lick Observatory has observed this comet regularly since Dec. 6. He says that it has been exceedingly small and faint, but that it is now (Dec. 12) apparently getting somewhat larger and brighter. No elements have yet reached us.

Comet e 1890 (Zona) has been observed at many places. The best elements at hand are those by Mr. Wendell, which are given below.

Orbit and Ephemeris of Comet e 1890 (*Zona Nov. 15.*) From Zona's observation of Nov. 15 and my own of Nov. 22 and 28, I have computed the following orbit and ephemeris of Zona's comet:

Elements.

$$T = 1890 \text{ Aug. } 7.10021 \text{ Gr. M. T.}$$
$$\pi - \Omega = 331^\circ\ 26'\ 36''$$
$$\Omega = 85\ \ 29\ \ \ 8$$
$$i = 154\ \ 26\ \ \ 5$$
$$\log q = 0.31148 \qquad q = 2.0487$$

Ephemeris.

Gr. M. T.	App. R. A. h	m	s	App. Dec. °	′	Log *r*.	Log *Δ*.
Jan. 1.5	2	3	46	+ 29	24	0.4279	0.3202
2.5	2	1	48	29	13		
3.5	1	59	55	29	2		
4.5		58	6	28	52		
5.5		56	21	28	41	0.4326	0.3416
6.5		54	42	28	31		
7.5		53	7	28	21		
8.5		51	35	28	12		
9.5		50	8	28	2	0.4373	0.3627
10.5		48	48	27	54		
11.5		47	31	27	45		
12.5		46	16	27	37		
13.5		45	6	27	29	0.4420	0.3829
14.5		44	0	27	22		
15.5		42	56	27	14		
16.5		41	54	27	7		
17.5		40	57	27	0	0.4467	0 4025
18.5		40	4	26	53		
19.5		39	12	26	47		
20.5		38	22	26	41		
21.5		37	36	26	35	0.4513	0.4214
22.5		36	54	26	29		
23.5		36	13	26	24		
24.5		35	35	26	19		
25.5		34	58	26	14	0.4560	0.4395
26.5		34	25	26	9		
27.5		33	53	26	5		
28.5		33	23	26	1		
29.5		32	55	25	57	0.4606	0.4568
30.5		32	29	25	53		
Jan. 31.5	1	32	5	+ 25	49		

The theoretical light of the comet on Jan. 31 will be less than half that on Jan. 1.

O. C. WENDELL.

Harvard College Observatory, Dec. 17, 1890.

Smith Observatory Observations. The following sun-spot observations were made with *helioscope* unless otherwise stated. They were taken by Charles E. Peet:

1890.	90° Mer. M. T.	Groups.	Spots.	Faculæ.	Seeing.	Remarks.
Nov. 18	2:55 p m	0	0	1	Poor.	Faculæ near SW. limb.
19	1:15 p m	0	0	0	Poor.	
20	1:15 p m	0	0	0	Fair.	
21	3:30 p m	0	0	0	Bad.	Seeing too poor to distinguish anything.
22	4:25 p m	0	0	0	Bad.	" " " " " "
23	2:30 p m	1	15	1	Fair.	One large spot with nuc. and penum.
24	1:45 p m	1	13	1	Fair.	Faculæ on NW. limb.
25	2:30 p m	1	11	2	Fair.	Faculous mottlings.
26	2:55 p m	1	19	0	Good.*	Four of the spots have nuc. and penumbra.
27	12:20 p m	1	13	1	Poor.	Faculæ on W. limb.
28	2:30 p m	1	17	1	Fair.*	Faculous mottlings near NW. and N. limb.
Dec. 1	9:40 a m	1	5	0	Poor.*	Group near NW. limb; 1 spot with nuc. [and penumbra.
6	1:25 p m	1	2	0	Poor.	Group near SW. limb.
8	12:55 p m	1	1	1	Good.	Faculous region about spot.
10	9:18 a m	0	0	0	Poor.	
14	3:10 p m	2	16	3	Fair.	Faculæ on E., SE. and NE.

* Projection on 20 cm. circle.

CHAS. A. BACON.

Carleton College Sunspot Observations. (Continued from page 468.)

1890.	Central Time.	Groups.	Spots.	Faculæ.	Observer.	Remarks.
Nov. 21	12:30 p m	0	0	0	C. R. W.	
22	10:40 a m	1	2	2 gr.	"	
24	2:20 p m	1	13	0	"	
25	12:40 p m	1	14	2 gr.	"	
27	10:20 a m	1			"	
28	10:30 a m	1	4		"	
Dec. 6	12:25 p m	1	1	2 gr.	"	One small spot surrounded by group of faculae SW. of centre. Group of faculae SE.—not prominent.
8	11:15 a m	1	1	1 "	"	One small spot very near W. limb surrounded by small bright group of faculae.
10	12:45 p m	1	1	1 "	"	Small spot on E. limb surrounded by small group of faculae.
11	12:45 p m	0	0	1 "	"	
12	12:20 p m	0	0	0	"	
16	12:20 p m	1	14	0	"	
17	12:20 p m	1	6	0	"	
18	12:45 p m	2	20	0	"	
19	12:35 p m	2	10	1 gr.	"	
20	12:40 p m	2	5	2 "	"	Large group of faculae on E. limb surrounding small spot.
22	11:10 a m	0	0	1	"	
23	12:40 a m	1	1	2 gr.	"	

Mount Holyoke Observatory. Sunspot Observations by Miss E. M. Bardwell.

1890	Eastern Time.	Groups.	Spots.	Faculae.	Remarks,
Nov. 3	About 12.00.	0	0	0	
" 4		0	0	0	
" 5		0	0	0	
" 6		0	0	0	
" 7	12.30	1	4		Hazy.
" 10	11.00	1	6	1	Floating clouds.
" 13	3.00	2	9		
" 14	About 12.00.	0	1	2	
" 18		0	0	3	
" 19		0	0	1	
" 21		0	0	2	
" 22	12.00	1	4	2	
" 24	12.00	1	13		Too cloudy to see faculae.
" 25	12.00	1	24		Cloudy. Could not count all the numbers.
" 26	12.00	1	26		
" 27	12.00	1	25		
" 28	12.00	2	20	2	Largest spot 24,000 miles across.
Dec. 1	11.30	1	3	1	Faculae around spots.
" 2	11.00	2	5	1	Large and very bright faculae around spots.
" 9	12.00	0	1	1	
" 12		0	0	3	
" 13	12.00	2	9		Cloudy.
" 15	12.00	2	14	2	One group of faculae was very bright.
" 16	12.00	1			Very hazy. Many small spots. Could not count them.
" 19	11.30	2	10	3	

South Hadley, Mass.

Solar Observations, Alta, Iowa.

OCTOBER 1890.

Date.	Central Time.	No. of New		No. of Visible		Definition.	Remarks.
		Groups.	Spots.	Groups.	Spots.		
1	11.25 a m	0	0	1	2	Good.	Faculæ NW.
2	11.45 a m	0	0	0	0	Fair.	
4	11.25 a m	0	0	0	0	Good.	Faculæ on NW. limb.
6	5.20 p m	1	?	1	?	Poor.	Sun too low to count spots.
7	12.00 m	0	0	0	0	Poor.	Hazy.
14	11.30 a m	0	0	0	0	Good.	Faculae near W. limb.
16	11.25 a m	0	0	0	0	Good.	Clear Disc.
17	11.20 a m	0	0	0	0	Good.	Clear Disc. Aurora this evening.
18	11.15 a m	0	0	0	0	Good.	Clear Disc.
19	2.20 p m	1	3	1	3	Good.	Spots SE. limb. Faculae E.
20	12.00 m	0	3	1	6	Good.	2 large spots, others small. Faculae on E. limb.
21	11.30 a m	0	0	1	6	Good.	3 large spots, 1 spot with umbra and penumbra. Faculae around Group.
22	11.30 a m	1	?	2	11	Fair.	Slight haze. Could not count all small spots.
23	11.20 a m	0	6	2	17	Good.	Spots small. 1 large one.
24	3.45 p m	0	0	2	15	Fair.	Brilliant "bridge" across large spot.
25	11.30 a m	0	0	1	?	Poor.	Single glimpse through clouds.
26	4.30 p m	0	0	1	?	Poor.	Sun too near horizon to count spots.
30	11.20 a m	0	0	1	2	Good.	Faculae NW.
31	11.30 a m	0	0	0	1	Bad.	Hazy. Large spot is on W. limb disappeapearing by solar rotation.

No observations owing to clouds on the 3d, 5th, 8th to 13th, 15th, 27th to 29th.

NOVEMBER 1890.

1	11.30 a m	0	0	0	0	Poor.	Apparently Clear Disc.
3	11.25 a m	0	0	0	0	Good.	Clear Disc.
4	11.20 a m	0	0	0	0	Good.	Clear Disc.
5	11.20 a m	0	0	0	0	Good.	Clear Disc.
9	3.00 p m	1	3	1	3	Good.	Group about 2 days in SE. surrounded by small [faculae.
10	2.00 p m	0	0	1	3	Good.	
11	11.50 a m	0	0	1	3	Fair.	Group on Meridian.
12	11.55 a m	0	0	1	2	Good.	
13	11.20 a m	0	0	1	2	Fair.	Spots small.
14	11.30 a m	0	0	0	0	Fair.	Apparently Clear Disc.
15	12.00 m	0	0	0	0	Poor.	Light clouds.
17	11.25 a m	0	0	0	0	Good.	Small faculae on E. limb. Groups faculae near SE. [and W. limb.
18	12.10 p m	0	0	0	0	Poor.	Faculae SE.
19	11.20 a m	0	0	0	0	Good.	Small faculae SE.
20	11.25 a m	0	0	0	0	Good.	Clear Disc.
21	12.00 m	0	0	0	0	Poor.	Haze.
22	11.25 a m	1	2	1	2	Good.	Group surrounded by faculae on E. limb.
23	1.40 p m	0	3	1	5	Good.	1 large spot. Large area faculae.
24	12.10 p m	0	2	1	7	Good.	1 large spot.
25	12.00 m	3	?	4	?	Bad.	Hazy. Single glimpse through clouds. Group N. Lat. 3 very large spots with umbra and penumbra.
26	12.00 m	0	?	4	19	Good.	Groups close together. Numerous small spots. Slight haze. 3 large spots unchanged.
27	11.45 a m	0	0	4	12	Fair.	Could not count all smaller spots.
28	11.50 a m	0	0	4	15	Good.	1 large spot with umbra and penumbra.
29	11.45 a m	0	0	4	11	Poor,	Large spot unchanged. Hazy. Could not count smaller spots.
30	2.45 p m	0	0	3	?	Poor.	Very hazy. Faculae E. limb. Group NE.

Cloudy on 2d, 6th, 7th, 8th, 16th.

DECEMBER, 1890.

Date.	Central Time.	No. of New		No. of Visible		Definition	Remarks.
		Groups.	Spots.	Groups.	Spots.		
3	11.45 a m	0	0	1	1	Fair.	Large spot on NW. limb disappearing by solar [rotation.
6	12.00 m	0	0	0	0	Poor.	Hazy.
7	1.30 p m	0	0	0	0	Good.	Small faculae on NW. limb. Faint group faculae [near E. and SW. limb.
8	12.10 p m	0	0	0	0	Good.	Apparently Clear Disc.
9	11,20 p m	0	0	0	0	Fair.	Apparently Clear Disc.
10	12.00 m	0	0	0	0	Poor.	
11	11.15 a m	0	0	0	0	Good.	Clear Disc.
12	11.25 a m	0	0	0	0	Fair.	Small faculae near E. limb.
14	2.20 p m	2	10	2	10	Good.	Larger group S. latitude on Meridian. Other group W. about ¼ across Disc.
15	11.40 a m	1	4	3	14	Poor.	Small faculae near SE. limb. Very hazy. Could not count all spots. New group E. of larger group.

DAVID E. HADDEN.

Solar Prominences for November.

DATE.	POSITION ANGLE.
1	80, 165, 250, 276, 316.
2	166, 245 to 268.
4	253, 260, 295.
5	150, 168, 255.
7	172, 251, 336.
16	144, 260.
20	88, 140, 262, 309.
21	50, 234.
22	50, 151, 255.
23	55, 150, 252, 270, 310.
27	150.
30	236, 327.

NOTE.—During latter half of month definition has been very bad.

Camden Observatory December 1st, 1890.

Astronomical Phenomena during the Year 1891.

The principal phenomena predicted for the year 1891 are four eclipses, two of the sun and two of the moon, a transit of Mercury over the sun's disk, and the disappearance and reappearance of Saturn's rings. Of these the last two will excite the most interest.

A total eclipse of the moon, May 23, will be invisible in the United States, but visible generally throughout the western part of the Pacific Ocean, Australia, Asia, Africa and Europe.

An annular eclipse of the sun, June 6, will be visible in the northern part of Siberia. It will be visible as a partial eclipse in the western part of the United States, in British America, Europe and Siberia.

A total eclipse of the moon, Nov. 15, will be visible throughout North and South America, Asia, Africa, Europe and the Atlantic Ocean. It will begin at 3^h 36^m and end at 9^h 03^m P. M. Central Time. We expect later to give a chart of the moon's path among the stars during this eclipse, and a list of the stars which will be occulted.

A partial eclipse of the sun December 1 will be visible only in the southern part of South America and the south polar region.

The Transit of Mercury across the sun's disk will take place on May 9, beginning at $5^h\ 55^m$ and ending at 10:53 P. M. central time. It will be partly visible in the United States and throughout the western part of North and South America and Asia. The whole transit will be visible in Japan, China, Eastern Siberia, Australia, and the Malaysian Islands. It is not likely that any expeditions will be sent out for the purpose of obtaining observations of this transit under favorable circumstances, for such observations would be of value only in determining the place of the planet. The solar parallax, for which such great pains have been taken in observing transits of Venus, has, by other means, been determined with much greater accuracy than could be attained from transits of Mercury. There are however, interesting questions as to the planet's appearance during transit, its atmosphere and motion. No one who has the opportunity to observe this transit should neglect to make all the use possible of it.

Professor G. W. Coakley, of the University of New York, has computed the times of the contacts for several of the observatories of the United States, data which will be found very useful to those wishing to observe the transit.

On Sept. 22 the earth will pass through the plane of Saturn's rings. The rings then, in telescopes of sufficient power to show them, will appear as a fine straight thread of light. From Sept. 22 to Oct. 30 the earth will be above the plane of the rings, while the sun will be below that plane, shining upon the south side of the rings. The rings then should entirely disappear, except the very fine thread of light which comes from the outer edges of Rings *A* and *B*. After Oct. 30 the sun will be on the north side of the plane of the rings, so that its light will illuminate the same side of the rings at which we look. Many interesting observations were made at the time of the disappearance of Saturn's rings in 1878 and, although the position of the planet will be very unfavorable, it is to be hoped that many of them will be repeated this year, and accurate data obtained for the solution of the problems connected with the rings. Saturn will be in conjunction with the sun on Sept. 12, so that at the time of the disappearance of the rings it will be very close to the sun and can be observed only very near the horizon.

We will give in our next number an abstract of a paper by Professor Trouvelot on his observations in 1877-78, with his suggestions as to the observations which should be made this year.

* * *

Transit of the Planet Mercury over the Sun's Disk, May 9, 1891.

At the Lick Observatory, Mt. Hamilton, Cal.,
The Exterior Ingress takes place, $11^h\ 54^m\ 17^s.99$ Greenwich Mean Time.
or, $3^h\ 54^m\ 17^s.99$ Pacific Standard Time.
The Exterior Egress takes place at $16^h\ 50^m\ 20^s.52$ Greenwich Mean Time.
or $8^h\ 50^m\ 20^s.52$ Pacific Standard Time.

At this last phase of the transit the sun will be below the horizon for alparts of the Pacific Coast, with the possible exception of some of the northern portions of Alaska. At places farther east the times of Egress will be still later, and hence have not been computed.

At Carleton College Observatory, Northfield, Minn.,
Exterior Ingress takes place at $11^h\,54^m\,26^s.68$ Greenwich Mean Time.
or $5^h\,54^m\,26^s.68$ Central Standard Time.

At Chicago, Ill.,
Exterior Ingress takes place at $11^h\,54^m\,19^s.73$ Greenwich Mean Time.
or $5^h\,54^m\,19^s.73$ Central Standard Time.

At New York City,
Exterior Ingress takes place at $11^h\,54^m\,25^s.81$ Greenwich Mean Time.
or $6^h\,54^m\,25^s.81$ Eastern Standard Time.

At the Naval Observatory, Washington, D. C.,
Exterior Ingress takes place at $11^h\,54^m\,18^s.64$ Greenwich Mean Time.
or $6^h\,54^m\,18^s.64$ Eastern Standard Time.

At Cambridge Observatory, Mass.,
Exterior Ingress takes place at $11^h\,54^m\,32^s.55$ Greenwich Mean Time.
or $6^h\,54^m\,32^s.55$ Eastern Standard Time.

GEORGE W. COAKLEY.

NEWS AND NOTES.

In sending names and addresses to the MESSENGER, correspondents are especially urged to write plainly, and in the case of renewals of subscriptions the address previously used should always be stated whether a change is desired or not. By so doing mistakes in the mailing lists will be prevented.

The prospects for Volume X of the MESSENGER for the year 1891 are certainly very bright. Never before have the books shown so long a list of renewals and new names in the month of December. The increase of the subscription price of the last year has had the opposite effect from that anticipated. Instead of a lessened number of subscribers the books show an actual and considerable increase. And a general and hearty support before unrealized has been given in various ways.

With such encouragement in our work, further improvement will be possible and is even now under contemplation. One new feature of which we have spoken before will have its beginning in our next number. Professor W. C. Winlock, Superintendent of the Bureau of International Exchanges, has furnished copy already for the Bibliography of Astronomy for a considerable part of the year 1890. This most useful addition to our annual record of the progress of Astronomy will hereafter appear regularly, and will follow the dates and events they record so closely as to be of the largest possible service to all interested in the various branches of Astronomy.

The reprint of Volume I of the MESSENGER will be undertaken as soon as the next publication of Carleton College Observatory is through the press. The second publication (though not so numbered) is a full set of tables for various reductions of observatory work, and this volume is now in the hands of the binder. The copy for the next publication is nearly all in the printer's hands and it will be completed and distributed before the middle of February, 1891. The calls for full sets of the MESSENGER continue to come, and we now hope to fill all such orders during the month of March. The prices for the several volumes unbound are as follows: Volume I, $5.00 (scarce); II, III, IV, V, VI, VII, VIII, $2.00 each: IX, X and later ones each, $3.00. Prices for bound volumes on application.

The appearance of a new periodical devoted to Astronomy, titled *The Journal* of the British Astronomical Association, is a welcome visitor at our table. Its first number bears date October 1890, and has the familiar name of E. W. Maunder as editor. This number contains an account of the general meeting of the Association on October 24, the list of officers of the Council, rules of the Association, report of the provisional committee and its circulars, two excellent papers, one, on the rotation periods of the planets Mercury and Venus, by Miss A. M. Clerke; the other, on the chief nebular line, by E. W. Maunder. These are followed by book notices, correspondence, and 'notes' of general and current interest. This number contains 48 pages and clearly indicates a vigorous beginning for the new association and a purpose to maintain a strong journal in the interest of Astronomy. The membership of the Association has already reached 350. THE MESSENGER extends hearty congratulations.

Copley Medal to Professor Newcomb. The Copley Medal of the Royal Society, London, has been awarded to Professor Simon Newcomb, Superintendent of the American Ephemeris, Washington, D. C., for his contributions to gravitational astronomy. The medal was first given by the Society in 1753, to Dr. Benjamin Franklin. The following named persons, respectively, have received this honor during the last thirty years:

1860.	R. W. Bunsen.
1861.	L. Agassiz.
1862.	T. Graham.
1863.	A. Sedgwick.
1864.	C. Darwin.
1865.	M. Chasles.
1866.	J. Plucker.
1867.	K. E. von Baer.
1868.	C. Wheatstone.
1869.	H. V. Regnault.
1870.	J. R. Joule.
1871.	J. R. Mayer.
1872.	F. Wöhler.
1873.	H. L. F. Helmholtz.
1874.	L. Pasteur.
1875.	A. W. Hofmann.
1876.	C. Bernard.
1877.	J. D. Dana.
1878.	J. B. Boussingault.
1879.	R. J. E. Clausius.
1880.	J. J. Sylvester.
1881.	K. A. Wurtz.
1882.	A. Cayley.
1883.	Wm. Thompson.
1884.	C. Ludwig.
1885.	A. Kekule.
1886.	F. E. Neumann.
1887.	J. D. Hooker.
1888.	T. H. Huxley.
1889.	G. Salmon.
1890.	S. Newcomb.

The mathematical medalists in the previous years have been ; Waring, 1784; Ivory, 1814; Gauss, 1838; Sturm, 1841, and Chasles, Plucker, Sylvester, Cayley, Thompson and Salmon as indicated in the above table.

It also gives us pleasure to notice in the *Washington Star*, Nov. 29, that Professor Newcomb has also been recently remembered in a very handsome way by distinguished persons and institutions in foreign lands. The University of Tokio, Japan, has presented him with two fine, large bronze vases, finished specimens of Japanese art, in recognition of his aid in selecting a suitable person to construct a photo-heliograph for the University.

A present from Russia by order of the Czar is also tendered to Professor Newcomb on account of esteemed services rendered in procuring, for the government, the great 30-inch telescope a few years ago mounted at Pulkowa. This gift is a large, jasper vase on a marble base. Such tokens of regard proffered from three different foreign lands, and that for incidental scientific services only, show well the rank of American science at the present time.

Observations of Venus near Inferior Conjunction in the first part of December. In answer to your request, I take pleasure in sending you my notes concerning the close conjunction of Venus with the sun in the first part of this month.

I had made preparations to observe the conjunction, but a spell of bad weather set in on the 1st of December and lasted until the 5th, thus completely blotting out the heavens during the important time. However, what few notes I did secure may be of interest.

November 29. The crescent is very thin. The southern horn extends farther than the northern. No trace of the dark part of Venus.

Dec. 1. The horns extend through about 270°. The southern cusp can be traced much farther than the other, and is much more slender.

Dec. 2. Cloudy.

Dec. 3. Cloudy.

Dec. 4. Cloudy.

Dec. 5. Sidereal $16\frac{1}{2}^h$. Nearly the entire circumference is visible; at least eight or nine-tenths of the ring of light is distinctly traceable. At times the circle appeared to be complete, but I do not think that it was nearly so. No markings of any kind were seen either in the crescent or on the dark body of Venus. The air was, as usual here in the day, very unsteady, and delicate details would have been lost. The body of the planet was of the same depth of shade as the sky and no contrast between the two was seen. The observations were made with the 12-inch equatorial and its finder (3¼-in.) with magnifying powers of 50 ±, 80 and 150.

I regret exceedingly the unfortunate storm which blotted out the planet on the 2d, 3d and 4th of December, for, from the observations of the 5th, I feel certain the entire circumference would have been visible on the 4th.

Mt. Hamilton, Dec. 12, 1890. E. E. BARNARD.

Hough's Catalogue of 94 New Double Stars. In *A. N.* 2977 will be found the catalogue of 94 new double stars by G. W. Hough, Director of Dearborn Observatory, Evanston, Ill. This catalogue contains 48 pairs having a distance of less than 0″.5, a larger number of close doubles than we remember to have seen in any other similar publication.

Swift's Ninth Catalogue of New Nebulæ. Dr. Lewis Swift is still at work in finding new nebulæ. His ninth catalogue of 100 new nebulæ will be found in the *Astronomische Nachrichten* No. 3004. He is now well started on the tenth catalogue of these faint objects.

Spectroscopy at the Paris Observatory. M. Deslandres has charge of the spectroscopic section recently created at the Paris Observatory, and in a recent number of the *Comptes Rendus* an account is given of the instruments to be used with the great equatorial whose aperture is 1.20 meters. The difficulty of adjusting a star to the slit of the spectroscope for the purpose of photographing the spectrum seems to be nicely overcome. To do this M. Deslandres has arranged a total reflecting prism near the dark side so that the red end of the spectrum may be seen while the blue end is being photographed. In this way he has obtained many photographs of stellar spectra in juxtaposition with comparison spectra. To adjust the instrument for observing the spectrum of a star, a small mirror having a hole in the center, about the same diameter as the length of the slit, has been fixed in front of the slit at an inclination of 45°. The image of the star is thus reflected to the side of the instrument, and, after another reflection reaches a small telescope fixed at the spectroscope. The telescope, therefore, gives the image of a star, in the plane of the slit, and constitutes a veritable finder for use with the spectroscope.—*Nature*, Oct. 30, 1890.

A Jena Glass Visual Objective Used as a Photographic Lens. I have a Jena glass objective of two and one-tenth inches aperture and thirty-five inches focal length, made by Brashear for visual use, which gives very good photographic images. With one second exposure the image of Polaris is less than 0.002 inch in diameter; with ten seconds' exposure, between 0.003 and 0.004 inch. Equatorial stars of the 6th magnitude give trails less than 0.001 inch wide. With very slight magnifying the plates bear measuring to within five seconds of arc. J. A. PARKHURST.

Marengo, Ill.

Report of Yale University Observatory. The last report of the Observatory of Yale University for the year 1889-90 has just been received. It bears date of June 18; so its contents are rather old. It was then said that the measures of Victoria and Sappho, by the heliometer, were well kept up, and required only a final revision. It was then proposed to take again the observations on the parallaxes of the first magnitude stars in the northern hemisphere, with the intention of carrying out the work as first planned. Dr. Elkin thinks that the advantages of the heliometer for these bright stars are such as to make it well worth while to pursue the investigation without the fear of being immediately supplanted by the photographic method of observation, although he thinks the latter method will prove certainly superior for all but the very brightest stars.

Progress of Astronomy in 1887 and 1888. An account of the progress in astronomy for the years 1887 and 1888, as prepared by William C. Winlock, Superintendent of the Bureau of International Exchanges, Smithsonian Institution, Washington, D. C., has been received. It is a pamphlet of about 90 pages, and essentially the same in plan and form as its companions of 1885 and 1886. It is a very general, compact and useful *resume* of the astronomy of those two years.

Saturn and Its Rings is the title to Appendix II of Washington Observations of 1885. It contains a list of observations of Saturn from 1875 to June 1, 1889, by Professor Asaph Hall of the U. S. Naval Observatory, Washington, D. C. By this study Saturn's rotation time is found to be 10^h 14^m $23^s.8 \pm 2^s.30$. This value has been adopted by the latest and best text-books on astronomy. Professor Hall speaks of the anomalous curvature of the outline of the shadow of the ball on the rings in 1876, when the convexity of it appeared to be turned toward the planet, contrary to what one would expect from geometrical considerations. In 1878 something of this kind was seen at Washington after the reappearance of the ring. Professor Hall thinks that this appearance seen when the ring was very narrow, arose from the shortness of the outline, and a little bluntness in the ends of the shadow. This would not account for the reversed curvature of the shadow as observed by Aldro Jenks April 25, 1889, an account of which was published in No. 86 of THE MESSENGER. Professor Hall further says: "No notch has ever been seen in the outline of the shadow." In 1851 Otto Struve, of Pulkowa, thought that the dimension of Saturn's ring was undergoing a secular change, that in a short interval of about 100 years would bring its inner edge in contact with the planet. This theory has been adopted by Maxwell and Hirn in their mechanical investigations on the constitution of the ring. In comparing his own measures with those of Bradley in 1719 and those of later astronomers Professor Hall finds that there is apparently no change in the dimension of the Ring during 167 years.

Following these notes and the discussion of them, two full page plates of Saturn are found. They are weak and disappointing representations of what is known of the details of Saturn's surface.

The Orbit of 70 Ophiuchi. With reference to Mr. Mann's interesting article on binary stars in THE SIDEREAL MESSENGER for November 1890, I computed an orbit for 70 Ophiuchi in the year 1888, and my results were published in the Monthly Notices of the R. A. S. for March of that year. The elements I found were as follows:

$P = 87.84$ years $\qquad \Omega = 120^\circ\ 5'$ (1880.0)
$T = 1807.65$ $\qquad \lambda = 171^\circ\ 45'$
$e = 0.4912$ $\qquad a = 4''.50$
$\gamma = 58^\circ\ 28'$

These elements, which do not differ much from Mr. Mann's, represent all the measures fairly well from 1802 to 1889. A diagram of the apparent orbit, drawn to scale, will be found in my "Scenery of the Heavens," p. 193, and also in *Knowledge* for August, 1890. I find, as Mr. Mann does, that the line of nodes nearly coincides with the projection of the major axis. My elements give the following ephemeris:

Date.	Position-Angle.	Distance.	
1890.50	334°.08	2''.03	
1891.50	325 .44	2 .13	
1892.50	317 .54	2 .22	
1893.50	310 .09	2 .28	
1894.50	302 .92	2 .30	
1895.49	295 .75	2 .27	{periastron passage.

Ballysodare, Ireland, Nov. 27, 1890. J. E. GORE.

Time Service and the U. S. Naval Observatory. A person who well understands how things go on the inside of the United States Naval Observatory, has recently written us pretty fully concerning the status of the time question and the attitude of those whose judgment has been depended on in the late action of the Secretary of the Navy. The information, as unfavorable as it is for some, is doubtless true every word of it, for it is only a piece of what has been developed during the last year, and shown in the papers generally to the utter disgust of four-fifths of those interested in astronomy. The plan suggested by this friend from whom we have not heard before, is a good one, and there is more hope of its success in view of the marked changes in political power now in progress than possibly could have been expected under existing authority. The indications are not only a "stiff breeze from the northwest," but a ventilating blizzard from every point of the compass to give Washington a little healthful airing.

Annals of the Harvard College Observatory, Vol. XXIV. The discussion of the measurements made with the Meridian Photometer during the years 1882 to 1888 is found in Vol. XXIII of the Annals. The principal results obtained will be found in the present volume. The stars were mainly selected from the Durchmusterung and are brighter than 9.1 magnitude. A further collection of miscellaneous objects whose brightness is derived by photography is also given. The total number of measurements in the work is 1,067, and the separate objects observed are 20,982; four photometric settings were made on each object, and these repeated three or four times. Total number of settings 267,092. The aperture of the telescope used was four inches, and stars of the ninth magnitude were, of course, easily observed, and the measures of different nights are accordant, showing a deviation of not more than 0.11 of a magnitude. Professor E. C. Pickering himself made about two-thirds of the measurements and Mr. O. C. Wendell the remainder.

Vol. XXI, Pt. 2, of the Annals is also on hand. It contains the investigations of the New England Meteorological Society for the year 1889.

Vol. XXX, Pt. 1, of the Annals contains observations made at the Blue Hill Meteorological Observatory in the year 1889.

Still another interesting publication from the same source is the History of the Harvard College Observatory during the period 1840 to 1890. This was prepared by Daniel W. Baker and appears in neat pamphlet form as a reprint from the Boston *Evening Traveler*. It is fully illustrated.

The Cordoba Durchmusterung. No. 230 of the *Astronomical Journal*, Boston, Mass., contains an account of the work at Cordoba, by John W. Thome, Director of the National Observatory of the Argentine Confederation, on the Southern Durchmusterung. The results discussed in the article are drawn from work that has been going on for the last five years. It is perhaps generally known that Schönfeld's great work reached to — 22° in declination. Mr. Thome has extended this star survey to —42° in declination, making more than a million of observations of the stars in this intervening belt of 20°, where such useful information is much needed.

Theory of Moon's Motion has again been under discussion of late by John N. Stockwell of Cleveland, Ohio, and G. W. Hill of Washington, D. C. The articles referred to will be found in the *Astronomical Journal*, Nos. 220, 226 and 231. Mr. Hill criticises Mr. Stockwell's method of computing the secular motion of the moon's perigee in two particulars; (1) he claims that the differential equation of the motion of the perigee should contain no instantaneous element; (2) that the eccentricity of the earth's orbit should be regarded as variable in developing the differential equations of the moon's motion. Mr. Stockwell admits that the first point of criticism is well taken, but the second he claims is not good, although such authorities as Professor Adams and Delaunay have previously reached the same conclusions by different methods as that supported by Mr. Hill. The weight of authority is certainly against Mr. Stockwell, yet we shall look with interest for the results of his further study of this particular phase of this intricate problem.

Photographic Notes. The great importance now attached to the photographic method in astronomical research is markedly shown in the proceedings of the meeting of the Royal Astronomical Society as reported in the December Observatory. Mr. McLean's paper on High Sun and Low Sun Spectra was accompanied by a series of parallel photographs. This paper gives the ortho-chromatic method for obtaining such pictures. Mr. Higgs presented photographs of the A line in the solar spectrum. Mr. Russell's paper was on celestial photographs taken at the Sydney Observatory. Pictures taken by Professor Pritchard with his photographic charting telescope were received by the society. In regard to this instrument the following statement is made: "One of the tests adopted was to expose a plate to the sky for three minutes. Professor Pritchard then stopped the clock and removed the plate; afterwards he replaced the plate, brought the guiding star to the cross-wires, and made a second exposure. The two images coincided perfectly, and there is nothing to show that two exposures were given. Professor Pritchard also speaks in the highest terms of the reticule, and of his apparatus for measuring the size of star discs." Attention was also called to the photographic research made at the Lick Observatory by Professor Holden for the determination of the parallaxes of stars. Mr. Fowler stated that a photographic study of stellar spectra had been commenced at South Kensington under the direction of Professor Lockyer, and that one of the first results obtained was the discovery that α Lyrae is a binary star of the β Aurigae type. The method by which this discovery was made is described in the same paper.

Oscillation of the Earth's Axis. The *London Mail* for Nov. 26, 1890, has a brief article to the effect that Professor Alfred Kirchoff of Halle, has published a paper in the *Saale Zeitung*, on the great interest that scientific men looked forward to the autumn meeting of the International Conference on Degree Measurement, which was lately held at Freiburg. It had been reported that a series of simultaneous observations carried on at Berlin, Strasburg and Prague went to show that a decrease in latitude was in progress apparently in middle Europe, and further reports from other observatories showed that a similar phenomenon had been noted in other places in Europe. This seemed to imply that a change was going on, in the direction of the earth's axis, amounting to a decrease of latitude at the end of the six months' period from Aug. 1889, to Feb. 1890, of one-half of a second of arc. But it was reported to the conference that the Berlin observations for the half year ending last August showed an increase of latitude amounting to two-fifths of a second. The question raised then is: Are there fluctuations of the earth's axis within the ball that will account for the changes of latitude observed wholly or in part? Or must astronomers find the explanation in other causes? Some American observatories will take part in the study of this important question soon, and simultaneous observations in the Prime Vertical will be taken by different observatories on or near the same parallel of latitude, but having as great a difference of longitude as six hours.

Dr. J. G. Galle, Director of the Observatory at Breslau, has recently kindly favored the Observatory Library of Carleton College with a number of publications prepared at Breslau since 1875.

BOOK NOTICE.

The Meteoric Hypothesis: A Statement of the results of a Spectroscopic Inquiry into the Origin of Cosmical Systems. By J. Norman Lockyer, F. R. S. Messrs. Macmillan & Co., London and New York. pp. 560. Price $5.25.

This volume is probably the most valuable one that has come from the ready pen of Mr. Lockyer. The object of it is to bring together and coördinate the observations that have been made up to the present time, on the spectra of the various orders of cosmical bodies in connection with laboratory work since 1868, and naturally follows the researches made by Mr. Lockyer relating to the origin of many solar phenomena as dependent on the fall of meteoric masses on the sun's surface. His investigations in this direction were published in 1887 in a book called *The Chemistry of the Sun*. In this volume the claim is made that the photographic study of nebular spectra has raised, so far, no new point of theoretical importance, and so it has been thought best not to delay its publication for detailed answer to objections that do not refer to the new hypothesis as a whole, but only touch it incidentally, or in minor detail. The author welcomes thorough and competent criticism and believes his hypothesis will be improved by all such thorough tests. As much is being said and will be said in THE MESSENGER about this new theory we will now give only a brief outline of the book. It is divided into nine parts. Part I has to do with the fall and nature of meteorites (1) a general record, the physical characteristics and the chemistry of these bodies.

Part II deals with the spectroscopy of meteorites by studying the spectra of metals found in them and of gases occluded in them.

Part III treats of meteorites in the air; the identity of origin of luminous meteors and falling stars with meteorites; the Aurora a phenomenon produced by the dust of meteors and falling stars, and the traces of meteoric dust in deep oceans.

Part IV is upon meteorites in the solar system, those which travel around the sun; demonstration of the cosmical hypothesis; these meteor swarms on comets; what the appearances of comets are when near and far from the sun, and the forces which produce the various forms of cometary swarms. The spectroscopy of comets and the origin of cometary phenomena.

Part V presents meteors in space, treating of the nebulae and of the stars.

Part VI gives the proposed new grouping of cosmical bodies in seven classes.

Part VII is on the origin of binary and multiple systems.

Part VIII, on the variability of light and color of cosmical bodies; and Part IX, the general conclusions, followed by appendices and an index.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 10, NO. 2. FEBRUARY, 1891. WHOLE NO. 92

ON WOLF AND RAYET'S BRIGHT-LINE STARS IN CYGNUS.

WILLIAM HUGGINS D. C. L., LL. D., F. R. S., AND MRS. HUGGINS.

In 1867 MM. Wolf and Rayet discovered at the Paris Observatory three small stars in Cygnus, which in the spectroscope showed several bright lines upon a continuous spectrum.* All three stars have a very bright band in the blue part of the spectrum.

These stars are:—

B.D. + 35°, No. 4001.
B.D. + 35°, No. 4013.
B.D. + 36°, No. 3956.

Their spectra were described in 1873, by Vogel, whose observations agree substantially with the original description given by Wolf and Rayet.† A more complete account of their spectra was given by Vogel in 1883, from observations at Vienna with the 27-inch refractor made by Sir Howard Grubb.‡

Vogel's measures of the bright blue band place it in the star No. 3956 at from λ 468 to λ 461, with a maximum at λ 464; in the star No. 4013 with a maximum at the same place in the spectrum; while the corresponding blue band in the star No. 4001 has a considerably less refrangible position, commencing at λ 470, reaching a maximum at λ 468, and ending about λ 465.

These later measures, though they differ from his earlier ones, in so far as they show that the blue band has not an identical position in all three stars, nevertheless support substantially his earlier observations, which Vogel considered to show, contrary to the statements of Secchi, that

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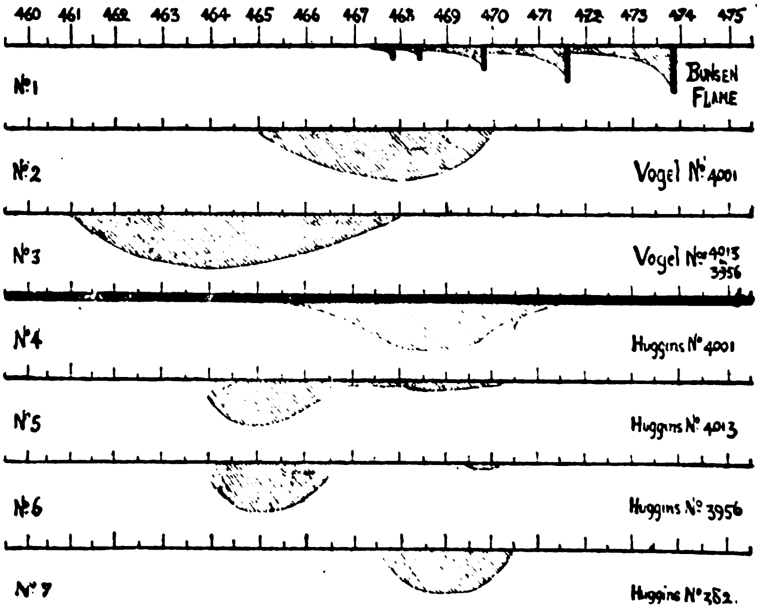
* 'Comptes Rendus,' vol. 65, 1867, p. 292.

† 'Berichte K. Sächs. Ges. der Wiss.,' Dec. 1873, p. 556.

‡ 'Publicationen Astrophys. Obs. Potsdam,' vol. 4, No. 14, pp. 17-21.

the bright lines, including the blue band, were not due to carbon.

In the diagram, Nos. 1, 2, and 3 show the positions of the bright bands in the three stars, according to Vogel's measures, relatively to the blue band of the hydrocarbon flame.



Vogel's measures are:—

	Beginning of the band.	Brightest part.	End of the band.
Star No. 4001........	λ 470	λ 468	λ 465
" 4013........	—	λ 464	—
" 3956........	λ 468	λ 464	λ 461

His diagram shows the band in No. 4013 to begin and end at about the same positions as in the star 3956.

It has been stated recently, that the bright blue band in all three stars is the carbon band in the blue commencing near λ 474*; and more recently, notwithstanding the difference of position, according to Vogel, of the band in one of

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* 'Professor Lockyer, in the Bakerian Lecture for 1888 (Roy. Soc. Proc., vol. 44, p. 57), says of the star No. 4001:—"The bright band with its maximum at λ 468 is the bright carbon fluting commencing at λ 474 and extending towards the blue, with its maximum at 468, as photographed at Kensington."

the stars from that which it occupies in the other two of as much as λ 0040, that direct comparisons showed an absolute coincidence of the band in all three stars with the blue band of a spirit-lamp flame.*

As the presence or absence of carbon in these stars, as shown by the coincidence or otherwise of the blue band with that of the hydro-carbon flame, was of great importance to us in connection with a wider investigation on which we are at work, we thought it necessary, after these recent statements as to the position of the band, to make direct comparisons of the spectra of these stars with that of the hydrocarbon flame under sufficiently large dispersion to enable us to determine whether Vogel's measures are substantially correct, or whether they are so largely in error as the absolute coincidence of the band with the blue band of a spirit-lamp flame in the case of all three stars would show them to be.

The obvious importance of making the observations with sufficient dispersion is supported by Vogel's own experience. With the small dispersion which he employed in his earlier

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Of the star 4013:—"The bright band in the blue at 473 is most probably the carbon band bright upon a faint continuous spectrum, this producing the absorption from 486 to 473" (*loc. cit.* p. 41).

Of the star No. 3956:—"The bright band at 470 is the carbon band in the blue, commencing at 474, with its maximum at about 468, as observed and photographed at Kensington" (*loc. cit.* p. 43). See Vogel's measures for the band in this star, which are given in the text.

Diagrams of the spectra of these stars are given at pp. 38, 40 and 41, based on Vogel's observations and his curves, which, on a slightly reduced scale, are placed at the bottom of the diagrams. The maximum of Vogel's curves is placed in all three diagrams at λ 468, and agrees in the diagrams with the carbon band, whereas Vogel's original curves and his measures place the maximum in the case of two of the stars at λ 464, beyond the carbon bands.

* Professor Lockyer, in a signed article in 'Nature' (August 7, 1890, vol. 42. p. 344), writes:—

"In the Bakerian Lecture for 1888 I gave a complete discussion of the spectra of bright-lined stars, as far as the observations went, and the conclusion arrived at was that they were nothing more than swarms of meteorites a little more condensed than those which we know as nebulæ. The main argument in favor of this conclusion was the presence of the bright fluting of carbon which extends from 468 to 474. This standing out bright beyond their short continuous spectrum gives rise to an apparent absorption band in the blue. . . . Direct comparisons of the spectrum of all the three stars in Cygnus with the flame of a spirit-lamp have been made by Mr. Fowler, and these showed an absolute coincidence of the bright band in the stars with the blue band of carbon seen in the flame. It was found quite easy to get the narrow spectrum of the star superposed upon the broader spectrum of the flame so that both could be obobserved simultaneously."

observations in 1873, he did not detect the large difference of position, about λ 0040, of the band in No. 4001, as compared with its position in the other two stars. On this point Vogel says, in his memoir of 1883:—"Etwas abweichend ist nur die Auffassung der Lage der breiten hellen Bande im Blau, die bei den früheren Messungen bei allen drei Sternen übereinstimmt. . . . Bei den verhältnissmässig geringen optischen Hülfsmitteln, mit denen jene Messungen ausgeführt wurden, ist die Uebereinstimmung aber eine ganz überraschande" (*loc. cit.*, p. 21.)

We observed the spectra of the stars successively, first with a direct vision prism of small dispersion, then with a spectroscope (A) containing one prism of 60°, and finally with a spectroscope (B) with two compound prisms, equal to about four prisms of 60°; with the last-named instrument the comparisons with the hydrocarbon flame were made.

A rapid preliminary comparison in the spectroscope (B) of the spectra of the three stars with the blue base of a Bunsen flame showed at once the substantial accuracy of Vogel's measures, and the striking difference of position of the band in the star No. 4001 from that which it holds in the other two stars.

The obvious want of agreement of the star bands with the blue band of the Bunsen flame was seen at once. Their relative positions appeared to agree substantially with the positions represented in No. 2 and No. 3 of the diagram, which are based on Vogel's measures. More careful and repeated observations brought out clearly, as is indeed shown by Vogel's curve, that the star bands differ in character as well as in position from the blue band of the hydrocarbon flame, and also in some respects from each other.

Before giving in more detail the results of our observation on each of the three stars, it should be stated that in all the stars the continuous spectrum is not in our instruments a short one, ending before the position of the bright blue band is reached. On the contrary, an examination with all three spectroscopes showed that the continuous spectrum, though enfeebled by absorption a little before reaching the blue band, can be traced, as is shown in Vogel's curves, quite up to the band, and indeed extends for a long distance into the violet beyond the blue band. The blue band does not in our instruments stand out bright beyond the end of a short continuous spectrum, but falls upon a fairly luminous continuous spectrum, which can be traced past the blue band into the violet, apparently as far as the eye could be expected to follow it.

We suspected bright lines or bands in the region more refrangible than the blue band, but in such faint objects this is a point which should be determined by photography.

Professor E. C. Pickering has since kindly informed us that his photographs of the star No. 4001, which extend into the ultra-violet region, show beyond the blue band the bright hydrogen lines at 434, 410, 397 and 389; and also other bright lines at 462, 455, 420, 406, 402, 395 and 388.

In his photographs of the stars 4013 and 3956, however, the only well-marked line is in the blue at 470.

Star 4001.—In this star, as is shown by Vogel's measures and curve, the bright blue band is less refrangible than in the other two stars, and approaches therefore nearer to the position of the blue band of the hydrocarbon flame. The appearance and position of the band in the star as contrasted with that of carbon, when observed in spectroscope B, are represented in spectrum No. 4 of the diagram.

The brightest part of the band, from about λ 468 to λ 469, falls off rather suddenly in brightness at about these wavelengths, but can be traced toward the red as far as about λ 471.5, and as far in the blue as about λ 465.5.

In our observation of this and the other stars we did not attempt micrometric measures of the blue band, but we estimated their positions by means of the intervals between the five flutings of the band of the Bunsen flame. In the case of objects so faint in our instrument when viewed under the dispersion of spectroscope B, we did not consider there would be any real gain of accuracy by attempting to take measures.

Though the wave-lengths assigned to our positions must therefore be regarded as not more than approximately correct, we have no hesitation in considering them fully accurate enough for the purpose of our investigation.

The star band is not split up into well-separated maxima, as is the Bunsen flame band, but we have little doubt that the brightest part of the band, from λ 468 to λ 469, which is much, and rather suddenly, brighter than its beginning and termination, consists of bright lines. Lines appear to flash out at moments, but in our instruments they cannot be seen with sufficient steadiness for us to be sure of their number and position.

Under certain conditions of the electric discharge, the normal relative brightness of the component flutings of the blue hydrocarbon band has been observed to be so far changed that the position of maximum intensity is moved from the less refrangible end of the band towards the blue end; but the five flutings remain without any change of their position in the spectrum.[*]

Dr. Hasselberg, by means of feeble disruptive discharges from tinfoil terminals placed outside an exhausted tube containing vapor of benzole, obtained a nearly pure spectrum of the order of that in a hydrocarbon flame mixed only with faint lines of hydrogen. He says: "Es war aber hier die violette Gruppe sehr schwach. Dagegen schein mir die blaue Gruppe relativ heller als im Flammenspectrum, und sie hatte ausserdem entschieden ihre grösste Intensität nicht an der weniger brechbaren Kante, sondern mehr nach dem Violettenhin. Dasselbe schien mir auch mit der gelben Gruppe der Fall zu sein. In Bezug auf die grüne Gruppe konnte ich aber keine Verschiebung des Intensitätsmaximums bemerken."

Dr. Hasselberg gives curves to show the amount of this change of intensity in the blue group and in the orange group. In the blue group the maximum is moved from the first to the third line, that is, about λ 4698. His curve gives the brightness of the maximum over that of the first lines as about 7 to 6, whereas the normal relative intensity of these two lines is in the inverse direction and as about 2 to 4 (Watts, 'Index of Spectra,' p. 30).[†]

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[*] It is necessary to state that the maximum luminosity of the blue band, under some conditions, is about 468. . . . The conditions under which this band has its maximum luminosity at 468 in Geissler tubes seem to be those of maximum conductivity. If the pressure be high, all the members of the group are sharp, and the luminosity of the band is almost uniform throughout. This always occurs when the pressure is very low. At intermediate stages of pressure, however, the luminosity has a very decided maximum at about 468" (Appendix to the Bakerian Lecture for 1888, 'Roy. Soc. Proc.,' vol. 45, pp. 167, 168).

[†] 'Mém. de l'Acad. Imp. des Sciences de St. Pétersbourg,' vol. 22, No. 2. 1880, p. 82.

A similar change from the normal relation of brightness of the flutings within the band, even if removed to λ 468, does not seem to us to bring the star band sufficiently into accordance in character and position with those of the band of the hydrocarbon flame to justify us in attributing the blue band in the star to carbon. Though we traced the band a little further towards the red, than the position of the beginning of the band given by Vogel's measures, yet it is very faint, and without any increase in brightness at the place of the second fluting of the carbon band, beyond which we were unable to see it.

According to Hasselburg's curve, the second bright fluting, where in our instruments the star band ends, still retains a brightness of about $\frac{1}{12}$ of that of the maximum, and the first line, at the position of which no brightening of the feeble continuous spectrum of the star could be detected, a brightness of about $\frac{2}{7}$ of that of the maximum. That the flutings of the band were not obscured by the absorption band at this part of the spectrum appears clear from the circumstance that we could trace the faint continuous spectrum up to the bright band.

Vogel's and our observations agree in making the band run on some distance beyond the visible termination of the blue band of the Bunsen flame. Piazzi Smyth, under some conditions, observed a large number of faint "linelets," beyond the "5th leader" of the band, where its visibility usually ends; and in the brilliant light of the arc the band can be traced further in the blue. The extension of the band under such circumstances does not seem to us to affect our present argument; for in the very feeble light of the star we may surely take it that the carbon band, if present, could not be seen, to extend further than its usual visible limit in a Bunsen flame, namely about λ 468.

Perhaps it should be stated in connection with the circumstance that we saw the band extend a little further towards the red than Vogel did, that at the time of our observations the hydrogen line at F was not visible in our instruments, whereas it was bright at the time when Vogel observed the star. In the spectrum of a similar star, D. M. + 37° 3821, in which the hydrogen line at F at the time was bright, the blue band was seen by us to stop near the place given by Vogel in his measures of the star No. 4001.

Not only is there no coincidence, so far as Vogel and we have observed, of the position of the band in the star with that of the blue band of the Bunsen flame; but, further, the want of accordance of its general characters is so great as to make the view that its origin is carbon very improbable. This improbability is very greatly increased when we find, as will be shown presently, that no traces whatever of the very bright beginnings of the more brilliant green and orange bands could be detected by us in any of the stars. Further, Professor E. C. Pickering has kindly sent to us an account of his photographs of this star, which, though they show the hydrogen line at λ 434, do not exhibit any brightness at the positions of the indigo hydrocarbon bands, beginning near 4312, and λ 4382.

This star, however, can scarcely be taken by itself; in the case of the other two stars, in the spectra of which, according to Vogel's, Copeland's, and our own observations, the brightest part of the blue band is from λ 464 to λ 465, but nearer λ 465, quite outside the ordinary visible limit of the carbon band, the evidence seems very strong indeed that the band does not owe its origin to carbon.

We satisfied ourselves that when the spectrum of the star is examined under the dispersion of spectroscope B, none of the brighter parts of its spectrum fell at, or very near, the green, orange, and indigo flutings of the hydrocarbon flame spectrum; at these positions we were unable to detect any sensible brightening of the star's spectrum. Professor Copeland's measure of the blue band in 1884 was λ 469.5.

No. 4013.—Vogel does not give measures of the beginning and the ending of the band in this star, but only of the brightest part:—"Hellste Stelle, nahezu Mitte, einer breiten verwaschenen Bande, λ 464." He gives, however, a diagram of the spectrum in which the bright blue band is represented as substantially coincident in position and in general character with that in the spectrum of No. 3956.

Our observations agree substantially with those of Vogel, but they make the band to consist of two parts, a very bright part, from about λ 466 to λ 464, but brightest near λ 465; and a very faint band, apparently detached from the bright one from about λ 4685 to about λ 4705. This faint band is brightest near where it ends rather abruptly at the more refrangible end. The very bright band has not the character of a fluting, nor is it broken up into maxima widely separated like those of the Bunsen flame band, but appears to be a group of bright lines. The lines were only glimpsed at moments; it is therefore difficult to make a drawing which truly represents the character of the band as seen in our instruments. The band which is shown at No. 5 of the diagram is left unfinished at the more refrangible end, as we were not certain how far we ought to consider it to extend.

In this star (as we shall show to be the case in No. 3956 also), the great body of bright radiation lies far beyond the ordinary visible limit of the blue carbon band, and no connection whatever with carbon is even suggested to us by the star's spectrum. Dr. Copeland's measure of the band in 1884 was λ 465.4.

The continuous spectrum of the star is unequally bright from the presence of bright groups and also apparently of absorption bands or lines, and therefore with small dispersion it might be easily supposed that the spectrum is brighter at the position of the green carbon band. We examined the continuous spectrum repeatedly with great care, and we were able to satisfy ourselves that, under the considerable dispersion of our instruments, there was no sensible brightening of the spectrum at the positions of the green and of the orange bands of the Bunsen flame.

No. 3956.—Vogel places the brightest part of the band in this star at the same position in the spectrum as in the star last considered, No. 4013, namely, at λ 464, a position beyond the carbon band. The position of the band as it appeared in spectroscope B with the third eye-piece, is represented at No. 6 in the diagram. The position of the band relatively to that of the Bunsen flame was determined by estimations made by means of the intervals between the bright flutings of the Bunsen band. The position agrees substantially with that given by Vogel, but places the maximum brightness nearer to 465. This bright part probably consists of a group of bright lines and falls off rather suddenly at both ends. We were not certain if the light beyond this bright part was due to a continuation of the band or to continuous spectrum, more or less dimmed by absorption; we have, therefore, left the ends of the band incompleted in the diagram. Copeland's measure of this band in 1884 was λ 464.9.

The sub-band seen in the star No. 4013 is very much fainter in this star, but we have little doubt that there is a very faint band present at about the same place in the spectrum.

Professor E. C. Pickering has found in the near neighborhood of these three stars other stars possessing bright lines in their spectra.* The brightest of these, independently discovered by Dr. Copeland in 1884,† namely, D. M. + 37° 3821, in which the spectrum is similar to that of the Wolf-Rayet stars, was examined. Dr. Copeland says of this star: "It has a spectrum of several bright lines near D, and a very bright band in wave-length 464" (*loc. cit.*). We were therefore surprised to find the blue band, which is very brilliant, not in the position of the band in the stars No. 4013 and No. 3956, but less refrangible, corresponding to the position of the band in the star No. 4001.

The bright line begins about λ 467 and runs on to nearly λ 470.5. It is clearly not made up of flutings similar to those of the Bunsen flame, but is a group of lines nearly uniformly bright throughout the length of the band. The band did not appear to extend in our instruments towards the red quite so far as the band of No. 4001; it stops near the place assigned by Vogel to the beginning of the band of No. 4001.

The band is represented in spectrum No. 7 in the diagram. Direct comparison with hydrogen showed that the line at F is brilliant in this star.

After some scrutiny of this part of the star's spectrum, we became conscious of a very feeble brightening of the spectrum beyond the bright band towards the violet, and as far as we could estimate its position, at about from λ 464 to λ 467, that is to say, about the position assigned to the band by Dr. Copeland in 1884.

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* "The following list contains the designations of all eight stars (with bright lines), the first four being those previously known:—35° 4001, 35 4013, 36° 3956, 36° 3987, 37° 3821, 38° 4010, 37° 3871, 35° 3952 or 3953. Of these 37° 3871 is P. Cygni, and 37° 3821 is the star in the spectrum of which the bright lines are most distinct" (letter in 'Nature,' vol. 34, p. 440).

† 'Monthly Notices, R. A. S.,' vol. 45, p. 91, 1884.

We then re-examined the spectrum of No. 4001, and were able to feel pretty sure that a similar faint brightening of the spectrum occurs in this star also at the same place, namely, about the more refrangible position of the blue band in the stars No. 4013 and No. 3956.

Dr. Copeland, during his travels in the Andes in 1883, observed γ Argûs and five small stars with bright lines in their spectra. He says: "As far as my measures and estimates go, all of them belong to the same class as the three Wolf-Rayet stars in the Swan, to which Professor Pickering has since added a fourth outlying member."*

Dr. Copeland gives the position of the bright blue band in γ Argûs as λ 464.6.

Among the stars in the great cluster G. C. 4245, near ζ Scorpii, Dr. Copeland found a star, P. XVI 204 = Stone 9168, which has a similar spectrum, namely, with a bright band in the blue and two in the yellow. He found the position of the blue band to be λ 465.1.

In the case of two other small stars with similar spectra, he found respectively for the blue band the approximate measures, λ 463.3 and λ 463.6.

These four stars were similar, therefore, at the time of the observations to No. 4013 and No. 3956, in which the maximum of the blue band is not far from λ 464, and therefore outside and beyond the ordinary visible limit of the blue carbon band.

Professor Vogel observed two other stars with similar spectra, of which the main feature is the very bright band in the blue region, namely, Arg. Oeltzen 17681 and Lal. 13412. These stars are too low in southern declination to be reached from our Observatory.

Vogel places the blue band in Lal. 13412 at λ 469, which shows that it has a position similar to that of No. 4001 and of Dr. Copeland's star. In the case of Arg. Oeltzen 17681 Vogel makes the band to extend through about the entire range of refrangibility occupied by the two positions of the blue band in the Wolf-Rayet stars according to his measures of them, namely from λ 461 to λ 470, with a maximum at the place where they would overlap, namely, λ 466.

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* "An account of some recent Astronomical Experiments at High Elevations in the Andes;" 'Copernicus,' vol. 3, 1883.

Let us consider the four stars with an intensely brilliant blue band which we have examined; in two of them the band extends from about λ 464 to λ 467, and in the other pair the band has a less refrangible position, from about λ 466 to λ 471, but there is also in the case of each pair a very faint band visible, or suspected, at the position of the blue band in the other pair. Further, in Arg. Oeltzen 17681, Vogel found the bright band sufficiently long to include both positions of the band.

One suggestion which presents itself is whether these bands, or, more correctly, these groups of bright lines, may be variable, so that, under certain conditions one or other of them becomes brilliant. Such a state of things would reconcile our observations of + 37° 3821 with the earlier measures of Dr. Copeland, and, indeed, might possibly explain, if this variability should be established, the circumstance that so accurate an observer as Professor Vogel did not detect, even with his smaller instrument in 1873, the very large difference of position of the band in 4001 from that of the corresponding band in the stars 4013 and 3956, which was so conspicuous in 1883, and is so still at the present time. In the broad characters of their spectra, and in their magnitudes, the Wolf-Rayet stars have remained unchanged since the discovery of their remarkable spectra in 1867.

As the only direct evidence of such a variability rests upon the change of position of the band in Dr. Copeland's star since his observation in 1884, I wrote to Dr. Copeland to ask if his position rested upon sufficiently accurate measures, or was arrived at by estimation only. In reply he says: "The place of the blue line (rather band) in D. M. + 37° 3821, given in the 'Monthly Notices,' is a mere estimate to show the character of the star."

Whether any change of position of the band has taken place must therefore remain at present uncertain; but independently of any such direct evidence of variability, the two positions of the very bright blue band, with the suspicion of faint bands at the alternate positions, appear to us suggestive of possible variation, especially when we consider that the spectra of these stars consist of numerous absorption bands and groups of bright lines upon a feeble continuous spectrum, a character of spectrum which seems to point to a probably unstable condition of the atmospheres of these stars. The large difference of position of the bands in the two groups of stars is much too great to admit of an explanation founded upon a possible orbital motion of the stars. Besides the near coincidence of Dr. Copeland's measures of two bright lines common to the stars 4001 and 4013 shows that the difference of position of the blue band is not due to motion in the line of sight.*

If future observations should show that the bright blue groups are variable, we must look, it would seem, to causes of a physical or a chemical nature.

If the two bright groups, differing in position by about λ 0040, belong to different substances, or, less probably, perhaps, to different molecular conditions of the same substance, it is conceivable that one or other substance or molecular state, may predominate and appear brilliant, according to certain unknown conditions which may prevail in the stars' atmospheres.

It might be suggested that both bands are due to a long group of bright lines extending from about λ 461 to λ 471, and that this long group is cut down by absorption bands; in one pair of stars an absorption from the green cuts off the less refrangible part of the long group down to about λ 467, while in the other two stars the more refrangible part is eclipsed, and the bright group appears as in 4001.

The appearance of the spectra in our instrument scarcely seems to us to be in accordance with such a view, because, though we did suspect brightenings in the alternate places, the appearance of the spectrum was not such as to suggest a bright group dimmed by absorption, for in that case the amount of absorption needed to all but obliterate a group, as bright as it appears in the other pair of stars, would have blotted out completely the relatively feeble continuous spectrum. This continuous spectrum, though faint, was still distinctly seen.

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* Dr. Copeland permits me to give the following measures of the bright lines in the Wolf-Rayet stars which were made by him and Mr. Lohse on January 28, 1884.

Star.	1st yellow line.	2d yellow line.	Bright line.	Faint line.	Large blue band.
+ 35° 4001......	—	—	541.2(3)	522.0(1)	469.5(3)
+ 35° 4013......	582.4(2)	568.9(2)	541.0(2)	—	465.4(2)
+ 36° 3956......	581.0(2)	570.4(2)	—	523.3(1)	464.9(2)

More observations are needed, but it appeared to us desirable by these suggestions to invite the attention of observers to the points in question.

As the main object of our examination of these stars was to determine whether the bright band in the blue was to be regarded as showing the presence of carbon by its coincidence with the blue band of the hydrocarbon flame, we were not able from the pressing claims of other work, to extend our examination to many other points in connection with the spectrum of these faint stars, for an exhaustive examination of which, indeed, our instruments are not sufficiently powerful.

We have stated already that the fairly luminous continuous spectrum reaches up to the bright band in all three stars and extends beyond into the violet, as far as the eye could be expected to follow it.

The spectra are weakened at many points by what appear to be absorption bands, and are crossed by several brilliant lines, the positions of some of which have been given by Vogel and by Copeland.

An examination with spectroscope B of some of these bright lines, as they appear under small dispersion, showed them to be really not single lines, but short groups of closely adjacent bright lines.

One of the brightest of these lines is found in the star No. 4013, at the position, according to Vogel, of λ 570.

Dr. Copeland's measure for this line is λ 568.9 in star 4013, and λ 570.4 in the star 3956.

As this position is not very far from that of the green pair of sodium lines at λ 5687 and λ 5681, it has been suggested that the line in the star is due to sodium, though there is no line of comparable brightness in the star's spectrum at the position of the dominant pair of the sodium spectrum at D.[*]

On confronting in spectroscope ℞ the star line with the green sodium lines, the bright space in the star's spectrum was seen to consist of a short group of several bright lines close together and nearly equally bright. This group ap-

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[*] The 570 line is most probably the green sodium line 569, the absence of the yellow sodium being explained by the half-and-half absorption and radiation mentioned in the discussion of the causes which mask and prevent the appearance of a line in a spectrum (Bakerian Lecture for 1888, 'Roy. Soc. Proc.,' vol. 44, p. 41).

peared to extend through about four times the interval of the sodium pair, which would make the length of the group about λ 0024. The green sodium lines cross the group at about one-fourth to one-third of the length of the group from its more refrangible end. The group in the star is rather less bright at the two ends, but there is no gradual shading off in either direction as in the case of a fluting.

When we examined this part of the spectrum with the small dispersion of a prism of 45°, we were pretty sure of a feeble bright line, less refrangible than the pair of bright groups in the yellow, and not far from the position of D. We were not able to see this line in spectroscope B with sufficient clearness to enable us to fix its position. It may be D, or, perhaps more probably D_3.

In No. 4001, Vogel saw a line at the position of the F line of hydrogen. It is probable that this line, as is the case in so many stars in which it appears bright, is variable, as we were not able to see it when the $H\beta$ line from a vacuum tube was thrown in. In the similar star D.M. $+37°$ 3821, as we have stated already, the F line of hydrogen was very bright.

We were unable to detect in any of the stars a brightening of the spectrum at the position of the chief line of the bright-line nebulæ. For this examination the lead line λ 5004.5 was thrown in, and the continuous spectrum of the star near to this position carefully scrutinised.

In their original paper, Wolf and Rayet state that they were not able to detect any nebulosity about the stars. They say: "Elles ne présentent non plus aucune trace de nébulosité" (*loc. cit.*, p. 292).

In a recent paper, Mr. Keeler, of the Lick observatory, confirms this view. He says: "At my request, Mr. Burnham and Mr. Barnard examined the Wolf-Rayet stars in Cygnus for traces of surrounding nebulosity, but with only negative result."

Notwithstanding these negative results, it appeared to us of great interest to ascertain further if any nebulosity would come out in a photograph of the stars taken with a long exposure.

Mr. Roberts responded at once to our wish when we asked his invaluable assistance, and on November 1st, of this year, he took a photograph of this region of Cygnus, with an exposure of two hours.

The three stars come out strongly upon the plate, but there is no nebulosity to be seen near any of them. There are faint stars in close proximity to the three stars, and apparently surrounding them, and, in the case of No. 3956, six of these faint stars are seen close to it, in an apparent spiral arrangement.

Though this surrounding of faint stars should be pointed out, it should, at the same time, be stated that the whole neighboring region is so densely studded with similar faint stars that it would be rash, perhaps, at present to suggest that this apparent connection of the bright-line stars with faint ones near them may be other than accidental.[*]

Professor E. C. Pickering informs me "that photographs have been obtained at the Harvard College Observatory of all the stars hitherto discovered whose spectra consist mainly of bright lines and are of the class discovered by Rayet. Part of these have been photographed at Cambridge, and the remainder in Peru." He states that they may be divided into three sub-classes, according to the characters of the bright lines. He says, further: "Photographs of the spectrum of fifteen planetary nebulæ have also been obtained. They resemble closely the spectra described above, except that the line 500 is strongly marked; 470 is seen in most of them, while the lines due to hydrogen are also bright."

It would seem that Professor Pickering's photographs do not permit him to distinguish the different positions of the bright blue band in some of these stars, for he gives for all the stars the same position, namely, λ 470.

[‡] [Mr. Roberts has furnished us with the following description of the stars as they appear on his photograph:—

"No. 4001 appears as a multiple star made up of one bright, two fainter, and one very faint star partly behind the others; there is also a fourth bright star close to the multiple star. The group is surrounded by at least eight faint stars within a radial distance of ± 86″ of arc from center to center.

"No. 4013.—The photo-image of this star is made up of three stellar images touching each other in a line slightly curved. Two are bright and one faint: and there are indications of two other faint stars behind the two bright ones. This multiple image of four or five stars is surrounded by five bright and seven faint stars; all within a radial distance of 82″ of arc measured from center to center of the multiple star. The multiple image measures ± 55″ in length and ± 19″ in breadth.

"No 3956.—Its photo-image is ± 27″ in diameter. It is encircled by three stars of lesser brightness, and six faint ones within a radial distance of 59″, *i. e.*, there are nine stars within a radical distance of 59″."—Dec. 5.]

We regret that the insufficiency of our instrumental means has left our examination of the spectra of these stars less complete than we could wish. Our observations appear to us, however, to be conclusive on the main object of our enquiry, namely that the bright blue band in the three Wolf-Rayet stars in Cygnus, and in D.M. + 37° 3821, is not coincident with the blue band of the Bunsen flame.

THE EXCENTRICITIES OF THE ORBITS OF BINARY STARS.

T. J. J. SEE.

FOR THE MESSENGER.

For some time past I have been engaged on a rigorous mathematical investigation of the secular effects of tidal friction—especially as respects the excentricity of the orbit—in a system of two viscous or fluid bodies, both endowed with rotatory motion in the same sense as the orbital revolution. It is intended to be applicable to the systems of the binary stars, where both the primary and secondary stars are relatively of the same order of mass. Whilst the work is not yet entirely finished, it is sufficiently advanced that the chief results are already incontestibly established. Some of the conclusions are so very remarkable that I think they will interest astronomers. It is well known that the orbits of binary stars present every degree of excentricity from almost 0 to 0.9 (in the case of γ Virginis). A table of more than fifty of the best orbits hitherto determined, which I have collected from a great number of publications, presents to the eye, when the ellipses are drawn, orbits of every degree of elongation from that of one of the great planets, which is almost circular, to that of a comet such as Halley's. The arithmetic mean of the excentricities of these fifty orbits is almost 0.50. The same mean for the orbits of the great planets of the solar system is 0.044. That of the small planets is somewhat higher, whilst that of the satellites will closely conform to the small mean deduced from the orbits of the great planets.

The orbits of the small planets, however, can not be taken as typical of the solar system, any more than can those of

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[*] Student in Astronomy at Berlin University, Berlin, Prussia.

comets or meteorites, on account of the great perturbations which the small planets suffer, and our inability to declare that the higher powers and products of the disturbing forces neglected in the planetary theory have not manifested themselves through a permanent secular increase in the excentricity of the orbits of bodies subjected during past ages to such great perturbations by the attraction of Jupiter and Saturn. The orbits of the great planets and of their satellites are therefore the only ones which can justly be taken as typical of the solar system. The average excentricity of these orbits is less than *one-tenth* of that of the fifty binary orbits. These latter very remarkable excentricities led me to suspect the operation of a physical cause (not distinctly impressed upon the orbits of the planets), whose continuous action had brought the star systems to their present configurations. The investigation proceeds upon a plan analogous to that adopted by Professor G. H. Darwin in his excellent researches on the history of the moon and planets of our system. Space does not allow me to detail the long and laborious mathematical investigation at hand, but the great importance of tidal action in a system such as γ Virginis may readily be conceived when we remember that the components are equal in magnitude, and therefore, perhaps, nearly equal in mass, each probably being of the same order of absolute mass as our sun. In a system composed of two such tremendous bodies of a gaseous or fluid nature, at any reasonable—say, planetary—absolute distance apart, the tides raised by mutual attraction would be simply enormous.

The relatively large mass of the secondary body in the binary systems contrasts strongly with the small, almost insignificant, mass of the planets in the system of the sun, in two respects:

(1) The great excentricity of their orbits, and

(2) The large relative mass ratio of their components (inferred chiefly from their relative magnitude) the binary systems are certainly radically and essentially different from our own. Now, the investigation shows that if we suppose the stars of a system, such as γ Virginis, originally to have been started close together in an almost circular orbit, they would have been wound off in the course of cosmic ages to a

great mean distance by the contiuous action of tidal friction; and meantime the excentricity of the orbit would have become extremely great, rising to a maximum at the maximum mean distance, where synchronism obtained, the momenta of rotation having been transferred into momentum of orbital motion, the parts of the exhausted system moving round slowly as though rigidly connected. The results of the investigation are so conclusive that I do not hesitate in the belief, not only that they establish the true origin of the remarkable excentricities of binary orbits, but also that the cosmical effects of tidal friction on the history of the heavenly bodies (except in the solar system) have been hitherto greatly underestimated.

The investigation seems to put it beyond all doubt that tidal friction is a sufficient cause to explain the great excentricities observed; and I hope eventually to show also that it is the *only possible* assignable adequate natural cause. It can easily be shown that binary systems are not products of the fortuitous approximations of separate stars; and hence it is necessary to suppose them genuine *ab initio*, and therefore to consider them products of some process of nebular evolution. This remark suggests interesting reflections on the process of formation and history of the binary systems; but this will be reserved for the present, and I merely remark that, for the reasons given above, and others, the mode of genesis appears to me to have been radically different from that embodied in the conception of Laplace as applied to the genesis of the solar system. This latter seems to be an exception and not the rule. Any hope of valuable results in cosmical investigations must rest upon a careful combination of the results of observation with those of rigorous analysis. Finally, I beg to add that the investigation on which I am engaged will be published in due time. Meanwhile I must beg the indulgence of astronomers in announcing results before the original work is available; the conclusions seemed to me to add an unusual interest to the astronomy of double stars.

BERLIN, PRUSSIA, Dec. 9th, 1890.

HOW TO MAKE A LENS.

GEORGE S. JONES.

FOR THE MESSENGER.

[The article on grinding and polishing a telescope mirror, published in the October number of THE MESSENGER, appears to have awakened some interest among amateurs, and a number of inquiries have been addressed to the editor for more particular information as to certain details of the work, the cost of materials, etc. The writer has consented to prepare a second article, in which is given a complete and detailed account of the process of making a small lens, which may be considered the A B C of mirror-making.—THE EDITOR.]

The outfit required by the amateur lens maker consists of a small lathe and accessory tools, a small supply of emery and jeweler's rouge, a few scraps of sheet brass, a supply of colorless glass (if optical glass cannot readily be obtained good plate glass, as free as possible from striated texture, will answer the purpose), and, in addition, some skill in working in metal.

THE EMERY AND ROUGE.

Procure half a pound of the flour of emery. Mix with water and knead well, to insure thorough wetting; put into a quart bottle, and fill the bottle with water, to which a little mucilage has been added; shake the mixture well and allow it to settle. The larger particles of the emery will fall to the bottom at once; the finest will remain in suspension for several hours. At the end of an hour draw off carefully with a siphon a portion of the still turbid water into a glass tumbler, and let it stand to settle for an hour or more. Pour the water from the tumbler back into the bottle. At the bottom of the tumbler will be found a deposit of fine emery—the finest, probably, that will be needed—which may be kept for use in a small vial filled with water.

The process of "elutriation" hardly need be described further. It will readily be seen that this process enables us to separate the flour, as it comes from the shop, into grades of different degrees of fineness. At least a half dozen grades should be prepared, the coarsest being obtained by allowing no more than one minute, or even less, for the first settling. The residue left in the bottle, after the finer particles have all been removed, will come into use; but a small supply of emery of a still coarser grade will be needed for the rough grinding.

The rouge, which is usually sold in balls, had best be kneaded with water and kept for use in a small, wide-mouthed bottle. This bottle, as well as those which contain the fine emery, should be kept filled with water, to prevent the material from caking, and before use they should be shaken up well and allowed to settle when the superfluous water can be poured off.

THE GRINDING CUPS.

The materials for grinding and polishing being ready, we will make our first essay with a plano-convex lens of, say, one inch in diameter and two inches focal length. A piece of thin plate glass will answer for our first trial, and will offer the advantage of having one face already polished.

We cut a disk of paper, one inch in diameter, and paste it to the glass to serve as a mark in cutting the glass. Having cut this as close to the paper as possible, with a diamond or by other means—this work can be performed with a small pair of nippers, skillfully used—finish shaping the glass disk upon a grindstone or an emery wheel.

Turn a spindle of wood two or three inches long and of the size of a lead pencil, terminating in a flat head, to which attach the glass by means of sealing wax, thus providing it with a handle.

A grinding-cup may be made of a piece of thick sheet-brass. The diameter of this cup should be about the same as that of the lens, and the radius of its curvature should be one-half of the focal length desired. It may be hammered into shape roughly; then soldered to a spindle (which will serve as a handle) and turned carefully to the required concavity in the lathe.

In turning the cup a gauge will be needed, which, if we are not too particular about the focal length of our lens, may be made the most readily of stiff writing paper, by means of a pair of compasses, to one leg of which a cutter is attached. If we wish for greater nicety the gauge may be made of thin sheet metal, thus: Set the compasses to the exact required length of the radius of curvature, and mark upon two separate plates of the metal two arcs of circles. One is to serve as a convex, the other as a concave gauge. Shape them as accurately as possible with a file, and then grind them together with fine emery and water or oil, until they fit each other perfectly. One of these gauges can be used for the cup, the other for the lens.

The rough grinding may be done in the lathe. Attach the brass cup to the chuck of the lathe and adjust it to run true. Hold the glass disk, wet and smeared with coarse emery, against the cup, by means of its spindle, in such a manner that one of its edges overlaps that of the cup. To do this the spindle must be held obliquely to the axis of the lathe. While the lathe is run in one direction, slowly, turn the glass regularly in the opposite direction, and continually vary the amount of the lap.

The cup will be ground as well as the glass, although less rapidly, and it will perhaps be well to rough-grind the glass in a special cup, which need not be shaped so carefully.

After the lens has been ground into shape, and, as tested by the concave gauge, is found to have the desired curvature, remove the cup from the lathe and finish the work by hand. Use in grinding both a twirling motion and straight, transverse strokes, and turn both lens and cup after each stroke, so that the grinding surfaces shall continually change their relation to each other. Hand-work, carefully done, is much superior to work done in the lathe. Before passing from one grade of emery to the next finer, examine the work with a glass, to be sure that all of the comparatively deep nicks are ground out. The last grinding should leave the surface of the lens of a milky whiteness with no marks upon it visible without a glass.

A polishing cup may be made of wood. Its diameter should be about one-tenth larger than that of the lens. The wooden cup should be lined with pitch, which is very conveniently prepared by melting rosin and adding a little spirits of turpentine. The hardness of the pitch should be such that, at the temperature of the room, it can be dented, not too easily, with the finger-nail. The cup should be fitted to the lens, which has previously been wet, while the pitch is still soft, or it should be warmed for the purpose. The polishing can be done in the lathe, but better work can be done by hand. The same strokes should be used as in grinding—a combination of a twirling and a rectilinear motion. If it is found that the border of the lens is polishing faster than the center, make the cup smaller, or increase the length of the stroke. If the center polishes too fast, this indicates that the polisher is too small. At this point experience, born of practice, must take up and continue the instruction.

To grind the edge of the lens, after it has been polished, insert it, still attached to its spindle, into the lathe, so that it runs true. Bend a strip of thin metal, an inch or so wide and two inches long, partially around the edge of the lens on the under side, and allow the lens to turn in it while it is kept liberally supplied with emery and water. In this way the edge of the lens may be ground perfectly true, and it may be cut down to any desired size.

If it is desired to make a lens of any other form than plano convex, the following formula will be found convenient for determining the length of the radii of the two faces:

$$F = \frac{2rr'}{r' - r}$$

when both faces curve in the same direction, as in the meniscus; and,

$$F = \frac{2rr'}{r' + r}$$

when they curve in opposite directions, as in the double-convex.

In this formula F is the principal focus; r and r', the radii of the two faces.

It is assumed in this formula that the index of refraction of glass is $\frac{3}{2}$, which is a little under its true value, and the focal length of the lens will, therefore, turn out a trifle less than calculated. If extreme accuracy is desired, the formula to use is:

$$F = \frac{rr'}{(n-1)\,(r' \pm r)}$$

in which n is the index of refraction of the glass used.

NOTE ON THE DOUBLE STAR Σ 186.

S W BURNHAM.*

FOR THE MESSENGER.

There has been a decided change in both the angle and distance of this pair since it was discovered by Struve. It was then an easy object with almost any instrument, but the distance slowly diminished until it was noted by many observers as single, or with an uncertain elongation. It is still a close pair, but readily within the reach of the large refractors with which it has been observed during the last few years. No orbit has yet been computed, although nearly half a revolution has been described since the first measures of Struve. Many of the measures have large errors, and probably only a very rough approximation to the period could be made from the data now available. Careful measures during the next few years are very important for this purpose. The relations of the two components are fairly well shown since 1874, but the measures between that time and 1831 are unusually discordant for a pair of this kind, as it is evident that it could not have been single at any time since its discovery, except perhaps apparently so with small instruments.

I have selected a few measures by the best observers and accurately platted them to scale on the accompanying diagram. These observations are as follows:

1831.12	64°.7	1″.23	Σ	3n.
41.70	241 .8	1 .11	OΣ	1n.
46.11	68 .2	0 .82	OΣ	1n.
57.92	67 .5	0 .42	Se	3n.
63.85	85 .1	0 .3	Da	1n.
74.90	145 .7	0 .23	N	1n.
79.89	180 .5	0 .31	Hl	3n.
87.02	199 .1	0 .27	Sp	2n.
88.05	206 .3	0 .28	Sp	3n.
90.88	227 .1	0 .31	β	3n.

The ellipse shown is the result of an attempt to find a curve which would fairly represent the more recent measures and the first observations of Struve. It is evident that the intermediate measures cannot be reconciled, without large

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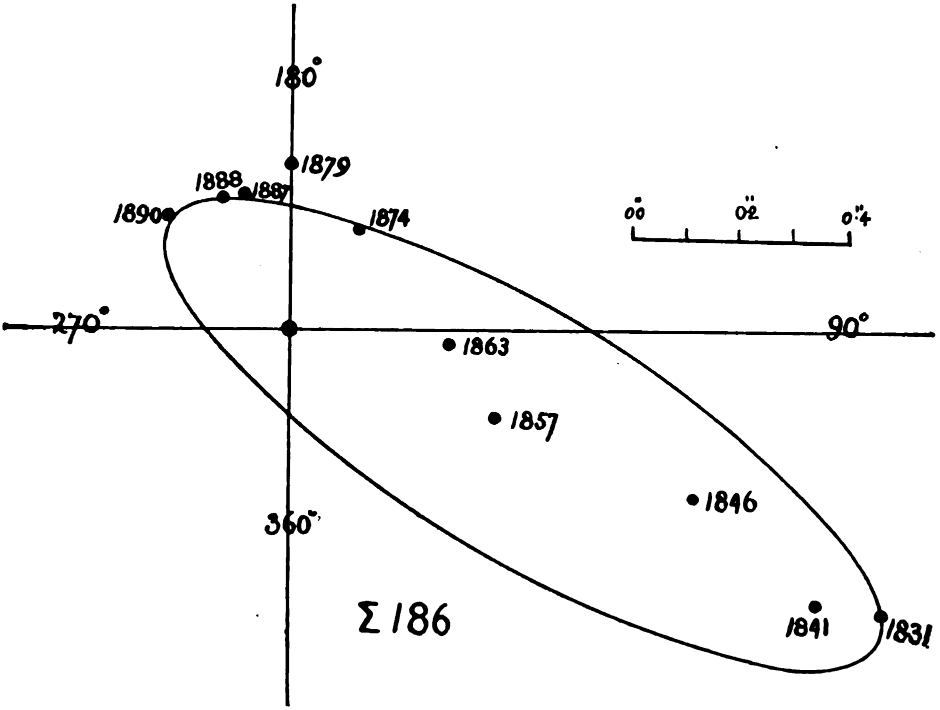
* Lick Observatory, Mt. Hamilton, Cal.

corrections, with any curve passing through the points referred to. If we disregard the last three measures, the path of the companion would be as well represented by a straight line as by any curve, but the later observations taken in connection with Newcomb's observation in 1874, make it quite certain that the relative change is not one of proper motion. According to Struve the meridian observations of the principal star, or rather of the two components considered as one star, for it must have appeared single with the meridian circle, show a proper motion of about a quarter of a second per annum, and this is evidently common to both components. Perhaps a flatter or more elongated ellipse could be used, but the plane of the orbit must form a considerable angle with the line of sight.



The last measures of this pair were made with the large equatorial, and should be fairly accurate as a double star of this distance is very easy with an aperture of 36 inches under ordinary conditions.

PHENOMENA OBSERVED UPON SATURN AT THE TIME OF THE PASSAGE OF THE SUN AND OF THE EARTH THROUGH THE PLANE OF ITS RINGS, IN 1877-1878.*

E. L. TROUEVLOT.

In a paper "On the Variation of the Rings of Saturn," published in the *Bulletin Astronomique*, I said a few words about the interesting phenomena which I observed in 1877 and 1878, before, during and after the passage of the sun and of the earth through the plane of its rings. Since conditions nearly identical with those to which the observed phenomena might be attributed are about to present themselves again in 1891 and 1892, toward the time of the passage of the earth and the sun through the plane of these same rings, and since we are permitted to suppose that similar causes will produce phenomena of the same kind, I believe this to be an opportune time to make known these phenomena, in the hope that by calling attention to them, observers, having a complete knowledge of their cause, will be able to prepare for observing them under the most favorable conditions, and for verifying them if they have opportunity. Toward the middle of May, 1877, a series of observations was undertaken with a view to studying and following, day by day, as circumstances would permit, the phenomena, as yet little known, which result from the progressive approach and retreat of the sun and of the earth to and from the plane of the rings of Saturn, as well as those which result from the successive passage of these two bodies through the same plane.

The conditions required for the observations of these phenomena should for a little while, be found united. In fact, the sun and the earth, both of them then being north of the plane of the rings, gradually lowered toward this plane which they crossed; the first toward the 6th of February, and the second about the 1st of March, 1878; then receded gradually and occupied on the south the positions successively identical with those which they had each occupied on the north before their passage.

This program was only partly realized, for after the passage of the earth through the plane of the rings, my health

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* Translated from the French by Miss Isabel Watson, teacher of French, Carleton College, Northfield, Minn.

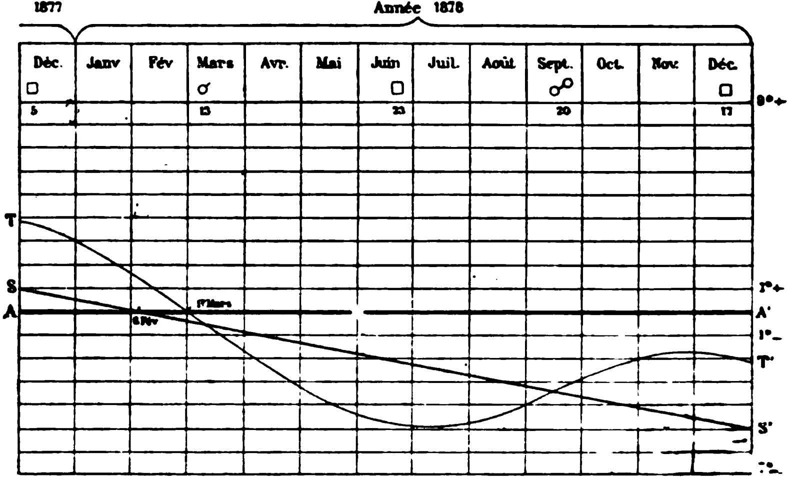
prevented the continuation of these observations, which, with the exception of that of May 27th, 1878, were not resumed and followed regularly until the 27th of the following September, and from that time to the 10th of February, 1879. Thanks to the state of the heavens, which were exceptionally favorable for astronomical observations during that period, Saturn was observed 221 times under excellent conditions; 139 times before and 82 times after the passage of the earth through the plane of the rings, and at the same time numerous drawings of the planet and of the principal phenomena observed were obtained. The observations were made by the aid of an excellent telescope by Merz, of $0^m.16$ aperture, and according to the state of the atmosphere and the phenomena to be observed, magnifying powers varying from 85 to 460 were employed.

The phenomena observed may be divided into two classes: (I) Those which concern the rings; (II) those which pertain to the sphere. Those of the first class relate (1) to the decrease and the increase of the brilliant light of the surface of the rings; (2) to the invasion of their illuminated surface by a shadow; (3) under a strong solar obliquity Cassini's division is more visible on one ansa than on the other; (4) the anterior part of the ring appears narrower than the posterior; (5) the disappearance of the rings.

Those of the second class relate, (1) to the deformation of the limb of Saturn; (2) to the inequality of the light between the central portions of the globe and those which form the edge.

To understand easily the phenomena which we have to explain, it is necessary that the reader should have an idea, at least approximate, of the position occupied by the sun and by the earth, whether to the north or to the south of the plane of the rings at the moment when these phenomena were observed. The diagram (Fig. 1) of which the ordinates represent the different months of the year, and the abscissæ the elevation of the sun and of the earth either to the north or to the south of the plane of the rings, will permit the reader to see at a glance the approximate positions occupied by the two heavenly bodies at any date whatever comprised within the period of the observations. The horizontal line AA′ represents the plane of the rings; the oblique line SS′ gives the apparent path of the sun, and the undulating line TT′ gives that of the earth. The arrows indicate the direction of the movement of the two bodies. The symbols ☌, ☍, □, mark the conjunctions, the oppositions and the quadratures of Saturn with the sun; and the figures which accompany them give the date of the phenomenon.

Fig. 1



I. *The Decrease and the Increase of the Brightness of the Illuminated Surface of the Rings.*

From the first days of my regular observations of Saturn, May 18, 1877, I remarked with surprise that, contrary to what I had always seen up to that time, the illuminated surface of the ring seemed decidedly less luminous than the planet. Subsequent observations only confirmed the first, and it was certain that its relative brightness had diminished since my observations of 1872–1876. Not only was it certain that its brightness had diminished, but it soon became evident that it was growing less and less from day to day.

All observations confirm this phenomenon and show in the most evident manner that the light reflected from the surface of the rings diminished gradually until the day of the passage of the sun through their plane. Not only had the brightness been gradually diminishing during this period of nine months, but also the color of the light changed, and, compared with that of the planet, it appeared yellowish and even slightly orange. While the results of my observations of 1872-76 were exactly opposite, that is to say, during that period the color of the planet compared with that of the rings appeared yellowish, while that of the rings themselves was white.

Although the observations of the same phenomenon, after the passage of the earth and the sun through the plane of the rings were much less numerous than those which were made before these passages, still there is no doubt that the phenomenon existed then as before. Indeed, it has been proved several times, and notably the 28th of August, 1878, that "the ring appeared less luminous than the ball and that its color was yellowish." At this last date it was just this yellowish tint of the ring which enabled one to distinguish it on the planet which was comparatively white. Nevertheless the phenomenon was approaching its end, for a month later, Nov. 26, it was ascertained that "the ring appeared almost as bright as the ball," and a few days later, Dec. 6, "one could easily see that the ring was brighter than the planet." From that day until this, the ring of Saturn has constantly held a brightness superior to that of the globe, just as it did before 1877. If one seeks the propable causes of this decrease and increase in the brightness of the ring, one is led to think that they are due either to the position of the earth or to that of the sun with relation to the plane of the rings. If it is to the position of our globe that this phenomenon should be attributed, we ought to be able to assure ourselves of it by the increase and decrease of its brightness corresponding to the periodical retreat and approach of the earth to the surface of the rings. Now, observations have never shown anything of the kind. From May 18, 1877, to Feb. 6, 1878, and from this last date until Oct. 28, of the same year, the brightness of the surface north of the ring was gradually decreasing in the first period, and that of the southern surface was gradually increasing during the second. Then one must admit that the position of the earth counted for nothing, or in any case for very little, in the production of the phenomenon. It is then in the position of the sun that we must seek the cause. We have already shown that the sun approached the plane of the rings until the day of its passage through this plane, and that afterward it receded with the same regularity. Now these phenomena of decrease and increase in the brightness of the light observed on the opposite surfaces of the ring are in perfect conformity with the successive positions of the sun, whose decrease in height corresponds exactly to the diminution of the light on the north surface of the ring and whose increase in height corresponds to the increased brightness of the southern surface. It is then necessary to admit that the phenomenon was due in great part, if not altogether, to the position of the sun with relation to the plane of the rings.

If, accepting these facts we assume, as indeed our observations from May 18, 1877, to Dec. 6, 1878, seem to authorize us to do, that the same things take place on the northern surface of the rings as on the southern, it will be easy for us to deduce approximately the date of the year 1877 when the ring began to diminish in brightness, as well as that when its brightness was equal to that of the planet. Indeed if a brightness always approximately equal corresponds to a given height of the sun above the plane of the ring, it follows that if we are able to find what the dates were in 1877 when the height of the sun equalled + 4° 30′ and + 4° 23′, we have solved the problem.

We find that the first height corresponds to April 6, and the second to April 16, 1877, that is to say, that it was about one month before we had begun our observations that the northern surface of the ring had commenced to undergo a decrease in brightness; so that on April 16 the diminution was such that the ring and the planet were equally bright.

According to these observations and the deductions that we have drawn from them, it would seem that when the height of the sun is reduced to 4° 30′, the surface of the ring gradually diminishes in brightness in proportion as that body lowered toward the plane of the ring, and that, after having crossed this plane, the opposite surface gradually increases in brightness in proportion as the sun goes higher, until the day when it reaches a height of 4° 30′. But how can the position of the sun affect the luminous intensity of the ring? Is this weakening a unique occurrence, and does it conform to the law of Lambert, who claims that the quantity of reflected rays diminishes in proportion as the angle of incidence increases? Or is it rather due to other causes, such as the absorption of solar rays by an atmosphere belonging to the rings, etc., etc.? At present we have no data for replying to these questions; but we may be permitted to hope that the observations made at the time of the approaching passages of the sun and of the earth through the plane of the rings will enable us to answer them.

II. *The Gradual Invasion of the Illuminated Part of the the Ring by a Shadow.*

From Oct. 6, 1877, when the sun was 1°49′ to the north of the plane of the ring, until Feb. 6, 1878, the day of its crossing the same plane, the illuminated surface of the ring kept gradually decreasing in size, in proportion as the height of the sun decreased, so that Feb. 5, the evening before the passage, the bright surface was no longer shown except by a narrow luminous thread, very difficult to recognise because of its extreme thinness (Fig. 2).

The phenomenon consisted in a gradual invasion of the anterior surface of the ring by something which resembled a shadow cast by an opaque body, and which, little by little, advanced upon it and obscured it.

The 6th of October the phenomenon was already rendered apparent by a pronounced eclipse of the part of the ring which crossed the planet. December 18, when the height of the sun was reduced to +0°44′, the phenomenon was much more accentuated, and all the part of the ring which crossed the ball, as well as the parts near the ansæ were obscured. Jan. 25, 1878, when the elevation of the sun was not more than 0° 12′, the encroaching shadow stretched so far upon the ring that it reached even to the posterior part, and seemed to mingle with that which the ball then cast upon it to the east (Fig. 3) in such a way that the eastern ansa seemed entirely separated from the planet by a dark gap, which in size and position corresponded with the shadow cast by Saturn upon its rings. Besides, the angular shape of this shadow, very easy to recognise, left no doubt about its identity. February 4, when the sun was not more than

+ 0° 5′ high, the lighted surface formed only a luminous streak sharply defined and of extreme thinness (Fig. 2), which the 5th of February, the evening before the passage of the sun through the plane of the rings, was very difficult to distinguish, and seemed, at moments, discontinuous and formed of luminous globules hardly perceptible.

Evidently the phenomena in question could not be explained by the increasing obliquity of the surface of the ring, caused by the progressive lowering of the earth towards its plane; in the first place, because the gradual decrease of the illuminated part of the ring was not at all in proportion to the lowering of our globe, but took place more rapidly; and also, because this illuminated surface, instead of being a perfect ellipse, had an irregular form (Fig. 3). And then, the elevation of the earth, which the 6th of October was +3°21′ and kept increasing until Nov. 16 when it was +3° 55′, was still + 1° 20′ the 5th of Ferbuary, 1878, when the illuminated portion of the ring was reduced to an interrupted luminous streak, and so narrow that it was difficult to distinguish it. Now when the earth occupies an identical position, or even one inferior to that which it held at the last date, the ring is still a very remarkable object, subtending an angle of 0″.86, and upon which one still distinguishes easily the opening of the ansæ, and which cannot pass unnoticed even with instruments of small aperture, while at

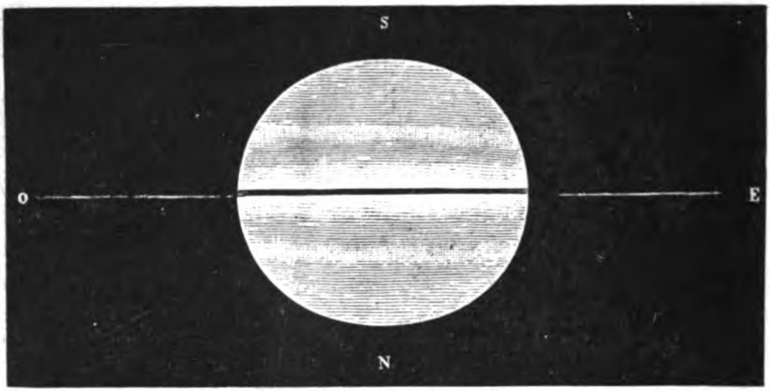


Fig. 2.

the same time the height of the sun is scarcely less than 2° (Fig. 4), which is the projection of Saturn and its rings for Feb. 4, 1878, shows the ring as it must have appeared if its surface had been flat and consequently exposed to the rays of the sun.

Neither can the phenomenon be attributed to an error of observation, when the shadow cast by the ring upon the ball would have been taken for and confused with it. In fact, the 6th of October this shadow cast toward the north already began to disengage itself from the nebulous ring C, from which it was separated by a narrow thread of light belonging to the globe. This thread of light separating the shadow from the ring C increased from day to day in the same measure that the shadow thus cast decreased; so that, if by an error, the thread of light belonging to the globe had been confounded with the ring, the illuminated surface of the latter ought to have grown larger instead of smaller, as the observation showed it. Besides the darkening of the ring stretched out beyond the globe, which amply suffices to show that it was distinct from the shadow cast by the ring since that could not reach beyond the globe.

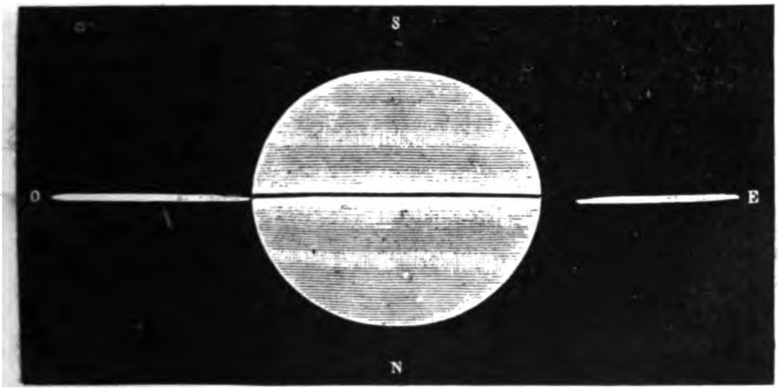


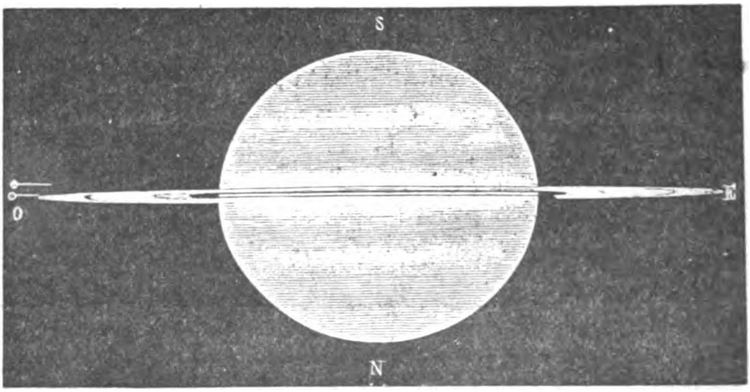
Fig. 3.

The close connection observed between the increase of the shadow on the illuminated surface of the ring and the lowering of the sun on its horizon shows clearly that that body was the principal cause of the phenomenon.

In reflecting upon the causes which would be capable of producing such a darkening on the ring, we hardly find more than one which can explain it and even that one offers some serious difficulties. We attribute the observed phenomenon to the elevation above the general level of a zone slightly inclined toward the planet. Supposing that the rings had a flat surface, it is evident that this surface would receive the solar rays and consequently would remain visible as long as the sun remained above it.

We have shown elsewhere (*Bulletin Astronomique*, t. II, p. 16 and following, 1885) that the form of the shadow of the ball cast on the rings could not be reconciled with a surface perfectly flat, and we have shown that the level of this surface is changeable and varies often in height. From the form of the edges of this shadow we have decided that the maximum thickness of these rings is found on the ring B, at some distance from the division of Cassini. Now if, inside of this division, the ring B possesses a variable zone of a considerable height, it will result that, when the sun approaches the plane of the ring, this more elevated zone, intercepting the solar rays, will cast a shadow behind, which will extend farthe and farther in proportion as the sun descends, and which will end by covering almost all the part within this zone and nearly the half of the surface of the ring A, the half most distant from the sun.—*Bulletin Astronomique.*

Fig. 4.



[To be Continued.]

A BRIEF BIBLIOGRAPHY OF ASTRONOMICAL LITERATURE FOR THE YEAR 1890, JANUARY TO JUNE.

COMPILED BY WILLIAM C. WINLOCK.

The following brief subject-index of astronomical literature is intended to form a continuation of the bibliography of astronomy that has been published in connection with the Smithsonian review of Astronomy since 1885. The year 1890 is divided into two parts, but is it expected that the bibliography for 1891 will be continued as a quarterly appendix to THE SIDEREAL MESSENGER.

To make a work of this sort exhaustive, even to the extent of including all the material that comes under the compiler's notice, would expand our index to undue proportions, and seems for the present to be out of the question. As some selection has been imperative, an effort has been made to meet what are conceived to be the general wants of the astronomer, assuming that the special papers that interest but few readers will come to the notice of the latter without difficulty. Any suggestions upon this point will be welcomed by the compiler, who will also be glad to receive the titles of any papers that it would seem desirable, for any reason, to include. It should be added that through the courtesy of the officers in charge, access is had to the library of the U. S. Naval Observatory, and to that of the Smithsonian Institution, which together probably furnish the most complete collection of current astronomical literature in this country.

Journal articles are included in the index, as well as more formal and elaborate publications—a few titles being taken from reviews or book catalogues.

The arrangement is by subjects, with a sub-arrangement by authors or catch-words. The abbreviated titles of Transactions or Journals follow in the main the principles laid down by Dr. Billings and Dr. Fletcher in their great subject-index catalogue of the Surgeon General's Library U. S. Army, in Washington. Of the less obvious contractions the following will probably be an adequate explanation:

abstr.	abstract.	k. k.	kaiserlich, koniglich.	p.	page.
Am.	American.	lfg.	lieferung.	pl.	plates.
bd.	band.	n. d.	no date.	portr.	portrait.
d.	die, der, del, etc.	n. p.	no place (of publication.)	pt.	part.
ed.	edition.	n. f.	neue Folge.	r.	reale.
hft.	heft.	n. s.	new series.	rev.	review.
hrsg.	herausgegeben.	not.	notices.	s.	series.
il.	illustrated.	obsry.	observatory.	sc.	science, scientific.
j., jour.	journal.			sup.	supplement.
				v., vol.	volume.

In the references to journal articles the volume and page are simply separated by a colon; thus:

Astron. nachr. 123: 275-82. 1890.

signifies, Astronomische Nachrichten, volume 123, pages (or columns) 275 to 282, published in 1890.

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COMMON (A. A.) Notes on reflecting telescopes and the making of large discs of glass for them. Month. not. 50: 402. 1890.

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HALL (M.) Spectrum of the zodiacal light. Obsry. 13: 77-9. 1890.

PENDING PROBLEMS IN SPECTROSCOPY.

GEORGE E. HALE.

FOR THE MESSENGER.

The great activity of scientific research at the present time cannot be regarded without astonishment. Thousands of investigators in all parts of the world are daily bringing to light new facts of the greatest interest and value. And especially is this true in the almost unexplored domain of spectroscopic astronomy. Here the physicist and astronomer meet on common ground, and their combined resources make clear the path of progress. It is impossible in a single paper even to mention all the objects of their search, but a few of the more important may be briefly reviewed.

Even those most opposed to the views set forth by Professor Lockyer in his "Meteoritic Hypothesis," will admit their value in stimulating enquiry, and already many uncertain points have been cleared up. Professors Liveing and Dewar have repeated and extended their studies of the magnesium spectrum,* proving almost conclusively that oxygen is neces-

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* Proc. Royal Society, vol. 44, p. 242.

sary to the production of the green fluting, and showing that a temperature much higher than that of the Bunsen burner is involved in its formation. At the same time they were not able to obtain the fluting in the presence of hydrogen, and were inclined to believe that the b group is more characteristic of magnesium at a low temperature. When it is remembered that hydrogen is clearly present in the nebulæ with no trace of the b lines, it is hard to accept all of Professor Lockyer's views of these bodies,* though at the same time it would not be wise to reject them entirely. The question as to the presence of the magnesia fluting in the nebula spectrum is not yet decisively answered, but the indications point to its absence.† The difficulties in direct comparison arise from the uncertain relative motions of the nebulæ and the sun, but in the case of the Orion nebula these do not enter to any appreciable extent. The character of the nebula line seems to most observers to preclude its identification with the magnesia fluting, but others take the opposite stand.‡ It may be said that there is still room for work on this important subject, but observations will be worthless unless conducted with the greatest care, and with a knowledge of their degree of accuracy.

Mr. Keeler's discovery of motions of the nebulæ in the line of sight is an important indication of spectroscopic progress as it signalizes the advent of high dispersion with its attendant advantages.§ The fact that there is a motion is not so much to be wondered at as the possibility of measuring it, for, as Mr. Keeler remarks, it would be more surprising to find the nebulæ at rest than in motion. The small probable error of these measures is especially to be noticed, and in the observations of α Bootis the comparison of Keeler's results with those obtained photographically by Vogel,‖ show plainly that the era is past when the motion of a star could only be certainly expressed as positive or negative. It is probable that the anomalies in the motion of Sirius will soon disappear under the new order of things.

Double stars have only recently become special objects of

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* Meteoritic Hypothesis.

† Sidereal Messenger, August, 1890; Pub. A. S. P., No. 11; Meteoritic Hypothesis, p. 297.

‡ Sidereal Messenger, January, 1891, p. 23.

§ Pub. A. S. P., No. 11, p. 265.

‖ *Ibid*, p. 284.

spectroscopic study, but now it is known that the prism can multiply about five thousand times the power of the object glass in separating close and rapidly revolving pairs.* By the periodic doubling of the K line in the spectrum of Mizar Professor Pickering has discovered a system of suns with a period of only 104 days, and a combined mass forty times that of our central luminary. β Aurigæ offers an even more remarkable example, for in this case the complete revolution is performed in only four days. Similar cases may at any time be picked up on the Harvard Observatory plates, for the northern skies are being explored at Cambridge, while a party sent out from the same Observatory to South America is working in the less familiar regions of the heavens. The studies of the stellar spectra which constitute the Draper Memorial are the most exhaustive ever undertaken, and the almost daily discoveries of stars with peculiar spectra are only the natural results of such diligent search.

The latest addition to the growing list of "spectroscopic binaries" comes from Professor Lockyer's Observatory at South Kensington, where Fraunhofer's method of using a prism over the object glass, so advantageously employed by Professor Pickering, has been adopted. Photographs of the spectrum of α Lyræ show a periodic doubling of the lines, the maximum separation corresponding to a velocity of 370 miles per second in the line of sight.† A period of 24.68 hours was deduced by Mr. Fowler, but this is considered by Professor Pickering as too short to allow the binary nature of the star to escape detection in the large number of photographs made at the Harvard Observatory.‡ He believes that the doubling of the lines can be accounted for on the supposition of a very elliptical orbit, in which case the duplicity would be apparent only for a few hours at periastron at the time of most rapid motion. Or, possibly, the presence of a third disturbing body may cause irregularities, as is the case in η Ursæ Majoris. The appearance of the lines in photographs taken at predicted times of doubling will be awaited with interest.

It has been supposed for over a century that the varia-

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* Pickering's Fourth Annual Report Draper Memorial, 1890, p. 7.

† Proc. R. S., November, 1890.

‡ Sidereal Messenger, January, 1891.

tions in the light of Algol were caused by the interposition of a dark satellite, but positive proof was lacking until the spectroscopic results of Vogel in 1888 supplied the requisite evidence.* In its motion about the center of gravity of the two bodies Algol alternately moves toward and from the earth, and consequently the lines in its spectrum are displaced first toward the blue and then toward the red. A careful series of measures of the photographic plates gave an orbital velocity of 26.3 miles per second for Algol, and its orbit is consequently some two million miles in diameter. Assuming the same mean density for both primary and satellite the photometric determination of the loss of light in eclipses gives a rough means of deducing the relative masses, and the system has thus come to be fairly well known. Algol has a diameter of about a million miles, while the satellite is somewhat smaller than our sun. Their distance of only a little more than three million miles from center to center is certainly not compatible with much eccentricity in their orbits. Only a few months ago α Virginis was found by Vogel to be the principle member of a similar system the period being about 4 days, and the maximum motion in the line of sight about 56.6 miles.†

In the study of stellar spectra apart from the question of motion in the line of sight, progress is almost equally rapid. It is unfortunate that the method employed at the Harvard Observatory precludes the use of comparison spectra; the interposition of absorption solutions etc., in the path of the rays has been wholly without success, largely from the diffuse nature of the lines thus obtained. As yet a slit is essential in determining the origin of any line, except perhaps in such well marked cases as the hydrogen series. Dr. Vogel has obtained photographs sharp enough to allow the identification of a large number of lines by Scheiner,‡ and Dr. Huggins has found the two lines necessary to complete the hydrogen series in Sirius, as well as a new group of six lines in the ultra-violet.§ Perhaps the most interesting spectroscopic information recently obtained by Dr. Huggins has been with regard to the photographic spectrum of the Great Nebula in Orion. The new photographs show many lines

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* Astronomische Nachrichten, No. 2947. † *Ibid*, No. 2923.

‡ *Ibid*, No. 2923. § Sidereal Messenger, Aug. 1890, p. 318.

not found in the 1889 plates, and especially noticeable is the presence of h and H, as well as the first two lines of the hydrogen series. It is an important fact that these lines grow stronger and broader as the Trapezium is approached, and that the spectrum differs considerably in other particulars in different regions of the nebula.* A complete spectroscopic study of the nebula in sections is evidently very desirable.

The changes in the spectra of variable stars also need to be carefully studied, and Lockyer's theory of variability offers at least a basis of comparison.† The probable complimentary relations of the components of double stars as revealed by their spectra suggests unlimited possibilities in still another direction. And solar work is not to be neglected. Though the prominences have been observed for more than twenty years they still have many secrets to reveal. The spectra at different elevations above the limb; the unequal distortions of different lines of the same metal;‡ the identity of the lines widened in spots at various times in the eleven year period,§ as well as the lines reversed in spots; these are a few of the many subjects still open to investigation. We are, moreover, still ignorant of the true nature of "helium," and the presence of the D_3 line in many star spectra renders its indentification more desirable than ever. "Coronium" also, is still a mystery. But the extensive investigations now in progress in Professor Rowland's laboratories will soon displace the highly inaccurate wavelength determinations of Angstrom, Thalèn, and other physicists and furnish the standard measures of metallic lines demanded by the high dispersion now employed. It is stated that Professor Rowland has already added several elements to the list of those known to be present in the sun.

The importance of laboratory work becomes daily more apparent. The innumerable results of telescopic observation must be interpreted, and peculiar spectroscopic appearances, if possible, reproduced. Lockyer's experiments on the spectra of meteorites may profitably be repeated with higher dispersion,|| and the variations of spectra at different temperatures offer a no less fruitful field of study.¶ Pro-

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* Sidereal Messenger, August, 1890, p. 316.

† Meteoritic Hypothesis, p. 475. ‡ Chemistry of the Sun, p. 348.

§ Ibid, p. 310. || Proc. Royal Society, vol. 43, p. 117.

¶ Chemistry of the Sun, p. 194. See also, Liveing and Dewar, Proc. Royal Society, vol. 44, p. 241.

fessors Liveing and Dewar are especially active in investigations of this nature, and their recent studies of the spectroscopic properties of dust are very significant.* Crew, Dunér and Wilsing have detected a difference between the time of rotation of the sun as given by observations of the spots and measurements of wave-length changes at the limb. Numerical relations between the lines in the same and different spectra, first noticed by Mitscherlich and investigated by Lecoq de Boisbaudran, have been studied by a large number of physicists, and Ames' recent researches on the spectra of cadmium and zinc establish an undoubted connection of the greatest interest.† Examples might be multiplied, but enough has been said to indicate the enviable opportunities of the spectroscopist.

Kenwood Physical Observatory,
Chicago, Jan. 19, 1891.

ASTRONOMY IN RECENT PUBLICATIONS.

The Astronomical Journal, Jan. 9, 1891, has for its leading article, "The Reduction of Astronomical Photographic Measures," by Harold Jacoby. The theme is presented by the aid of geometrical figures and mathematical formulæ. Then follow "Note on the Elements of γ Cygni," "On the Period of 2100 U Orionis," and "Observations of Variable Stars in 1890."

The Journal of the British Astronomical Association, No. 2 of Vol. I, is for November, 1890, and its contents contain a report of the meeting of the Association, on Nov. 26, 1890, paper communicated to the Association by A. W. Thompson on the determination of the heliographic latitude and longitude of sun spots; by A. M. W. Downing, on the eclipses of Jupiter's satellites; by S. J. Johnson, on British astronomical sights in ancient days, and by A. Stanley Williams, on recent observations of the canals and markings of Mars.

Knowledge (London). January number begins Volume XIV, and is handsomely and fully illustrated. The full page

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* Sidereal Messenger, Jan. 1891, p. 9.

† Phil. Mag. [5] 50, (1890) p. 33.

plate, by the direct photo-engraving process, showing a group of sun-spots, taken at Meudon June 1, 1881, by Janssen, with an object glass of five French inches aperture, is a noble specimen of what can be done with a small telescope. It shows the structure of the photosphere of the sun well. Two such plates accompany an article by A. C. Ranyard, entitled "The Sun's Photosphere."

Observatory, January, 1891, gives reports of the meetings of the Royal Astronomical Society December 12, 1890; of the Astronomical Society of the Pacific, Nov. 20, 1890; of the Liverpool Astronomical Society on Dec. 1, 1890, and of the meeting of the Royal Astronomical Society, Dec. 17, 1890. The articles are, Bright-line stars of the Wolf-Rayet type, by Miss A. M. Clerke; the extension of the corona and the details of its structure, by F. H. Bigelow, Washington, D. C.; Motions of the nebulæ in line of sight, by J. E. Keeler of Lick Observatory; Comet Perihelia, by W. E. Plummer; the proper motion of Σ 547, by S. W. Burnham, of Lick Observatory.

Astronomische Nachrichten, No. 3010, has a timely article on provisional results of observations at Berlin, Potsdam, and Prague, concerning the variation of latitude by von Th. Albrecht. This number also contains a series of observations of Comet Spitaler by R. Spitaler himself at the Royal Observatory of Wien-Währing under date of Dec. 20, 1890. The ephemeris of Comet 1890 IV (Zona) for months of January, February and March is by A. Berberich.

Himmel und Erde for December contains a leading article on the theories of the aurora, with a fine full-page plate as frontispiece. Other papers are on the system of ζ Cancri, photography in meridian observations and a description of the Observatory at Nice, besides a number of brief articles.

Solar Prominences in December 1890.

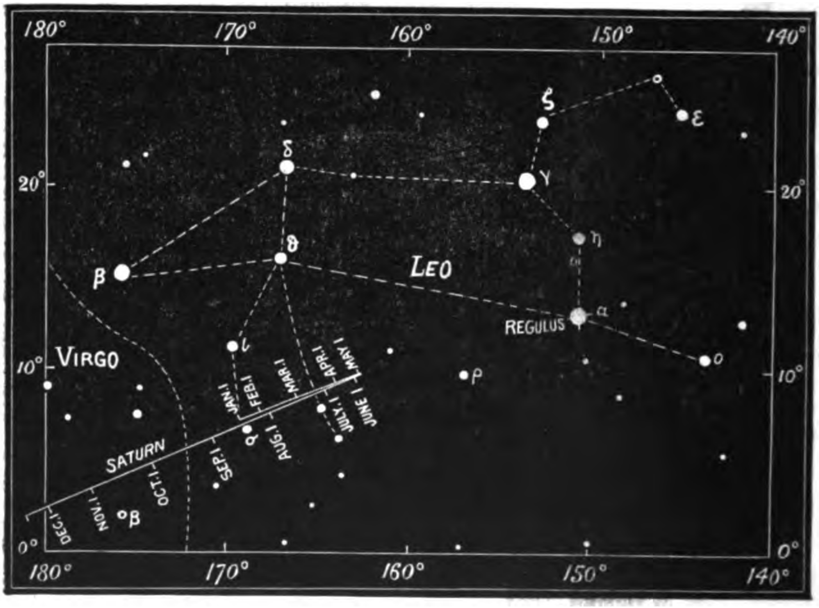
DATE.	POSITION ANGLE.
2	120, 242, 311.
4	284, 302, 348.
12	75, 122, 148, 230, 320.
19	80, 160, 227, 240.
20	45, 139, 226, 229.
22	45, 64, 150, 259, 274, 324.
28	117, 243, 295 to 305, 280, 288, 320.

Camden Observatory, January 1st, 1891. E. E. Reed, Jr.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury, for the first few days of February, will be visible to the naked eye in the morning an hour before sunrise. He will at that time be only a few degrees above the southeastern horizon. On the morning of Feb. 7 Mercury will be just above the moon. Mercury and Jupiter will be in conjunction on the morning of March 5, but both planets will then be too near the sun to be seen except during the day.



PATH OF SATURN AMONG THE STARS IN 1891.

Venus is also "morning star." All early risers have doubtless been struck with the brilliancy of this planet, seen toward the southeast in the morning, up to the time of sunrise and even later, far surpassing the brightness of any of the neighboring stars. During this month the brilliancy will decrease nearly one-third because of the increasing distance of the planet from us, while the phase will change from crescent to gibbous. On Feb. 13 the disk will be exactly half illuminated, the planet being then at greatest elongation west from the sun, 46° 51′. On the morning of Feb. 6, Venus, Mercury, and the crescent moon will form an interesting triangle, Venus being the highest and most westerly, moon and Mercury at almost equal altitudes, Mercury farthest to the east.

Mars has an apparent diameter now of only 5.6″, so that but little of detail can be be seen upon his surface. His distance from the earth is about 170,000,000 miles. He is moving eastward and northward among the inconspicuous stars of the constellation Pisces, and may be seen in the southwest from 6 to 9 P. M.

Jupiter will be in conjunction with the sun on the morning of Feb. 13.

Saturn is in splendid position for observation after midnight, and may be well observed in the evening. He will be at opposition to the sun March 4. The earth is now about 3° below the plane of Saturn's rings while the sun is a little over 4° below that plane. The angle of the earth below the plane of the rings will for a few months increase, but that of the sun will steadily decrease until Oct. 30, when the sun will pass through the plane of the rings. It is important that observers begin at once to closely watch the changes in the rings so as to verify or throw some light upon the phenomena observed by Trouvelot in 1878 (see article p. 74). We give this month Mr. Marth's ephemerides of the satellites for the benefit of those who wish to study the phenomena of the satellites. We give also a diagram of the path of Saturn among the stars of Leo and Virgo during the year 1891, which we hope will be of use to students of astronomy.

Uranus may be observed after midnight. He is in the foot of Virgo about 10° east of Spica and 2.5° south-west of κ Virginis. He will be stationary in right ascension Feb. 4, and after that date will have a retrograde motion. He will be in conjunction with the moon, south 2° 49′, Feb. 28 at 4 A. M. central time.

Neptune may be observed in the evening. He is still in the same field of view with the two eighth-magnitude stars, west of ε Tauri, mentioned last month. The planet is about a half-magnitude fainter than the stars and has more of blue color in its light.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Feb. 23	21 07.2	− 18 13	6 06 A. M.	10 54.0 A. M.	3 42 P. M.
Mar. 5	22 09.7	− 13 40	6 09 "	11 17.0 "	4 25 "
15	23 15.7	− 6 57	6 08 "	11 43.5 "	5 19 "
			VENUS.		
Feb. 23	19 17.8	− 19 40	4 23 A. M.	9 04.8 A. M.	1 47 P. M.
Mar. 5	20 03.6	− 18 40	4 25 "	9 11.3 "	1 58 "
15	20 49.9	− 16 48	4 23 "	9 18.0 "	2 13 "
			MARS.		
Feb. 23	1 17.4	− 8 13	8 30 A. M.	3 03.6 P. M.	9 42 P. M.
Mar. 5	1 44.4	+ 10 59	8 04 "	2 51.2 "	9 39 "
15	2 11.7	+ 13 34	7 41 "	2 39.1 "	9 38 "
			JUPITER.		
Feb. 23	21 57.3	− 13 19	6 35 A. M.	11 45.0 A. M.	4 55 P. M.
Mar. 5	22 06.5	− 12 31	6 02 "	11 14.8 "	4 28 "
15	22 15.5	− 11 42	5 28 "	10 44.4 "	4 01 "
			SATURN.		
Feb. 23	11 06.1	+ 8 07	6 15 P. M.	12 50.6 A. M.	7 26 A. M.
Mar. 5	11 03.2	+ 8 26	5 32 "	12 08.4 "	6 45 "
15	11 00.2	+ 8 44	4 48 "	11 26.1 P. M.	6 04 "

Date. 1890.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			URANUS.		
Feb. 23	13 57.1	− 11 23	10 23 P. M.	3 41.1 A. M.	8 59 A. M.
Mar. 5	13 56.3	− 11 18	9 43 "	3 01.0 "	8 19 "
15	13 55.2	− 11 12	9 02 "	2 20.6 "	7 39 A. M.
			NEPTUNE.		
Feb. 23	4 09.4	+ 19 23	10 31 A. M.	5 55.1 P. M.	1 20 A. M.
Mar. 5	4 09.8	+ 19 25	9 51 "	5 16.1 "	12 41 "
15	4 10.3	+ 19 27	9 12 "	4 37.4 "	12 02 "
			THE SUN.		
Feb. 18	22 07.7	− 11 32	6 56 A. M.	12 14.1 P. M.	5 32 P. M.
23	22 26.9	− 9 44	6 48 "	12 13.5 "	5 39 "
28	22 45.8	− 7 52	6 40 "	12 12.7 "	5 46 "
Mar. 5	23 04.5	− 5 57	6 31 "	12 11.6 "	5 53 "
10	23 23.0	− 4 00	6 22 "	12 10.4 "	5 59 "
15	23 41.3	− 2 02	6 13 "	12 09.0 "	6 05 "
			THE MOON.		
Feb. 24	11 41.6	+ 7 17	6 36 P. M.	1 22.5 A. M.	7 58 A. M.
28	14 43.5	+ 13 27	10 48 "	4 08.0 "	9 19 "
Mar. 5	18 29.7	− 25 35	3 18 A. M.	7 38.0 "	11 57 "
10	23 45.9	− 6 48	6 53 "	12 33.7 P. M.	6 17 P. M.
15	4 26.1	+ 21 42	9 09 "	4 53.6 "	12 48 A. M.

Phases and Aspects of the Moon.

			Central Time. d	h m
First Quarter	1891	Feb.	15	12 29 P. M.
Apogee	"	"	23	Noon.
Full Moon	"	"	23	9 18 P. M.
Last Quarter	"	Mar.	3	1 37 "
Perigee	"	"	9	6 40 "
New Moon	"	"	10	5 51 A. M.

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m.
Feb. 17	132 Tauri	5.3	8 04	62	9 27.8	283	1 24
18	ε Geminorum	3.2	7 57	92	9 30.4	265	1 33
19	ϰ Geminorum	3.6	12 27	65	13 22.5	328	0 55
21	B.A.C. 3206	6.3	10 47	86	12 06.2	325	1 15
22	η Leonis	3.3	7 21	19	7 25.9	10	0 04
24	ν Virginis	4.0	12 59	85	14 03.0	350	1 09
Mar. 1	41 Librae	5.9	17 36	180	18 14.8	234	0 39

Minima of Variable Stars of the Algol Type.

[The times are given, to the nearest hour of Central Time, of only those minima which can be observed in the United States.]

U CEPHEI.

R. A. .... $0^h\ 52^m\ 32^s$
Decl. .... $+81°\ 17'$
Period......... $2d\ 11^h\ 50^m$

Feb. 15	Midn.
22	11 P. M.
27	11 "
Mar. 4	11 "
9	10 "
14	10 "

ALGOL.

R. A. .... $3^h\ 01^m\ 01^s$
Decl. .... $+40°\ 32'$
Period......... $2d\ 20^h\ 49^m$

Feb. 17	4 P. M.
Mar. 1	3 A. M.
3	midn.
6	9 P. M.

λ TAURI

R. A. .... $3^h\ 54^m\ 35^s$
Decl. .... $+12°\ 11'$
Period......... $3d\ 22^h\ 52^m$

Feb. 18	7 P. M.
22	6 "
26	5 "
Mar. 2	4 "

R CANIS MAJ.

R. A..............$7^h\ 14^m\ 30^s$
Decl...............— 16° 11′
Period...........$1d\ 3^h\ 16^m$

Feb. 21	7 P. M.
22	10 “
24	1 A. M.
Mar. 1	5 P. M.
2	8 “
3	midn.
10	7 P. M.
11	10 “

S. CANCRI.

R. A..............$8^h\ 37^m\ 39^s$
Decl...............+ 19° 26′
Period.........$9d\ 11^h\ 38^m$

Feb. 20	9 P. M.
Mar. 11	8 “

S ANTLIÆ.

R. A..............$9^h\ 27^m\ 30^s$
Decl................—28° 09′
Period................$7^h\ 47^m$

Feb. 18	midn.
19	“
20	11 P. M.

S. ANTLIÆ, *Cont.*

Feb. 21	10 P. M.
22	10 “
23	9 “
24	8 “
25	8 “
26	7 “
Mar. 2	midn.
3	“
4	11 P. M.
5	10 P. M.
6	10 “
7	9 “
8	8 “
9	8 “
10	7 “
11	6 “
14	midn.
15	11 P. M.

δ LIBRÆ.

R.A.............$14^h\ 55^m\ 06^s$
Decl.................— 8° 05′
Period.........$2d\ 07^h\ 51^m$

Feb. 22	1 A. M.
Mar. 1	1 “
7	midn.
14	“

U CORONÆ.

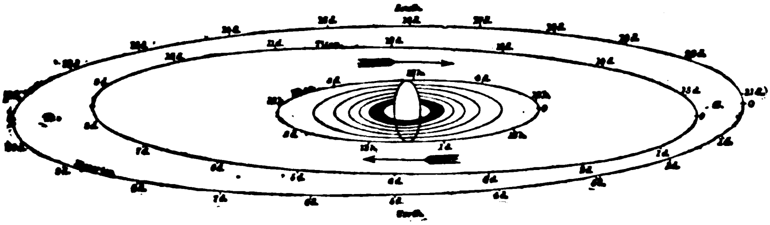
R. A...........$15^h\ 13^m\ 43^s$
Decl................+32° 03′
Period.........$3d\ 10^h\ 51^m$

Feb. 19	10 P. M.
Mar. 9	4 A. M.

U OPHIUCHI.

R. A............$17^h\ 10^m\ 56^s$
Decl................+ 1° 20′
Period.........$0d\ 20^h\ 08^m$

Feb. 18	4 A. M.
18	midn.
23	5 A. M.
24	1 “
28	6 “
Mar. 1	2 “
5	6 “
6	2 “
11	3 “
11	11 P. M.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, MAY 17, 1891, AS SEEN IN AN INVERTING TELESCOPE.

(*The Vertical Scale is Twice the Horizontal One.*)

Mr. Marth's Ephemerides of Saturn's Satellites.

[Reduced to Central Time; from Monthly Notices, Vol. LI. Nov. 1890; Di = Dione; En. = Enceladus; Mi. = Mimas; Rh. = Rhea: Te. = Tethys; Ti. = Titan; c = conjunction with the center of planet; f = conjunction with following end of ring; p = conjunction with preceding end; n = north; s = south of the major axis of the ring; e = eastern elongation; w = western elongation.]

1891		
Feb. 1	6.2 p.m.	Di. ps.
	7.0	Mi. fn.
	7.5	Te. pn.
	7.7	En. ps.
2	12.9 a.m.	Mi. pn.
	1.9	Rh. fn.
	2.0	Di. fs.
	2.0	En. fs.
	3.3	Te. w.
	2.5 p.m.	Di. e.
	5.6	Mi. fn.
	6.1	Te. fs.
Feb, 3	6.5 p.m.	En. pn.
	11.5	Mi. pn.
3	2.0 a.m.	Te. e.
	3.1	Di. fn.
	4.2 p.m.	Mi. fn.
	4.8	Te. pn.
	9.0	En. fn.
	10.1	Mi. pn.
	11.4	Di. w.
4	12.6 a.m.	Te. w.
	3.3	En. pn
	3.5	Mi. ps.
Feb. 4	3.4 p.m.	Te. fs.
	5.1	Rh. fs.
	7.7	Di. fs.
	7.8	En. fs.
	8.7	Mi. pn.
	11.3	Te. e.
5	2.1 a.m.	Mi. ps.
	3.7 p.m.	Rh. e.
	7.2	Mi. pn.
	8.7	Di. fn.
	9.9	Te. w.
	10.3	En. ps.

Feb. 6	12.7 a.m.	Mi. ps.
	4.5	Di. pn.
	4.6	En. fs.
	3.2 p.m.	Tit. inf. c. n. 10″
	5.0	Di. w.
	6.0	Mi. pn.
	8.6	Te. e.
	9.1	En. pn.
	11.2	Rh. pn.
	11.4	Mi. ps.
7	4.4 a.m.	Te. fn.
	4.6 p.m.	Mi. pn.
	7.2	Te. w.
	9.8	Rh. w.
	10.0	Mi. ps.
	11.6	En. fn.
8	1.9 a.m.	Di. e.
	3.0	Te. ps.
	4.0 p.m.	En. ps.
	5.8	Te. e.
	8.4	Rh. ps.
	8.6	Mi. ps.
	10.2	Di. pn.
	10.4	En. fs.
9	1.7 a.m.	Te. fn.
	2.5	Mi. fs.
	2.8 p.m.	En. pn.
	4.5	Te. w.
	7.2	Mi. ps.
	11.2	Di. ps.
10	12.3 a.m.	Te. ps.
	12.9	En. ps.
	1.1	Mi. fs.
	3.1 p.m.	Te. e.
	5.4	En. fn.
	5.8	Mi. ps.
	7.5	Di. e.
	10.0	Te. fn.
	10.7	En. pn.
	10.7	Mi. fs.
11	2.6 a.m.	Rh. fn.
	1.8 p.m.	Te. w.
	3.8	Di. pn.
	4.2	En. fs.
	4.4	Mi. ps.
	9.6	Te. ps.
	10.3	Mi. fs.
12	2.2 a.m.	En. fn.
	3.7	Mi. fn.
	4.3	Di. w.
	4.6	Te. fs.
	4.8 p.m.	Di. ps.
	6.7	En. ps.
	8.2	Te. fn.
	8.9	Mi. fs.
13	12.6 a.m.	Di. fs.
	1.0	En. fs.
	2.3	Mi. fn.
	3.2	Te. pn.
	5.5 p.m.	En. pn.
	5.7	Rh. fs.
	6.9	Te. ps.
	7.6	Mi. fs.
14	1.0 a.m.	Mi. fn.
	1.7	Di. fn.
	1.9	Te. fs.
	3.5	En. ps.
	4.3 p.m.	Rh. e.
	5.5	Te. fn.
	6.2	Mi. fs.
	8.0	En. fn.
	8.6	Tit. sup. c. s. 12″
	10.0	Di. w.
	11.6	Mi. fn.
15	12.5 a.m.	Te. pn.
	2.4	En. pn.
	2.9 p.m.	Rh. fn.
	4.2	Te. ps.
	4.8	Mi. fs.
	6.3	Di. fs.
Feb. 15	6.8 p.m.	En. fs.
	10.2	Mi. fn.
	10.7	Te. fs.
	11 9	Rh. pn.
16	4.1 a.m.	Mi. pn.
	4.9	En. fn.
	2.9 p.m.	Te. fn.
	3.4	Mi. fs.
	7.3	Di. fn.
	8.8	Mi. fn.
	9.3	En. ps.
	9.9	Te. pn.
	10.5	Rh. w.
17	2.7 a.m.	Mi. pn.
	3.1	Di. pn.
	3.7	En. fs.
	3.6 p.m.	Di. w.
	7.4	Mi. fn.
	8.1	En. pn.
	8.5	Te. fs.
	9.1	Rh. ps.
18	1.3 a.m.	Mi. pn.
	4.2	Di. ps.
	4.3	Te. e.
	6.0 p.m.	Mi. fn.
	7.1	Te. pn.
	10.6	En. fn.
	11.9	Mi. pn.
19	12.5 a.m.	Di. e.
	2.9	Te. w.
	4.7	Rh. e.
	3.1 p.m.	En. ps.
	4.6	Mi. fn.
	5.8	Te. fs.
	8.8	Di. pn.
	9.4	En. fs.
	10.5	Mi. pn.
20	1.6 a.m.	Te. e.
	3.2	Rh. fn.
	3.2 p.m.	Mi. fn.
	4.4	Te. pn.
	9.2	Mi. pn.
	9.8	Di. ps.
	11.9	En. ps.
21	12.2 a.m.	Te. w.
	2.6	Mi. ps.
	3.1 p.m.	Te. fs.
	4.4	En. fn.
	6.1	Di. e.
	7.8	Mi. pn.
	10.7	En. pn.
	10.9	Te. e.
22	1.2 a.m.	Mi. ps.
	12.9 p.m.	Tit. inf. c. n. 12″.
	1.7 p.m.	Te. pn.
	2.4	Di. pn.
	3.2	En. fs.
	6.4	Rh. fs.
	6.4	Mi. pn
	9.5	Te. w.
23	3.5	Di. ps.
	5.0	Rh. e.
	8.2	Te. e.
24	3.6	Rh. fn.
	3.6	Mi. fn.
	4.5	En. pn.
	6.8	Te. w.
	9.0	Mi. ps.
25	12.3 a.m.	Di. fn.
	12.6	Rh. pn.
	2.6	En. ps.
	2.6	Te. ps.
	2.9	Mi. fs.
	5.5 p.m.	Te. e.
	7.0	En. fn.
	7.6	Mi. ps.
	8.6	Di. w.
	11.1	Rh. w.
26	1.3 a.m.	Te. fn.
	1.4	En. pn.
	1.5	Mi. fs.
Feb. 26	4.1 p.m.	Te. w.
	4.9	Di. fs.
	5.8	En. fs.
	6.2	Mi. ps.
	9.7	Rh. ps.
	11.9	Te. ps.
27	12.1 a.m.	Mi. fs.
	3.9	En. fn.
	2.8 p.m.	Te. e.
	4.9	Mi. ps.
	5.9	Di. fn.
	8.3	En. ps.
	10.6	Te. fn.
	10.8	Mi. fs.
28	1.7 a.m.	Di. pn.
	2.7	En. fs.
	1.4 p.m.	Te. w.
	2.2	Di. w.
	3.5	Mi. ps.
	7.1	En. pn.
	9.2	Te. ps.
	9.4 p.m.	Mi. fs.
Mar. 1	2.8 a.m.	Di. ps.
	2.8	Mi. fn.
	3.9	Rh. fn.
	4.2	Te. fs.
	12.0 m.	Te. e.
	12.9 p.m.	Rh. pn.
	2.1	Mi. ps.
	7.9	Te. fn.
	8.0	Mi. fs.
	9.6	En. fn.
	11.1	Di. e.
2	1.4 a.m.	Mi. fn.
	2.9	Te. pn.
	4.0	En. pn.
	2.1 p.m.	En. ps.
	6.2	Tit. sup. c. s. 14″
	6.5	Te. ps.
	6.6	Mi. fs.
	7.4	Di. pn.
	8.4	En. fs.
	12.0 midn.	Mi. fn.
3	1.5 a.m.	Te. fs.
	12.9 p.m.	En. pn.
	5.2	Te. fn.
	5.2	Mi. fs.
	7.0	Rh. fs.
	8.4	Di. ps.
	10.6	Mi. fn.
	10.9	En. ps.
4	12 2 a.m.	Te. pn.
	2.2	Di. fs.
	3.4 p.m.	En. fn.
	3.8	Te. ps.
	3.8	Mi. fs.
	4.7	Di. e.
	5.6	Rh. e.
	9.2	Mi. fn.
	9.7	En. pn.
	10.8	Te. fs.
5	3.1 a.m.	Mi. pn.
	1.0 p.m.	Di. pn.
	2.2	En. fs.
	2.4	Te. fn.
	2.4	Mi. fs.
	4.2	Rh. fn.
	7.8	Mi. fn.
	9.4	Te. pn.
6	12.3 a.m.	En. fn.
	1.2	Rh pn.
	1.5	Di. w.
	1.8	Mi. pn.
	1.0 p.m.	Mi. fs.
	1.1	Te. ps.
	2 1	Di. ps.
	4.7	En. ps.
	6.5	Mi. fn.

COMET NOTES.

Periodic Comets due in 1891.—Four periodic comets are due this year. All are telescopic, and all but one have been observed at more than one apparition.

Tempel's first periodical comet, discovered by Temple in 1867, is due in April unless its period has been changed by perturbations since 1879. It was observed in 1873 and 1879 but escaped detection in 1885. The period is a few days less than six years.

Wolf's comet, 1884 III, was found by Thraen (*Astr. Nach.*, 2790 p. 97) to have a period of 6.775 years. It should be at perihelion in August, 1891. There is some uncertainty, however, about the elements, so that the comet may appear earlier or later than the designated time.

Swift's comet, 1880 V, known now as Temple-Swift's, is due at perihelion in October. Its period is 5.50 years. It was first observed by Tempel in 1869, and is unfavorably situated for observation at alternate returns to perihelion. It probably will not be detected this year.

Encke's comet is due in the same month, October. This comet has been seen at every return since Encke determined its period in 1818-19. The problem of the "resisting medium" or the cause of the gradual diminution of the period of this comet has not been satisfactorily solved, so that much interest still attaches to the successive apparitions.

Comet 1890......(Spitaler Nov. 16)—Dr. Spitaler has computed the elements of this comet from his own observations of Nov. 16, Dec. 4 and Dec. 13 (*Astr. Nach.* 3009), and finds that the orbit is not parabolic. Mr. Rosmanith computed the following elliptic elements, which show that the comet is one of short period.

$$\begin{array}{rl} T & = \text{1890 Oct, 26.50833 Berlin M. T.}\\ \begin{array}{r}\pi\\ \Omega\\ i\end{array} & \left.\begin{array}{l}= 58^\circ\ 24'\ 28.2''\\ = 45\ \ 07\ \ 51.2\\ = 12\ \ 51\ \ 49.0\end{array}\right\}1890.0\\ \varphi & = 28\ \ 11\ \ 26.6\\ \log a & = 0.537532. \qquad a = 3.4477.\\ \mu & = 554.2''\\ \text{Period} & = \text{6.4 Years.}\end{array}$$

The perihelion distance is 1.819 and the aphelion distance 5.076 times the earth's distance from the sun. The comet is so faint as to be seen only with telescopes of very large aperture. In *Astr. Nach.* 3010. Dr. Spitaler suggests that the comet has described this orbit only since 1887, for in the latter part of that year it was at its descending node very near to Jupiter, and probably suffered great perturbations.

Zona's Comet will be almost stationary in right ascension and declination during the month of February. Its place is about 5° west and a little north of Alpha Arietis in the head of The Ram. Its theoretical brightness is less than one fifth that which it had when discovered.

Ephemeris of Comet e 1890 (Zona Nov. 15). From the elements of my orbit as given in the "SIDEREAL MESSENGER" for January I have computed the following ephemeris:

Gr. M. T.	App. R. A.			App. Dec.		Log *r*.	Log Δ.
	h	m	s	°	′		
Feb. 1.5	1	31	30	+ 25	44		
2.5		31	15	25	41	0.4652	0.4737
3.5		31	0	25	38		
4.5		30	45	25	36		
5.5		30	32	25	34		
6.5		30	19	25	32	0.4699	0.4889
7.5		30	7	25	30		
8.5		29	56	25	28		
9.5		29	46	25	26		
10.5		29	38	25	24	0.4745	0.5038
11.5		29	32	25	22		
12.5		29	26	25	21		
13.5		29	21	25	20		
14.5		29	18	25	19	0.4791	0.5179
15.5		29	16	25	18		
16.5		29	15	25	17		
17.5		29	15	25	17		
18.5		29	16	25	16	0.4836	0 5312
19.5		29	18	25	16		
20.5		29	21	25	16		
21.5		29	25	25	16		
22.5		29	29	25	16	0.4882	0.5438
23.5		29	34	25	16		
24.5		29	40	25	16		
25.5		29	47	25	17		
26.5		29	55	25	17	0.4927	0.5556
27.5		30	4	25	17		
28.5	1	30	14	+ 25	18		

The theoretical light of the comet on Feb. 28 will be less than half that on Feb. 1.

O. C. WENDELL.

Harvard College Observatory, Jan. 14, 1891.

Carleton College Sun-spot Observations. (Continned from page 37.)

Date 1890.	Central Time.	Groups.	Spots.	Faculæ.	Observer.	Remarks.
Dec. 23	12.40 p m	1	1	2 gr.	C. R. W.	Faculae W.
24	2.15 "	1	4	2 "	H. C. W.	Faculae W.
27	11.00 a m	1	3	1 "	"	Faculae E.
30	12.00 "	1	1	1 "	"	Faculae N W.
1891.						
Jan. 2	12.00 "	0	0		"	
3	12.00 "	0	0		"	
5	2.00 p m	0	0	3 "	"	
7	2.45 "	1	4	1 "	C. R. W.	Large gr. of fac. E. Spots small.
8	12.40 "	1	2	1 "	"	
13	12.30 "	0	0	0 "	"	
14	10.05 a m	0	0	0 "	"	
15	12.25 p m	1	1	1 "	"	Large spot E.
17	12 45 "	1	4		"	
19	10.30 a m	2	4	1 "	"	Two small spots N. W. One large and one small spot S. E. Faculae E.
20	2.45 p m	2	5	1 "	"	

Smith Observatory Solar Observations. The following were observed with the helioscope unless otherwise specified:

1890-1.	90 Merid M. T.	Groups.	Spots.	Faculæ.	Seeing.	REMARKS.
Dec. 17	3.30 p m	1	7	0	poor.	Gran. fine.
18	9.30 a m	2	15	0	poor.	Group near N.E. and S.W. limbs.
19	3.45 p m	2	4	0	poor.*	Glimpsed for a moment in clouds.
21	3.00 "	2	2	0	fair.*	Gran. plain: fac. about each group.
23	1.25 "	0	0	0	fair.	Gran. fair.
27	11.00 a m	1	4	0	fair.	Gran. good.
29	10.00 "	1	4	2	fair.*	Fac. N.W. limb and around spots.
30	2.00 p m	1	3	1	poor.	Fac. N.W. limb.
Jan. 3	4.00 "	0	0	0	bad.	Bad definition.
4	1.00 "	0	0	0	poor.	Bad definition.
5	2.30 "	0	0	2	fair.	Fac. near E. and W. limbs.
6	11.45 a m	0	0	1	fair.	Suspected spots forming N.E. large. gr. fac S.E.
7	11.15 "	2	?	1	poor.	Could not count spots (3 in N.E. gr.?)
8	9.30 "	0	0	0	bad.	Could distinguish nothing.
9	11.30 "	0	0	0	fair.	Gran. fair.
13	11.40 "	0	0	0	poor.	Definition poor, high wind.
14	11.15 "	0	0	0	bad.	Could distinguish nothing.
15	12.00 m	1	1	2	good.	Fac. around spot and also north of it.
17	1.45 p m	3	9	1	good.	Large typical spot: penumbra finely marked.
18	3.30 "	4	4	1	poor.	Impossible to count spots in one group.
19	10.00 a m	5	14	1	good.	At 12 m. 2 small spots had appeared in fac. group: at 1.30 a new spot just outside penumbra of large spot; unusual activity.

* Projection on 20 cm. circle.

Belolt, Wis., 20 Jan., 1891. CHAS. A. BACON.

Interesting Phenomena. Under date of Jan. 12. Professor C. M. Charroppin, S. J., of St. Charles, Mo., writes concerning interesting phenomena observed in his locality. On the evening of Jan. 4, at 6 o'clock, at an altitude of 35° or 40° southeast of Polaris, a very luminous object was seen. Those who observed it claim that it looked like the tail of a comet, though much brighter, and of a reddish hue. Though Professor Charroppin did not see the object, he thinks, from the description of others, that it was elliptical in shape, with major axis vertical, and probably occupying 40′ or 50′ of arc; that it was stationary and continued for five minutes, and then disappeared. He is unable to give a satisfactory explanation of the phenomenon, and suggests that other readers of THE MESSENGER may have seen it.

He further says that on the 18th of December he was at the Observatory of Capt. Petitdedier, who has a 12-inch reflector made by himself. The night was fair, and the six stars in the Trapezium or θ Orionis appeared distinctly with a power of 300. The moon was nearing first quarter and had just passed culmination. The mirror of the instrument being well corrected gave no color whatever. Mons Christi was just looming up beyond the terminator. The peak was very bright, and showed some of the prismatic colors. It appeared to Professor Charroppin and his friend, the captain, like the reflection of the morning sun striking a mountain covered with icicles. Different eye-pieces were tried with the same result. No sign of color could be seen on any other mountain of the moon. This high peak was the only one then visible beyond the terminator.

As Professor Charroppin is inclined to favor the theory that the moon is covered with ice and snow; he is, of course, interested to know if others have made the same observations.

NEWS AND NOTES.

It is taken for granted that subscribers who have not renewed or signified a wish for the continuance of THE MESSENGER prefer that it should be stopped, and we have done so. In passing names to a new book mistakes may have been made. Errors will be promptly corrected if friends will notify us.

To present Dr. Huggins' valuable paper as a whole, and to give place to other important new matter, we have added sixteen pages to this number more than usual. The definitive work of the spectroscope rightly claims large place in an account of the progress of astronomy at the present time.

We notice with pleasure that a full account of James E. Keeler's study of Jupiter during the year 1889 has been published in German in *Himmel und Erde*. The reproduction of his eight drawings of the surface markings of the planet is admirable.

Although we have added much to our space this time, we have not found room for considerable matter to aid in the study of the constellations which has been already proposed. It was our plan to present this month, a map of the constellation of Orion and call attention first to features readily seen by the naked eye, then further study by the opera-glass, and finally notice the work done by telescopes, large and small. We are not sure that such an outline study will be very useful, but it will be tried in the hope that it will elicit comment from those interested, when it appears, to guide us in further attempts of a similar kind.

Foreign subscribers will please remember that the post office at Northfield is not a foreign money order office. All foreign money orders in favor of the MESSENGER should be drawn on the post office at St. Paul or at Faribault.

With great regret a little while ago we learned of the affliction of Professor Daniel Kirkwood, of Riverside, California, in the sudden death of his wife, by heart failure, which occurred Nov. 8, 1890. It is indeed a beautiful and a brave spirit that can say, as he did, in such trying circumstances, "The Lord gave and the Lord hath taken away."

Dresden Astronomical Observations. Three very neat volumes of astronomical observations, in quarto form, have been received from B. D'Englehardt, of Dresden. One volume was issued in 1886 and the other two for 1890. The first part for last year contains micrometrical observations of the satellites of Saturn, observations of planets and comets, double stars of Bradley, and other important lists made mainly since 1887. The second volume gives a description of the astronomical instruments and buildings of the Observatory at Dresden.

Astronomical Expedition to Peru. Professor William H. Pickering sailed from New York for Arequipa, Peru, on December 20, accompanied by Mr. A. E. Douglas and Mr. R. D. Vickers, who will assist him in his astronomical work. The Harvard College Observatory has, until recently, occupied a station on Mount Harvard, near Chosica, in Peru, where under the direction of the Messrs. Bailey, photographs of the southern heavens have been obtained with the Bache photographic telescope, aperture 8 inches, focal length 44 inches. Measures of the light of the bright and faint stars have also been made with the meridian photometer. These measures will furnish the material for determining the magnitudes of the southern stars brighter than the magnitude 6.3, and thus extending the "Harvard Photometry" to the South Pole. Measures have also been obtained of stars of the ninth magnitude and brighter, distributed in zones similar to those recently published in Vol. XXIV of the H. C. O. Annals. In consequence of the long duration of the rainy season at Mount Harvard, the instruments have been removed to Arequipa, which has an elevation of about 8,000 feet above the sea level, where a station has been established. There, under the direction of Professor W. H. Pickering, the photometric observations will be completed and the work of the Bache telescope continued and extended. The plan of work for this instrument is to cover the sky from —20° to the south pole; first with chart plates having 10 minutes' exposure; second with chart plates having 60 minutes' exposure; third with spectrum plates having 10 minutes' exposure; and fourth with spectrum plates having 60 minutes' exposure. Each of these researches will cover the sky twice, so that at least eight photographs of every bright star will be obtained. It is further proposed that, while the instrument remains in Peru, the first of this series of plates be repeated each year, in order to furnish a means of determining and discussing variability or large proper motion in the stars. Professor Pickering has taken with him the Boyden photographic telescope, aperture 13 inches, which, until lately, has been employed in photographing the objects of interest in the heavens which could be advantageously obtained at the station on Wilson's peak in southern California. With this instrument he will continue to photograph the moon, planets, double stars, clusters and nebulae. In addition to this, by placing a prism over the object glass, the spectra of the brighter southern stars will be obtained with this instrument, on a scale which will render the photographs comparable with those of the northern stars obtained with the 11-inch Draper telescope at Cambridge, thus extending this important investigation also from pole to pole. A meteorological station will be attached to the Observatory at Arequipa, which will furnish interesting records of atmospheric conditions prevailing at this elevation. The series of meteorological observations at Vinconcaya, elevation, 14,600 feet; at Puno, elevation 12,500 feet; and at Mollendo, near the sea level, will also be continued. The Messrs. Bailey, who at present have charge of the observing station at Arequipa, will probably return to Cambridge in April, bringing with them the meridian photometer.

Professor W. A. Crusenberry, of Drake University, Des Moines, Iowa, is planning for astronomical work and is getting a small telescope in place for it.

Stars Having Peculiar Spectra—New Variable Stars in Aquarius and Delphinus. [Communicated by Edward C. Pickering, Director of Harvard College Observatory.] Photographs of stellar spectra taken at the Harvard College Observatory, with the 8-inch Draper telescope, continue to add to the list of interesting objects in the heavens. On plate 2533, taken Dec. 19, 1890, the star D. M. + 63° 83, magn. 9.5, whose approximate position for 1900 is in R. A. $0^h\ 37.5^m$, Decl. + 64° 14′, shows a spectrum consisting mainly of bright lines, and similar to that of the Wolff and Rayet stars in Cygnus. On plate 2224 taken November 8, 1890, bright hydrogen lines are visible in the spectrum of a star whose approximate position for 1900 is in R. A. $20^h\ 41.2^m$, Decl. — 4° 26′. Chart plates of the region were examined which proved the variability of this star. The following approximate magnitudes were obtained, 8.6, 8.6, 8.4, 9.1, and 9.6, on Oct. 18, Nov. 8, Nov. 13, Dec. 12, and Dec. 15, 1890. Another variable star, having a similar spectrum, was found on plate 2542, taken Dec. 20, 1890. Its approximate position for 1900 is in R. A. $20^h\ 43.1^m$, Decl. +18° 58′. Chart plates of this region were also examined, and the star was found to be fainter than the tenth magnitude on June 30, July 29, Aug. 15, Sept. 25, Sept. 29, Oct. 11, and Oct. 28, 1890, while on Nov. 28, Dec. 19, and Dec. 22, 1890, it had the approximate magnitudes 9.3, 8.6, and 8.7. M. FLEMING.

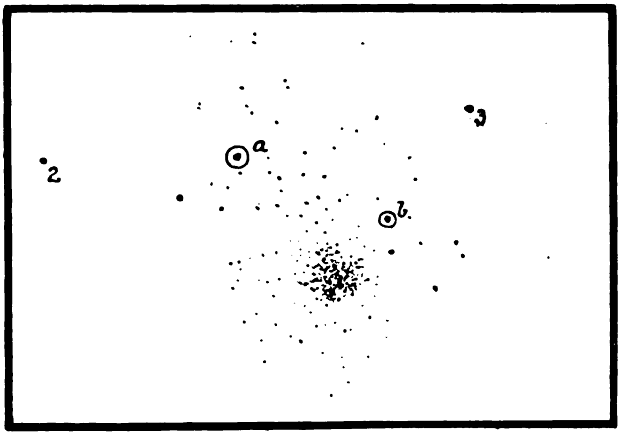
Harvard College Observatory, Cambridge, Mass., Jan. 13, 1891.

Honors for Professor C. A. Young. The readers of THE MESSENGER will be interested to learn that the Janssen prize for 1890 by the French Academy of Sciences has been awarded to Professor Charles A. Young, of Princeton, for his discoveries in spectroscopy.

The Explosion of a Meteor. The *Ohio State Journal,* Dec. 20, 1890, contains a brief account of the explosion of a meteor near Utica, Ohio, at 9 o'clock on the evening of December 18. The concussion was noticed by many people and was preceded by a bright red light which illuminated the sky in the direction of northwest. Persons residing about three miles northwest of Utica say the shock was "stunning" in that vicinity. At Utica two distinct shocks were felt, the first slight, the second, after an interval of a few minutes strong enough to shake houses. The tremor was like an earthquake. Professor John Haywood, of Otterbein University, Westerville, Ohio, situated about 25 miles southwest from Utica, says he saw a light through the north window of a building where he happened to be at the time. Other persons at Westerville saw the light and heard a report which they supposed to be thunder. We hope to get a fuller report of these phenomena in the near future.

A Correction. It is sometimes dangerous to correct one error, as in opening your mouth to do it you may let slip another. That is what I did last month in saying incidentally that Sirius is 60 times our sun in mass. The statement would be improved by a decimal point after the 6. Error of one (1) in the characteristic of the logarithm! The school-boy who committed it is digraced and discharged. N. M. MANN.

New Variable Stars near the Cluster 5 M Libræ. Through some unaccountable oversight I omitted mentioning my observation upon another star, the south component of a wide pair just following the cluster. In the *Astr. Nachr.*, No. 2986, Professor Pickering communicates a note by Mrs. Fleming fully confirming the variability of both stars from a careful discussion of seventeen photographic plates at Harvard College Observatory. The following are the resulting light ranges and magnitudes: For the star s. preceding the cluster (marked *a* in the chart) a variation of 1.9 mag. is found, from 9.7 to 11.6, and for the star immediately s. following the cluster (marked *b* in the chart) a variation of 2.9 mag. is found, from 9.3 to 12.2, while the comparison stars used (marked 1, 2, and 3) are of magnitudes 9.5, 11.0, and 12.2 respectively. The accompanying chart is identical with one taken on the night of June 9th, and will serve to identify these mysterious objects and their comparison stars excepting No. 1, which is 18′ or 20′ south of cluster and preceding the bright star 5 Serpentis; hence it cannot be included.



THE VARIABLE STARS AROUND 5 M LIBRÆ.

The cluster 5 Messier is one of the most beautiful of its kind, and easily resolvable with a moderate aperture, and from its position, well situated for observation in both hemispheres. The existence, therefore, of two new variables among the brightest of its outlying stars will considerably enhance its interest, and affords another instance of the association of variable stars with dense star clusters. D. E. PACKER.

London, 1890, Nov. 10.

T. J. J. See, Student in Astronomy at the University of Berlin, Prussia, has kindly furnished us with an outline of the mathematical work and a drawing showing the results of his new theory as applied to the system of γ Virginis. His paper on the eccentricity of the orbits of binary stars, elsewhere printed in this issue, gives the principal points of the theory.

Photographic Notes.—A body known as the American Photographic Conference has been recently organized in New York city. The conference proposes to establish a photographic institute where instruction will be given in various branches of photographic work.

A photographic plate, exposed in Algiers, has brought out 4,800 stars in the region of the nebulous spot in the constellation Lyra. The plate took a record of 3 square degrees.

The Harvard Peru expedition is about to be reinforced by the arrival of improved instruments. Among these instruments is a new photographic telescope of twenty-four inches aperture.

In the November number of Monthly Notices of the Royal Astronomical Society, Mr. H. C. Russell, writing of celestial photographs taken at the Sydney Observatory, makes the following statement: "Certain it is that these pictures present the Milky Way in an entirely new light, quite different from the telescopic or naked-eye view, and give it such a different aspect that the question arises which are we to accept? It seems evident that the photograph may be made to present the stars to us under an aspect quite different from that presented to the eye, because, by continued exposure, the faint stars may have time to produce as much effect as brighter stars, because the effect is limited by the amount of silver in the film, which, when altered by the bright star, stops any further effect of that star, while the faint ones may go on piling up their effect."

In the same publication Mr. Russell has a paper on "Electrical Control of Drive Clocks."

Knowledge, of January, contains two beautiful photographs of the sun's surface taken by Dr. Jules Janssen.

Albert Lea Scientific Association. The meeting of the Science Association at Albert Lea, Minn., on January 20, was largely attended. The paper that attracted special attention and which elicited considerable discussion was given by Mr. D. G. Parker, the theme being the Nebula Hypothesis. It was prepared for a popular audience. The first part of the address treated the subject historically and theoretically, giving attention chiefly to the principal points in proof of the support of the nebular theory. The last part deals with the weak points of the theory, and the modifications made by late writers to meet objections. The latter part of the theme will be presented at a subsequent meeting. Such papers and such popular gatherings are exceedingly helpful in lifting the common thought to a plane of activity and individual study from which must come only good results. Every small town ought to awaken and stimulate an interest in science for the common good. There is home ability enough for it if a few thoughtful persons will counsel together and plan to make use of it.

Astronomical Instruments. A recent catalogue of astronomical instruments by Jas. W. Queen and Company, of Philadelphia, has been received. We are agreeably surprised to find in it so large and varied a line of fine astronomical instruments. The showing for quality aud size of instruments is very creditable.

Meteor Radiants. I regret that in my article on Meteor Radiants I did not do full justice to Mr. Denning's unwearied assiduity as an observer. Some of his remarks led me to think that he had not watched during whole nights, but I find that they are susceptible of a different meaning. The only inference which I drew, however, was that a radiant which appeared to be isolated in Mr. Denning's Catalogue need not be so in reality, and this inference, I think, his own list of Stationary Radiants is sufficient to establish.

As to the charge of making "harassing attacks, etc.," on Mr. Denning, I may perhaps mention that my other letters, etc., to which he refers are written in the same tone as my article in THE SIDEREAL MESSENGER; and I would not have founded my conclusions almost exclusively on his catalogue if I did not entertain the highest opinion of his qualities as an observer. Whether I have attacked him or he has attacked me I leave your readers to judge; but I have no desire to retaliate.

His argument that because I am not myself an observer I have no right to form any theory about meteors seems to me a strange one. Are my friend Mr. Gore's orbits of double stars worthless because he has not (as perhaps he has not) ever measured the distance and position-angle for himself? But at all events Mr. Denning in his prefatory remarks to his catalogue throws down his facts—intimates that he has no theory to propound—and invites others to carry on the investigation. This I have endeavored to do, and for this endeavor I am denounced as an ignorant blunderer. This does not hold out a very inviting prospect to others who may feel disposed to enter on a branch of investigation indicated by Mr. Denning himself.

Mr. Denning seems in doubt as to what my views are. Permit me therefore briefly to relate them, leaving out some explanations which I always considered doubtful. They are: 1. Stationary or long-enduring radiants are not the exception but the rule, and this rule may even be an invariable law. 2. This being so, the connection between certain showers and certain comets cannot be so close as has hitherto been supposed. 3. No decided case of shifting in a radiant has as yet been established. Now on the first two of these propositions Mr. Denning has not in any of his attacks on me given a decided opinion, and he merely negatives the third by his *ipse dixit.* With this *ipse dixit* I should rest satisfied if the question was one of pure observation; but it plainly is not so. To establish the shifting of the Perseid radiant from 3° + 49° on the 8th of July to 78° + 58° on the 22d of August it would be necessary to set out all the radiants between 3° + 49° and 78° + 58° which were observed during the intervening time, to state the reasons for rejecting some of them as not being Perseids, and to show that, omitting these, the remainder exhibit a continuous change in R. A. and Decl. And even then observations made in other countries should be compared, seeing that during the great Andromede shower of 1885 Mr. Denning (supported by Col. Tupman) noticed a shifting in the direction of decreasing R. A., while Schiaparelli and Denza in Italy observed a shifting in the opposite direction. A radiant area, in which the point of maximum intensity varies with the conditions of time and place affords perhaps the best explanation of such phenomena.

Dublin, Dec. 13th, 1890. W. H. S. MONCK.

BOOK NOTICES.

New Light from Old Eclipses: or Chronology Corrected, and the Four Gospels Harmonized, by the Rectification of Errors in the received Astronomical Tables. By William M. Page. C. R. Barnes Publishing Co., St. Louis; 1890. pp. 590.

This book is evidently written by a seeker after truth and one who is actuated by a worthy purpose. The light sought is needed, and the way to the place where light dwells, as indicated by the writer, is not to be despised, for science is asked to aid where sacred chronology is in doubt. The use made, however, of the materials is open to objection, as must be easily seen by any careful reader able to judge of the facts. Let us look at a few instances:

The Introduction, consisting of ten pages, covers well the point of the uncertainty of early chronology from the best of historical sources. Then the question is asked, in the first chapter, have we any means outside of the testimony of ancient historians by which the three dates of the birth and crucifiction of Christ can be determined? The author answers affirmatively and seeks to prove his position by a study of the data of eclipses. He thinks the proof would be easy if existing astronomical tables were not so inaccurate; and hence his first duty is to show wherein and how much these tables are wrong, and he cites the differences between the successive lunar intervals of 1860 and 1861 as shown by Bailey's tables, and then says on pages 16 and 17 that because astronomers are not content with these observed errors they "have formulated a theory which adds to them," meaning of course the acceleration of the moon's mean motion. If we understand the author's meaning in this connection, we think he claims there is no such thing as a secular acceleration of the moon's mean motion. In this he is certainly wrong, for scarcely any fact in astronomy is better established than this. On pages 18 and 19 the author thinks that if the tables were changed a little, the calculation of certain early eclipses by them would be in accord with the times of their observation as recorded in history; but the chronology of history has before been declared wholly untrustworthy for definite results, and should the author now use its dates as an exact standard, by which to judge of the accuracy of his corrected tables? By so doing he treats well known facts of astronomy as false and sets aside, as of no consequence, some of the best work of which the master mind of Laplace was capable. We had always before given that renowned Frenchman the credit of knowing how "to do a sum in simple division in arithmetic." On page 27, it is said that the eclipses referred to do not prove the moon's acceleration, but, on the contrary, the errors of the tables. Evidently the author does not understand the elementary astronomy of this subject, or he never would have written this page. What has been discovered in astronomy is in perfect keeping with the laws of Nature generally, and the revealed will of God in the Bible, and when he says that God's "laws, whether for the regulation of the heavenly bodies or for the action of men, are forever the same," he certainly does not mean, as a believer in the Bible, to proclaim the eternity of material existence in its present form. If this is not the meaning of the paragraph we do not know what it means. On page 28 the author assumes that astronomers are not as much interested in correct tables as they ought to be. We are sure he does not understand the facts, or he would not have made such a statement. At the bottom of the same page he says "the corrected tables, as seen below, make this eclipse (B. C. 481, April 19) to have taken place at nine minutes past six in the morning of April 19." The computation on page 30 gives that as the time of conjunction, but parallax is left out, and that alone would accelerate the eclipse by about two hours; the middle of an eclipse has a very loose connection with the time of conjunction. We have not space to pursue this study further except to call attention to a few more points:

P. 45, first paragraph, same error as before noted. Second paragraph the contrary is proved from that assumed. In the third paragraph the point claimed does not seem to us to be established by the Bible reference.

P. 47, the same reference unsatisfactory.

P. 49, same error as before noted.

P. 55, assumption in first paragraph unwarranted.

P. 56, the admission of the second paragraph is fatal.

In reading fifty pages we find what seems to us grievous errors numbering more than a score. Now we are sorry to find such a piece of work coming from the pen of a man whom good people, who know him, would gladly trust as an author, especially since another scholarly man of wide reputation has given added currency to this book by his explicit endorsement of it. True men ought to be more careful and not allow themselves to be caught in this way.

ONE LIFE; ONE LAW. By Mrs. Myron Reed, New York; John W. Lovell Company, 150 Worth Street, Corner Mission Place. pp. 223.

This is chiefly a book that deals with science, philosophy and religion. It has scarcely nothing to say about astronomy, and hence what we shall have to say of it must be in general terms through the eyes and mind of a layman, especially in regard to philosophy and religion and some of the sciences upon which it draws for its materials.

This book is divided into ten chapters with the following titles: The Word Spoken with Authority, The Power of Spirit, The Law of Natural Selection, Variations Under Four Heads: (1) The Struggle for Existence, (2) Inheritance, (3) Use and Disuse, (4) Surroundings; The Readiness for the New Kingdom, The Laws of the New Kingdom, The Character of Job and Prayer.

The first chapter sets out the principle of love and the authority that goes with it, and closes with the statement that *God is spirit, and spirit is all.* In the second chapter the power of the Spirit is spoken of, and the statement is made that "every obedient child goes through three distinct processes in his spiritual growth." At first, he recognizes in some measure the spirit he is of. This is the new birth which is a birth of consciousness. Then he enquires, 'What is God?' This question is in the province of philosophy, and here he must look for its answer. Having received one, he can not be sure of its authority, and asks, 'How can I prove that these things are true?" For answer he is directed to science, and in her domain he finds that GOD is divine principle working always by law."

We are not sure that we have the author's meaning in regard to what the new birth is. If by the new birth is meant the origin of consciousness as said on page 27, then certainly the Bible idea of this state of the human soul is a very different one, and wholly incompatible with it. If God is only Divine Principle, as we commonly use the word principle, then God is not a person; neither is there a personal agent acting as a cause to produce the new birth as an affect. That means that the whole question of sin, as understood in common Christian doctrine is at once read out of man's nature and all the wickedness of this life is not charged to the account of personal being at all. The consequences of such a belief are easily understood by those who believe in the cardinal doctrines of Christianity.

The chapter treating of the book of Job is just what might be expected from the views mentioned in previous ones. The book is treated as an epic poem, and the statement is made that "probably no Bible student of this day believes that a man by the name of Job ever lived in a land bearing the name of Uz." If we understand the expressed views of every leading evangelist of to-day that we know of, including D. L. Moody, that is exactly what they believe. Every believer in plenary inspiration, as it is called, must hold such views, and they do most conscientiously.

In the last chapter the need and office of prayer are not, as it appears to us, stated in such a way as to be consistent with previous positions. We have not space to speak of this at length. As a whole, the book is a neat specimen of the printers' art, and we wish as much could be said of the writer's part of it.

Upward Steps of Seventy Years. By Giles B. Stebbins. Publishers, Messrs; John A. Lovell Company, 142 to 150 Worth Street, New York City. pp. 308.

This book is autobiographic, biographic and historic. As a whole it is well written, and mingles, in rather pleasing way, the three-fold features of its story especially in its earlier chapters, barely intimating certain views entertained by the author which become more pronounced in the later ones. The reader is given to understand that Unitarianism and Universalism were the doctrines that brought broad, free ideas to the people who were under the narrow bondage of Puritanism, and on page 43 this sentence occurs: "Thus it became possible for Theodore Parker to stand before the largest Protestant audiences in Boston and preach in Music Hall for years, saying frankly and manfully that the Bible was a human book, valuable but fallible—to be judged by our reason, but never to be set up as authority over us. To-day liberal ministers, especially Unitarians, begin to take the same ground, and many of the people are in advance of most of the clergy." After finding such statments as the above, we are not surprised to find the author later avowing the belief of spiritualism, and treating its modern manifestations as a glorious and inspiring reform. Of course, the true believer has no controversy with such views. He pities the poor mortal who does not know any better than to put evil for good and light for darkness. A true Christian knows and constantly warns such deceived teachers of the consequences that will inevitably follow such a course. When we opened this book we hoped to find something better than we had found in some other books recently received; but in this we are disappointed. The book is wrongly titled.

THE SIDEREAL MESSENGER.

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 10, NO. 3. MARCH, 1891. WHOLE NO. 93

HOW TO MAKE GOOD MERIDIAN OBSERVATIONS.

TRUMAN HENRY SAFFORD.*

FOR THE MESSENGER.

FIRST ARTICLE.

Photography has been so perfected, that, as I have elsewhere shown, it has rendered needless for the future a good deal of the meridian observing like that done in the past; and especially needless such observations as have been hurriedly done owing to the existence of many stars very close to one another. For where the stars are most crowded it is easiest to take accurate photographs, and the zero points needed for the plates can be obtained quite as much at leisure as in other parts of the heavens. A plate of 2° 10′ square will, in such a crowded part of the sky, contain more stars easily reached by a meridian circle of moderate size, and a better selection of them, as to convenience in observing, can be more readily made. For example, on the plate whose center would be the Trapezium in the Orion nebula, there are fourteen stars of the seventh magnitude or brighter, and about twenty-four of the eighteenth. But, on the other hand, the observations to be so made must be thoroughly accurate. Immense improvements have been made within half a century, both in instruments and observing; and work which in 1840 was quite of standard character is now far inferior to the best that can be done. How then shall astronomers bring their work of this kind up to the very highest degree of perfection? I venture to offer some suggestions, derived from at least forty years' experience; first as pupil, then as assistant, and finally in charge of meridian instruments of the first quality; during some years also as

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* Williams College, Williamstown, Mass.

geographical astronomer using portable transits of various degrees of excellence.

The first series of suggestions I have to make refer to the Observatory. The best, in theory, for success, is a mere tent or hut; and for winter it is better to employ as simple a shelter as possible, so that, all things considered, an Observatory for permanent meridian instruments should not have too thick walls. A house with a strong wrought iron frame, covered with corrugated or galvanized iron, like the Field Memorial Observatory at Williamstown, is both strong enough not to be swayed by the high winds, and thin enough to permit of a free circulation of air and equalization of temperature; so that I have far better seeing here than I used to enjoy at Harvard College Observatory from 1850 to 1866. It is, of course, needful to have wide slits from north to south, and to ventilate the transit rooms very thoroughly before beginning to observe. The width of slit should be not less than three feet, or a meter for an ordinary meridian circle; the room should be spacious enough to prevent too large an effect of temperature changes on the metallic parts of the instrument.

The instrument itself, whether transit, vertical circle, or meridian circle, should have the solidity of modern mechanical engineering. When machinery was not so highly developed as it is now, the instruments of astronomy were awkwardly and unsymmetrically constructed; and a good many traditions of that time still survive among the inexperienced instrument makers. Nor have the attempts to apply machine work to astronomical instrument making always been perfectly successful. The last touches given by skillful hand-work to the various parts of the instrument are the thing which renders it fit for the most delicate observations. Artists like the successive heads of the firm of Repsold & Sons do as much for the perfection of observations as the observers themselves.

There are a number of special points about the best modern meridian instruments which are noteworthy. The object-glasses are made as perfect as possible, so that the center of the image shall be symmetrically placed; or, technically, the collimation shall be the same for bright and faint stars. The illumination of the field is effected through a small mirror cemented on the inside of the object-glass; a method which assures the identity of collimation by day and night, and diminishes certain ocular illusions as to the real place of the image of the wires; the circles are made small, so as to be free from flexure; the errors of division, in spite of this, are minimized by high microscopic power, both in the construction of the circle itself and the image of its lines in the reading microscopes; the division-lines are made very numerous (1 to 2′), so that any one star can be observed with reference to several of them in succession; the focal length of the telescope is shortened so that the flexure of the tube shall be small; and for the same purpose the materials of the tube, and its proportions, are most carefully studied and worked out.

The pivots are made glass-hard, and so highly polished that they have the feel of velvet. A careful scrutiny of a list of over one hundred meridian circles about which I know something, shows that about one-half are old enough to need radical rebuilding; those which are modern enough for observations of great precision have not in all cases the very latest improvements.

The observer who is to do meridian work of the highest excellence must have training and experience; must be orderly and regular in his method, not allow himself to be hurried or get nervous, but time his work carefully to avoid this; he must hasten rather slowly; must know when the seeing is too bad for precise observation, and discontinue working at that point; must look carefully to the ventilation of his transit-room, see that everything is in precise working order.

Above all he must watch over himself as to physical condition. One of the greatest drawbacks, aside from mere mistakes, to the best work is the variability of personal equation, which is most irregularly affected by bad seeing and by hurry; and is liable to injurious fluctuations between bright and faint objects.

A good clock is necessary, but as one will readily see, the best watchmaker's regulators in market are more severely tested in their commercial use than in the Observatory. For here they are only required to run uniformly for a few hours; in their ordinary use they are expected to keep good time over several days. I assume, however, that the astronomer is not observing for a fundamental catalogue. The chronograph needs, of course, to be well made, but as its use is only to count seconds and divide them accurately, a comparatively simple telegraphic register can do the work, although less conveniently than an expensive cylinder instrument. Fillet chronographs are largely used by European astronomers.

PERSONAL ERROR IN OBSERVATIONS OF POSITION ANGLE.

F. P. LEAVENWORTH.

FOR THE MESSENGER.

My attention was called to this subject, while working on stellar parallax, by finding large errors in my measures of the double star South 503. In order to see whether the trouble was due to personal error I began a series of measures on this and other stars. A night's observation of position angle consisted of two or more measures in each of three positions of the eyes. The "normal" observation was made with the head so inclined to the right or left that a line through the stars was at right angles to a line through the eyes. The "parallel" observation was made with the line through the stars parallel to the line through the eyes. The "horizontal" observation was made with head erect and line through eyes parallel to the horizon. When the three observations were made in the above order the micrometer was rotated one hundred and eighty degrees and the observations repeated, only in the opposite order; so that the mean of the times of observation should be the same for each position of the eye.

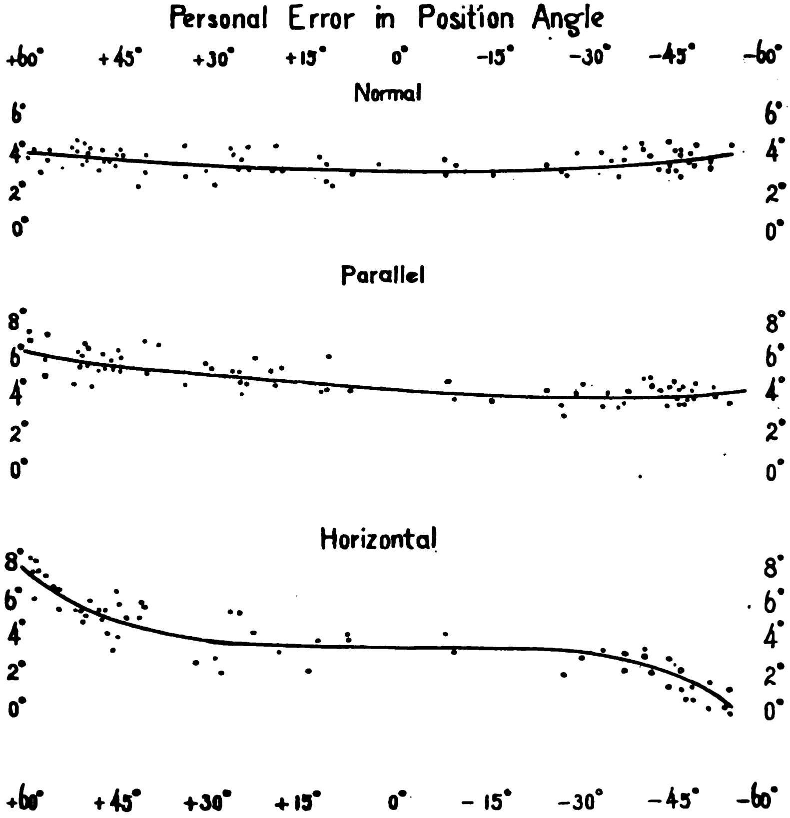
About sixty observations were obtained at various hour angles.

I have corrected these angles for refraction and proper motion, and drawn through the plotted positions a smooth curve, as shown in the accompanying diagram. The right and left co-ordinate is the angle with the vertical, or is the complement of the angle which the line through the stars makes with the line through the eyes when "horizontal." The up and down co-ordinate is the observed position angle corrected for refraction and proper motion.

I have found the following empirical formulæ will satisfy the observations within the limits of accidental error.

$$Pn = +\ 3^\circ.3 + 4^\circ.0 \sin^2 \tfrac{1}{2}\, q.$$
$$Pp = +\ 4\ .0 + 5\ .7 \sin^2 \tfrac{1}{2}(q + 25^\circ).$$
$$Ph = +\ 3\ .7 + 13 \left(\frac{q}{90}\right)^3$$

where q is the angle with the vertical.



Another series of observations on Σ 2180 shows scarcely any evidences of personal error.

The positions of the stars are for 1890.

	α	δ	P	Δ	
S 503	$5^h\ 50^m$	$+\ 13^\circ\ 56'$	4°	3.5″	$7.0^m - 8.5^m$
Σ 2180	$17^h\ 26^m$	$+\ 51^\circ\ 0'$	264°	3.0″	$7.0^m - 7.2^m$

It follows from the above results with some degree of probability, that "normal" and "parallel" observations are in a great measure free from the variable part of personal error, are but little injured by the twisting of the neck, and are therefore better observations than those made "horizontal." Also, there is no doubt that personal error is different with different stars.

Haverford College Observatory, Haverford, Pa.

γ ANDROMEDÆ.

S. W. BURNHAM.*

FOR THE MESSENGER.

As something has been said heretofore in this journal concerning the distance and visibility of the close pair of γ Andromedæ, the following observations with the 36-inch telescope may be of some interest:

B AND C.

1890.526	Elongation doubtful with 1900. Distance much less than 0″.1.
1890.573	Seems to be slightly elongated in 304°.6. Distance decidedly less than 0″.1.
1890.594	Elongation, if any, too uncertain to measure with the highest power.
1890.660	Tried with all powers, and the elongation, if any exists, is so slight that any attempted measure would have no value. Seeing magnificent, and the star nearly in the zenith.

To one who is familiar with the separating power of the large telescope, this means that the distance between the stars cannot exceed much, if any, 0″.05. Evidently large telescopes will have to wait a few years longer before they will be able to deal with this pair. It will probably be useless to attempt to do anything within the next three or four years, as the closing up has been very gradual.

It is impossible to tell anything, even approximately about the period of this binary from the measures already made; but a single set of measures when this pair can be observed again, will certainly give all that is required for a preliminary orbit. The path described by that time will probably make at least 180° since the first measures of OΣ

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* Lick Observatory, California.

in 1842. The period is certainly long and for that reason this pair will hardly be regarded hereafter as specially interesting.

PHENOMENA OBSERVED UPON SATURN AT THE TIME OF THE PASSAGE OF THE SUN AND OF THE EARTH THROUGH THE PLANE OF ITS RINGS, IN 1877-1878.*

M TROUVELOT.

Calculation shows that in order that the protuberant belt of the ring B, which we have supposed to be 6,000*km* from the exterior edge of that ring, should be able to cast a shadow which reached, Jan. 25, 1878, to the one that the ball casts on the ring, its crest must have been elevated to nearly 400*km* above the plane of the rings. Supposing all this to be true there was then a zone of 400*km* of elevation existing at that period on the northern surface of the ring B.

If we assume that the opposite surfaces are nearly symmetrical, as our observations of 1872 to 1889, made on the northern and southern surfaces, seem to authorize us to do, it will be necessary to double this number to obtain the total depth of the protuberant zone of the ring B, and call it 800*km*. Now 800*km* is a considerable thickness if one compares it with that given by other observers, but the observations which we have just made known will scarcely permit us to reduce it. If the protuberant zone of the ring B is 800*km* in depth, this entire thickness would not be visible from the earth except at very rare and short intervals. In fact, since the protuberant part is not found on the exterior border of the ring A, but is situated at 25,600*km* from it on the ring B, the result is that most of the time half of this protuberant zone is invisible from the earth, either because it is hidden from our sight by the interposition of the ring A, or because it is on the obscure side and is hidden by the darkness.

The entire thickness of the protuberant zones north and south could scarcely be seen except when the sun and the earth cross the plane of the rings at the same time or at

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*Continued from page 82.

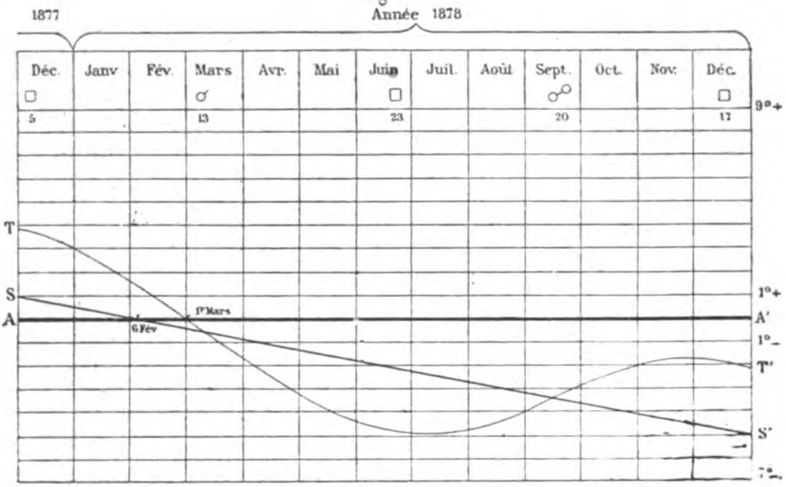
very nearly the same time; and also it is necessary for this that these passages should take place near the date of the opposition of Saturn; for, if they should occur near the conjunction it would hardly be possible to observe such delicate phenomena, because of proximity of the sun and of the horizon. The phenomenon in question then, presents itself very rarely, so that we never see much more than half of the protuberant zone of the ring B. Practically then we must reduce its thickness to 400*km*. Now, 400*km* equal 248.6 miles a number in perfect accord with Herschel's estimate; he gave to the ring a thickness of 250 miles. It is true that G. Bond believed the thickness of the ring to be very much less, since he estimated it at less than 40 miles, only 64*km*. This thickness might possibly belong to the ring A, though we think it too much when we remember that this ring is sometimes so thin that it becomes transparent, as seems to be shown by our observations of Nov. 21—Dec. 6, 1880, which we have spoken of elsewhere. (*Bulletin Astronomique*, t. I. p 530, 1884.) But Bond, who did not know that Saturn's system of rings is not flat, and that it is at quite a long distance from the edge that it reaches its maximum thickness, could not arrive at a valuation of this thickness anything but erroneous and too small. Besides, it is very doubtful that Bond has ever seen the illuminated edge of the ring A, and consequently that he has ever been able to estimate its thickness. In fact that which he calls "edge of the ring" evidently is not the outer edge of this ring. First, because the luminous thread which he names thus did not form a continuous line and one of uniform thickness, but was, on the contrary, always interrupted and formed of lines and points differing in brightness; and also, because it did not occupy the place which belonged to the outer edge of the ring A. In fact the outer edge of this ring if it had been visible should appear as an uninterrupted luminous thread; and this thread should have been found exactly at the place opposite where Bond observed it. From April 22 to Sept. 3, 1848, he observed this thread of light above, *i. e.* to the south of the dark band which crossed the ball, while the edge of the ring A presented to the observer was below, or to the north of this band. From Sept. 13, 1848, to June 19, 1849, it was below, *i. e.* north of the dark band that he observed the thread of light which he so often calls "edge of the ring," while it was above, or to the south, that the outer edge of the ring A then was.

And yet Bond was not deceived as is shown clearly by his observation of Nov. 3, 1848, when he says: "The interruptions in the light of the ring are so plainly seen that no one could for a moment hesitate as to their explanation, *namely the light reflected from the inner edges*" (Annals of the Harvard College Observatory, Vol. II, part I, p. 31.) The estimate of Bond, which rests upon erroneous data, can not agree with the system of rings and could not serve as an argument against the thickness which we have tried to deduce from the encroachment of the shadow on their surface. There is also another important consideration which has not escaped this distinguished observer, and which is opposed, so to speak, to so small a thickness; for with this, the medium density of the matter composing the rings must be three times greater than that which composes the globe. To satisfy this last objection it would be necessary for the ring to have a greater thickness.

In 1848, nevertheless, the conditions for measuring the total thickness of the rings were very favorable, for during nine days, Sept. 3 to 12, the protuberant part which we claim to have recognized must have presented itself nearly in front of the earth. Also Bond, who, it would seem, observed it without suspecting it, was surprised at its brightness which was such that the ring was visible even with a telescope of 3-inch aperture. The 12th, after midnight, he made the remark that since Sept. 3 the brightness of the ring was almost too great to be compared with what it was before that date. According to the same observer, the black band which crossed the planet before Sept. 3 was, after that date, replaced by a brilliant belt which remained visible until the 12th, and which the 13th had disappeared and was replaced by a dark band as before.

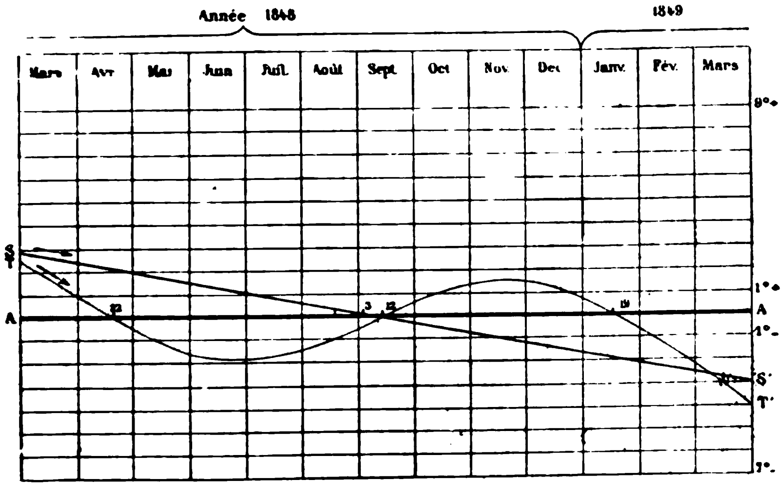
The brilliant belt which appeared so suddenly Sept. 3, and which disappeared with the same suddenness the 13, could not be attributed to the illuminated surface of the ring as Bond thought; for, if it had been so, it seems that it would have been gradually diminishing in size and at the same time in brightness, since the earth approached this surface rapidly and the angle that it subtended, supposing the surface to be flat, diminished proportionately to the lowering of our globe, whose height, which was —0° 21′.1 the 3d of Sept., was reduced to 0° 0′ the 13th. Now, since according to the observation this zone was as large and as brilliant on the 10th and 12th of September as it was the 3d, we may be allowed to think that Bond's observations concerned the protuberant zone of the ring B and not the light reflected by the southern surface of the ring. This is the zone that ought to have been measured to obtain the thickness of the ring.

Fig. 1



In the following passages of 1861-1862, Saturn was not situated under favorable conditions for presenting at the same time its two protuberant zones to the sun and to the earth, nor for permitting anyone to observe the encroachment of the lighted part by the shadow of this zone, the passage of the sun through the plane of the rings taking place toward the quadrature (fig. 6) when the earth was almost 3° above the ring. In 1878 it was almost the same; neither were the conditions favorable, the passage of the earth through the plane of the rings taking place a few days before the conjunction, when Saturn was so near the sun and the horizon that one could, with difficulty, see the planet, enveloped as it was in solar rays and the vapors of the horizon. (Fig. 1).

The protuberant zone, which, with the sun, is the cause of the phenomena of which we have just been speaking, was naturally suggested to us by the deviations which have so often been seen on the borders of the shadow of the globe cast on the ring B. But, although it easily explains the deviations of the shadow and of the gradual invasion of the lighted part of the rings, and though we are convinced of its existence, yet we ought not to pretend, as we have already intimated, that this explanation does not present very serious objections to which it is not easy to reply with our present actual knowledge. In fact if it is true that very oblique solar rays are intercepted by a protuberant zone situated near Cassini's division one does not see why the interior face of this zone which is turned toward the sun and toward the earth, as well as the anterior surface of the ring A, equally exposed to the sun and to the observer, should not be visible. Now, our observations have revealed nothing to us on this subject. From Oct. 6, 1877, to Feb. 5, 1878, we did not perceive the slightest trace of the narrow thread of light which theoretically ought to have stretched from the eastern to the western extremity of the ring A, nor of the slight swelling of shorter length which the protuberant zone ought to produce. To what must we attribute

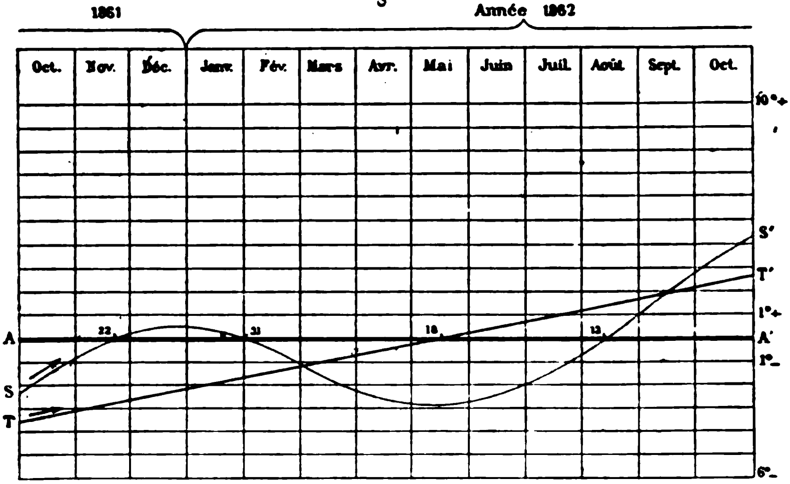


Orbite apparente du Soleil et de la Terre par rapport au plan des anneaux.

this anomaly? For it seems very certain that the ring B carried a shadow on its other parts. The luminous thread which, theoretically, ought to exist, was it too slender to be recognized with our instrument? It would seem not. Or must we attribute its invisibility to an unknown cause? Perhaps the observations of 1891 will bring us some light on this subject.

Herschel and Dawes, struggling, it would seem, with the same difficulties, both arrived at this conclusion, which may seem extraordinary, "that there are very strong reasons to induce us to think that the edge of the ring is of such a nature as not to reflect much light." We have shown that Bond, in 1848, never saw a trace of the edge of this same ring, any more than we did in 1878. It is scarcely admissable, however, that the materials which compose the edges of this ring and of this protuberant zone should be destitute of the power of reflecting light, especially when we know that the protuberant zone is precisely the most brilliant of all the system when we observe it under other conditions, when the sun and the earth are more elevated above its surface. There certainly is a mystery here to be explained.

Fig. 6



III. *Under a great solar obliquity Cassini's division becomes more visible at one end than at the other.*

If it is true that there exists a protuberant zone of a certain elevation, near the outer edge of the ring B, as our observations have led us to suppose, the result will be not only that, under a very oblique sun, the anterior half of this zone will cast a shadow on the part of the rings situated behind it with relation to the sun; but also that the posterior half of this same zone, of which a part passes behind the globe, will also cast a shadow behind it, that is to say, on Ring A. Only, because of the slight opening and the apparent narrowness of this ring when the sun is a little elevated, the shadow cast on the ring A will be much more difficult to observe than that which is due to the larger anterior zone, especially that before being recognized it will have crossed the dark gap of the division of Cassini.

A phenomenon which seems to have a direct relation to what we have just said, and which we may attribute to this cause, has been revealed to us by our observations. In fact, when the angle of the elevation of the sun above the ring was only + 0° 45′, until the day when it was not more than + 0° 27′, the division of Cassini which, up to the first date always appeared to us to have an equal intensity on the opposite ends, became much more apparent on the eastern end than on the western. On Dec. 18, 25, 26, 27, 28 and 29, 1877, the phenomenon was observed with certainty, and seemed to accentuate itself from day to day. It was again observed Jan. 6, 1878, and did not cease to be visible until the encroaching shadow of which we have spoken reached the division of Cassini and made it disappear. It seemed that the outer edge of the ring B cast a shadow on the posterior part of the ring A, which reached out a little to the northeast, toward the extremity of the ring B, which it made to stand out, and rendered it much more visible than on the opposite end. It is precisely on the eastern end, the most distant from the sun, that the phenomenon was observed, and a few days after the quadrature, when the shadow of the ball on the rings reached its greatest size.

(To be Continued.)

A FURTHER NOTE ON METEOR RADIANTS.

BY W. H. S. MONCK.*

FOR THE MESSENGER.

I desire to correct a misapprehension into which some persons appear to have fallen as to my arrangement of the Meteor Radiants comprised in Mr. Denning's (or any other) Catalogue in order of Right Ascension. I did not mean to assert that wherever meteors are found to emanate from the same radiant point at different periods of the year we have a stationary or long enduring radiant. Among a large number of radiants there will no doubt be a certain number of coincidences in direction between showers having no connection with each other. What I asserted, and what I think a short examination of Mr. Denning's Catalogue (or almost any other catalogue containing a sufficient number of radiants) will show is that the number of coincidences is vastly too great to be the result of chance, and that therefore the connection between different showers coming from the same point at different dates is in the great majority of instances the result of law. It is idle to urge against this conclusion that there are certain diversities between these different showers—that, for instance, some are fast and some are slow. These very diversities are themselves the result of law, and of a law which I have already indicated, viz; meteors from the same radiant are faster or slower according as the earth is receding from or approaching the radiant in its annual motion.

I have already given the arrangement of Mr. Denning's radiants in order of right ascension for the second quadrant. I now give a table arranging them similarly for the other three quadrants. I have underlined the cases in which meteors from the same radiant are found at intervals of over a month. As I have confined this underlining to the cases where the radiants are strictly the same it does not afford a complete index to the stationary radiants deducible from the catalogue, but I think any one who will go through the catalogue (in the *Monthly Notices* of the Royal Astronomical Society for May, 1890) in the order defined in this article will entertain no doubt as to the existence of stationary or long-enduring radiants however they are to be explained.

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* Dublin, Ireland.

One explanation I may here suggest, though I do not think it a probable one, viz: that of *families* of comets—comets having a different longitude of the node but nearly the same radiant. This is the only form in which I think the cometary theory can possibly explain the phenomena.

First Quadrant (0° to 90° R. A. in order of R. A.) Nos. 392, 522, 476. 334, 248, 188. 492, 335. 185, 293, 465. 561, 529, 412, 456, 431, 193, 218, 419, 219, 758. 420, 210, 250, 286, 356, 199, 574, 294, 318, 620, 259, 200, 277, 584, 666. 221, 384, 631, 336, 369, 457. 251. 357. 319, 519, 400, 375. 715, 295, 211, 287, 296, 530, 643, 551, 597, 564, 649, 236, 458. 585, 493. 747, 260, 244. 337, 744, 226, 288. 544, 562, 521, 149, 320. 237. 667. 261, 180, 837, 652, 278, 826, 401, 626, 393. 385, 305, 668, 441, 819, 809, 411, 669, 740. 238, 240, 531, 602, 623, 321, 813, 466, 442. 726, 262, 829. 838. 252, 201, 253, 488, 870, 557. 754. 818, 254. 644, 748, 322. 532. 567 582, 632, 467, 279, 627, 653. 289. 377. 628, 568, 670, 851. 331. 587, 280, 735. 323. 604, 443. 633. 264. 265, 290, 650, 266, 514, 311, 267, 702. 586, 297, 312, 202, 306, 827, 324, 695, 736, 421, 313. 755. 654. 338, 655, 565. 171, 317. 339. 422, 489, 729, 558, 839, 341, 351, 340, 645. 332, 634. 329, 359 A, 358. 721. 575. 730. 731, 281, 444, 342, 353. 362, 298, 361, 656, 360, 354, 830, 847. 365, 363. 359 B, 364. 708. 709, 366, 370, 745, 766, 515, 299, 671, 480, 413, 343. 445, 371, 355. 629, 635, 710, 906, 45, 231. 545. 621. 372, 893, 737, 820. 246. 325. 767, 533, 394, 598, 373. 378, 657, 499, 534. 300, 386. 546. 523, 379. 234, 388. 387, 395, 494. 793, 524, 821, 423, 624. 716. 732, 552, 7, 749. 753, 768, 547. 576, 733, 446, 784, 525, 738, 495, 831, 503, 380, 840, 459, 402, 724, 35. 500, 548. 841. 636, 403. 504, 535, 569, 777, 496, 741, 432, 742, 759. 798, 760, 447, 505, 468, 483, 511, 553. 822, 696. 577, 746, 554, 832, 778, 307, 344, 799, 555. 526, 833, 301, 448, 367, 477, 672. 769, 433. 856. 497, 711, 673. 9. 516. 536. 549. 506, 424, 606, 785. 520, 578. 637, 469, 563. 599. 717, 241, 473. 527. 658, 794. 571, 570, 761, 638, 750, 898, 537. 823, 802, 674, 810, 852, 885. 795, 639, 857, 779. 890, 572, 858, 842, 528. 706, 640, 12, 685, 800, 498, 579, 517, 550, 600. 863, 588. 646, 573. 559, 538. 697, 859.

Third Quadrant, 180° to 270°, Nos. 32, 807, 41, 70, 901, 56, 836, 616, 883, 95, 47. 118, 59. 791, 845. 846, 776, 566, 651, 65, 910. 848, 793. 896, 178, 886, 808, 792, 897, 874. 115. 902, 66, 30, 816, 867, 20, 14, 67. 37, 21, 34, 828, 77, 33, 73. 173. 725, 683, 868, 381, 78, 49. 903. 136, 177, 16, 887, 28, 501, 96, 15, 888, 1, 884, 116. 611. 29, 71, 97, 79, 131, 6, 5, 62, 98, 889, 64, 2, 869, 74, 139, 913, 8, 132, 42, 99, 38. 80, 81, 172, 127, 68, 125. 100, 414, 484. 137, 50, 189, 17, 904, 22, 51, 101, 160, 57, 485, 26. 425, 617, 133, 82, 123, 212. 83, 141. 126, 154, 282, 222, 84, 72, 23, 124, 508, 245. 255, 39, 153, 27, 140, 155, 630. 43. 52, 283. 63, 117, 426, 449, 138, 147. 129, 75. 434, 191. 509, 85, 227. 161, 86, 88, 102, 87, 284.

Fourth Quadrant 270° to 360°, Nos. 162, 203, 213, 596, 103, 256, 119, 104, 105, 107, 106, 166, 247. 53. 111, 892, 54. 204, 168, 89, 194. 145, 112, 326, 183, 120. 257, 44, 158, 163, 217, 90, 108, 490, 91, 205. 461, 170, 195, 150, 214, 618, 314, 159, 435. 308, 404, 330, 407, 479. 580, 113. 914. 143, 176, 164, 164, 25, 206, 109, 374. 427, 415, 223, 235, 92, 110, 345. 242, 470, 121, 397, 167, 396, 165, 93, 179, 215, 196, 144, 151, 268, 224, 156, 619, 190, 486, 471, 390, 701, 416, 152, 184, 481, 269, 142, 510, 216, 228, 181, 94, 462, 436, 207, 346, 625, 55. 182, 694, 58, 232, 408, 405, 197, 450, 398, 309, 285, 134, 76. 451, 406, 391, 208, 11, 347, 348, 474, 452. 437. 475, 229, 382, 438, 439. 417, 303. 270, 512 A, 249, 310, 817, 429, 315. 225, 271, 186, 148, 330, 230, 472, 399, 512 B, 349. 243, 169, 581, 518,

304, 316, 273, 272, 135, 274, 209, 757, 429, 178, 612, 327, 275. 368, 350, 453, 187,
157, 409, 556, 130, 410, 491, 463, 192. 603, 430, 464. 198. 383, 440, 233, 276, 454.
328, 239, 418, 455, 582, 487, 174, 146, 258, 502, 684, 543, 583, 513.

Personally I am inclined to think that none of the coincidences which I have underlined are due to chance, but it would not affect my general argument if a dozen of them were so. With regard to the stationary or long-enduring character of both the Perseid and the Andromede radiants, the evidence contained in my former article can easily be extended. Mr. Denning's reduction of the Italian observations of 1872 gives perhaps the most conclusive evidence of the former. He found a radiant at 47° + 57° for the date of July 15–Aug. 2, at 44° + 56° for Aug. 6–12, at 45° + 57° for Aug. 24–Sept. 14, at 47° + 56° for Oct. 29–Nov. 13, and at 46° + 57° for Nov. 25–Dec. 31. The gaps in this list consist of the periods when there were too few observations to deduce any possible result; and Mr. Denning accordingly says, "Many of the showers endured apparently for much longer periods than is usually attributed to them. Thus the *Perseids* (or a succession of coincident radiants in *Perseus*), continued in feeble action during the whole of the last five months of the year." (*Monthly Notices*, for March, 1878, p. 316.) He seems, moreover, to have met with meteors from the Andromede radiant throughout the month of December and even in February. The stationary character of both radiants is thus strongly attested. But I am inclined to think that what really possesses this stationary or long-enduring character is a radiant area of considerable dimensions embracing most, if not all, of the positions which Mr. Denning ascribes to his shifting radiant. I doubt if there is a single radiant point in his catalogue which he characterizes as a *Perseid* from which meteors do not come to us at other times of the year. His first position at 3° + 49° on July 8 agrees with one of Schiaparelli's for July 31, and very nearly with Tupman's for August 20–29. His second position at 11° + 48° on July 11–14 agrees with one of his own (deduced from a large number of meteors) on July 31–Aug. 1, which Mr. Sawyer confirms. His third at 19° + 51° on July 19 agrees with one of Heis's for Aug. 1–2, and the remainder will, I think, be found similar in character. Not one of them ceases to be active as soon as the shifting radiant is supposed to have passed it, and some are active before the shifting radiant is supposed to reach them. The eastern portion of the radiant area becomes better placed for observation as the season advances, and hence presents an appearance of increased activity. I doubt if there is anything more, but I await the publication of the full evidence on which the shifting radiant theory is supposed to rest before discussing the question further. When the full evidence is published your readers will be able to form their own estimate of its conclusiveness.

A PERPETUAL CALENDAR,

R. W. McFARLAND.

FOR THE MESSENGER.

In the year 1848 I came into possession of a perpetual calendar, found in an old book, and copied it off for further examination. It was somewhat different from this, but really involved the same principle, but there was no hint of the way to construct it. But this was made manifest by the following procedure, which underlies all styles of perpetual calendar. Begin by setting down in tabular form, the new year days:

—Say 1891 began on Thursday.
1892 will begin on Friday.
1893 " " " Sunday.
1894 " " " Monday.
1895 " " " Tuesday.
1896 " " " Wednesday.
1897 " " " Friday.
1898 " " " Saturday.
1899 " " " Sunday.
1900 " " " Monday.

Trace a few years in reverse order:
1890 began on Wednesday.
1889 " " Tuesday.
1888 " " Sunday.
1887 " " Saturday.
1886 " " Friday.
1885 " " Thursday.
1884 " " Tuesday.
1883 " " Monday.
1882 " " Sunday.

In this way a whole century can, in a few moments be regularly arranged, and 15 or 20 centuries in a few hours. As a general rule each succeeding year begins one day later in the week; but the year following leap year goes forward two days—the 29th day of February being one of them. Suppose one has set down 20 centuries, say from 1500 to 3400 inclusive. The centesimal years fall into groups as follows:

Begin on Monday.	Begin on Saturday.	Begin on Friday.	Begin on Wednesday.
1500	1600	1700	1800
1900	2000	2100	2200
2300	2400	2500	2600
2700	2800	2900	3000
3100	3200	3300	3400

But here are 20 centuries and the centesimal years all begin on one of the four days given. No centesimal year, new style, ever began or ever will begin on Tuesday, Thursday or Sunday. The table may be extended indefinitely both forward and backward. In like manner commencing any where, say at 1800, let the new year's day for a century be gathered up in tabular form. Besides 1800, the following years also have Wednesday for new year's day (omitting the 18 for convenience), 6, 12, 17, 23, 34, 40, 45, 51, 62, 68, 73, 79, 90 and 96. Other groups begin on Thursday, Friday, etc.

Having every fourth year (old style) a leap year, the centesimal years will run through the whole week. If those beginning on Sunday be put in one column, those on Monday, in another, etc., there will be seven columns. But it is not necessary to repeat the rather tedious course of putting down the New Year's day for twenty centuries. The following course is short and simple. It is seen above that 1800 began on Wednesday, but in January of that year the difference between old style and new was eleven days, old style lagging behind. Then count forward eleven days from Wednesday, and you find Sunday for Jan. 1, 1800, old style. In like manner 1700 began on Friday, new style; but the old style on that day was ten days behind—add ten days to Friday—and you reach Monday. So 1600 began on Saturday, new style, and then the difference was ten days; count forward ten from Saturday, and you reach Tuesday for old style. Bringing the years together we find

1600 begins on Tuesday, old style,
1700 " Monday, "
1800 " Sunday, "

1900 will be Saturday, each centesimal year in order falling one day earlier in the week,—so that twenty centuries may be set down in a few minutes.

In order to bring both styles into the same table a sliding to the right is made of one day for each of the centesimal years which are common years. But they are properly arranged in the general table given below. The days of the week, the days of the month, and the months themselves are arranged in due order, making the calendar complete for both styles and for all time.

About the year 1859 some one who had seen the old calendar above spoken of, or who had made an independent investigation of the subject, wrapped the table round a cylinder, and with a movable collar containing the days of the week and the twelve months, took out a patent as I have heard. The cylinder is by far the most convenient form, but it is not on the market, and so far as I now remember it was sold only at private sale by its originator.

	Old Style.	*New Style.*			
4 9 15 20 26 **32** 37 43 48 54 **60** 65 71 76 82 **88** 93 99	600 1300 2000 2700 etc.		1, 8, 15, 22, 29.	Sun.	Jan., Oct.
3 8 14 **20** 25 31 36 42 **48** 53 59 64 70 **76** 81 87 92 98	700 1400 2100 2800 etc.	1700 2100 2500 etc.	2, 9, 16, 23, 30.	Mon.	May.
2 **8** 13 19 24 30 **36** 41 47 52 58 **64** 69 75 80 86 **92** 97	100 800 1500 2200 2900 etc.		3, 10, 17, 24, 31.	Tues.	August.
1 7 12 18 **24** 29 35 40 46 **52** 57 63 68 74 **80** 85 91 96	200 900 1600 2300 3000 etc.	*1800* 2200 2600 etc.	4, 11, 18, 25.	Wed.	Feb., Mar., Nov.
0 6 **12** 17 23 28 34 **40** 45 51 56 62 **68** 73 79 84 90 **96**	300 1000 1700 2400 3100 etc.		5, 12, 19, 26.	Thur.	June.
0 5 11 16 22 **28** 33 39 44 50 **56** 61 67 72 78 **84** 89 95	400 1100 1800 2500 3200 etc.	1500 1900 2300 2700 etc.	6, 13, 20, 27.	Fri.	Sept., Dec.
4 10 **16** 21 27 32 38 **44** 49 55 60 66 **72** 77 83 88 94	500 1200 1900 2600 3300 etc.	1600 2000 2400 2800 etc.	7, 14, 21, 28.	Sat.	April, July.

MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, JAN. 31, 1891.

The society met for probably the last time in their rooms at 408 California street, their new quarters in the California Academy of Sciences' new building not being quite ready for occupancy. In the absence of President Holden, Vice-President Pierson presided.

At the meeting of the directors the minutes of the last meeting were approved. The following gentlemen and ladies were elected to membership:

H. C. Swain, 1107 Post street; N. A. Robinson, 430 Kearney street; Miss Harriette C. Butler, 1909 Pine street; Miss Josephine Harker, 1909 Pine street; Charles H. Crocker; William S. Moses, Masonic Cemetery; Capt. Oliver Eldridge; Professor Gustav C. Lueben, 215 Geary street: I. E. Thayer, 204 Front street; Tully T. Young, 805 Pine street, of San Francisco; H. P. Carleton, 716 Nineteenth street; Miss Caroline C. Jackson, 1379 Eighth avenue (East Oakland); Rev. A. M. Le Veau, 809 Thirteenth street; F. G. Blinn, Highland Park (East Oakland), of Oakland, Cal.; Profeseor C. W. Treat, S. E. Holden, Napa; A. Keith, Riverside; Daniel Appel, Cleveland, O.; O. E. Harmon, Chehalis, Wash.; Miss Sara Carr Upton, Washington, D. C.; Fraser Ashurst, Edward B. Reilley, Philadelphia, Pa.; Frank L. Smith, Oshkosh, Wis.; Charles A. Bacon, Director, Beloit, Wis.; Mrs. Mary H. Willmarth, Ruthven W. Pike (life member), Frank M. Smith, Gayton A. Douglas, Fred. Ellerman, Dr. H. W. Rogers, Rev. E. F. Williams, W. E. Hale, G. W. Hale, Dr. M. D. Ewell, Dr. H. H. Belfield, F. S. Osborne, C. O. Boring, D. H. Burnham, Norman B. Ream, Professor G. W. Hough, A. E. Adams, J. R. Steward, Mrs. Ruth W. Brewster, E. Burton Holmes, Chicago, Ill.; Professor C. B. Thwing, Professor C. S. Cook, Francis Bradley, Evanston, Ill.; A. C. Behr, Bloomington, Ill.; G. W. Ritchey, Engelwood, Ill.; A. W. Wagner, Joliet, Ill.; Rev. E. H. Rudd, D. D., Knoxville, Ill., H. A. Allen, Milwaukee, Wis.; Joseph Brook, Sydney, New South Wales; R. L. J. Ellery, E. J. White, F. R. A. S., Melbourne, Victoria.

A new section was added to the by-laws, authorizing groups of members of the society outside of San Francisco to form sections. The proceedings of the sections may be printed in the Publications of the society, and each section may elect their own officers and adopt their own rules of government. No person shall be eligible to membership in a section without being a member in good standing in the society.

Under the provisions of this amendment a Chicago section has effected an organization, and has elected officers and an executive committee as follows: G. A. Douglas, chairman; G. E. Hale, secretary, and R. W. Pike, C. B. Thwing, and M. D. Ewell. It was moved and carried "That the Chicago Section of the Astronomical Society of the Pacific is hereby authorized and duly recognized." The names of the members of the Chicago Section will be found in the list of members elected.

The directors adopted a seal for the society, a cut of which will be found in the next publication.

It was also resolved that, beginning with the present year, that all moneys received as life membership fees should be invested in a separate fund, and only the interest derived therefrom to be used in defraying the expenses of the society.

Messrs. Schaeberle and Burckhalter were re-appointed to serve on the Comet-Medal Committee for the year 1891.

The regular meeting was held immediately after the director's meeting and largely attended.

As the next meeting will be the annual meeting, a committee of three, consisting of Messrs. Ziel, Johnson and Leuschner, was appointed to audit the accounts of the treasurer, and Messrs. Von Gelden, Treat, Dewey, Ewer and Lowden were appointed as a committee on nominations for the next board of directors and committee on publications.

The following papers were presented to the meeting:

a. The Carleton College Observatory, by the director, Professor W. W. Payne.

b. The August Meteors, by W. H. S. Monck, Dublin, Ireland.

c. Corrections to Watson's Theoretical Astronomy, by W. W. Campbell, Ann Arbor, Mich.

d. Notes on Dark Transits of Jupiter's Satellites, by John Tebbutt, Windsor, N. S. W.

After reading of papers the meeting adjourned to March 28th, 1891. CHARLES BURCKHALTER, Secretary.

ASTRONOMY IN 1890.

The last year was one of as great activity in astronomy as any of its recent predecessors. Interest has been general in all the prominent lines of research. The study of the surface markings of the planets has been fruitful and has given some definite results of a surprising character. Special studies of the surface of Mars continued from 1889 through the favorable part of the opposition of 1890 confirm the discoveries of Schiaparelli in regard to the "canals" of Mars. A more favorable time for the study of the wonderful surface marking of this planet will be in the year 1892, when it will be much nearer the earth and in better position for observation in northern latitudes. Very general preparations will be made for exhaustive work one year hence, that some of the questions raised by the discoveries of Schiaparelli may be settled. On the surface of Jupiter, Mr. Keeler, of Lick Observatory, finds some spots in the great northern belt whose shape and color are significant. The cloud formation abóut the great red spot, as observed in October last by the aid of the great telescope, gives added data of unusual value. The most wonderful advance in knowledge, however, concerning the planets comes from the discoveries of Schiaparelli in regard to the rotation periods of the planets Mercury and Venus. The time of rotation of each of these planets has been believed to be about twenty-four hours, from earliest knowledge of surface markings. But the studies of 1889 and 1890 have definitely settled the point that the period of rotation in each case must be nearly the same as the time of revolution around the sun. At first thought it may seem very strange that astronomers should not have found out so important a fact as this long ago. Those only who try to observe these planets and fix upon definite surface features, know how difficult it is to make trustworthy observations on account of the strong sunlight reflected from their surfaces. Details are generally obliterated except a few prominent markings near the margin of the lighted portion of the planet's disc.

Thirteen new minor planets were discovered during the year 1890. The first, Glauke (No. 288), was found by Luther of Hamburg, Feb. 24, 1890. The remaining twelve were discovered by Charlois of Nice and Palisa of Vienna, each finding six. All the new asteroids of the year 1890 are yet without names except the first. The number of the latest discovery is 301 for last year. During the last month two later discoveries are reported and will be found elsewhere in this issue. They are probably new planets, and if so, will make the total number at this writing (February 23) 303.

The comets of the last year were seven in number. The last comet of 1889, discovered by Borrelly Dec. 12, properly belongs to the year 1890 because its perihelion passage was in January of that year. The following table gives the common data for discovery, the time of perihelion passage and the longitude of the ascending node denoted by the character ☊ :

Designation.	Synonym.	Date.	Perihelion.	☊		
				c	′	″
Comet 1890 I.	*f* 1889 (Borrelly).	Dec. 12	Jan. 26.869	12	16	00
Comet 1890 II.	*a* 1890 (Brooks).	Mar. 19	June 1.8414	320	26	08
Comet 1890 III.	*b* 1890 (Coggia).	July 18	July 8.730	14	25	36
Comet 1890 IV.	*e* 1890 (Zona).	Nov. 15	Ang. 7.10021	85	29	08
Comet 1890 V.	*d* 1890 (D'Arrest).	Oct. 6	Sep. 16	146	9	00
Comet 1890 VI.	*c* 1890 (Denning).	July 23	Sep. 24.2523	96	25	35
Comet 1890 VII.	*f* 1890 (Spitaler).	Nov. 16	Oct. 26.50833	45	07	51

A more complete statement of the special characteristics of these comets will be published soon, in connection with all the useful data known, by means of which astronomers may make further study of them for the permanent records of science for this year.

Work in the discovery of new nebulæ continues active by the aid of large telescopes in the hands of a few observers. Dr. R. Spitaler of Vienna, Messrs. Keeler and Barnard of Lick Observatory, Dr. L. Swift of Rochester, N. Y., and Professor Ormond Stone, Virginia. Dr. Swift's Eighth Catalogue of new nebulæ, containing one hundred each, was published in August, 1889. We have learned from private letters that he is already at work on the tenth catalogue, although we are not aware that the ninth has yet been published.

In the field of variable star work S. C. Chandler of Cambridge, Mass., and E. F. Sawyer of Brighton, Mass., are indefatigable workers. Mr. Chandler's Catalogue of Variable Stars published in 1888 was the most complete piece of work of the kind known to astronomy. During the last year a supplemental part to this first catalogue was published which largely extends the number of new variable stars and in other particulars improves our knowledge in this new branch of astronomy. Other observers of prominence are Paul S. Yendell of Dorchester, Mass., John G.

Hagen, S. J., Georgetown, Mass., and by the aid of photography especially the observers at Cambridge, Mass.

By means of the spectroscope and by the aid of photography some of the most wonderful results pertaining to variable stars and binary systems have been determined recently, so that now apparatus in these two lines of work is being called for and manufactured as never before.

The question whether or not the latitude of a given place changes has received considerable attention from prominent astronomers in different parts of the world during the year 1890. This question was started several years ago, and the more it is examined, the more need there seems to be for a thorough, systematic study of it, by competent observers favorably situated in different countries with facilities for definitive tests. Such work will probably be undertaken during the present year. The study of the question so far is unsatisfactory, because astronomers whose opinions are entitled to most weight do not agree. This state of things may not be the fault of the astronomers, but rather it may be due possibly to the want of sufficient data upon which to base a general judgment broad enough to include and to explain all known facts.

Some very important books on different themes in astronomy have been published during the last year. We can now name by title four of the most important ones that we have seen. The "Meteoritic Hypothesis," by J. Norman Lockyer, published by Messrs. Macmillan & Company. "The System of the Stars," by Agnes M. Clerkc, published by Messrs. Longmans, Green & Co.; "Die Spectralanalyse der Gestirne," by Dr. J. Scheiner, published by Wilhelm Engelmann, Leipsic, and "Tycho Brahe," by J. L. F. Dreyer, director of the Armagh Observatory, and published by Messrs. Adam and Charles Black, Edinburgh, Scotland.

THE SPECTER OF THE BROCKEN.

J. M. SCHAEBERLE.*

FOR THE MESSENGER.

The astronomers on Mt. Hamilton frequently have the opportunity of viewing their own shadows cast upon the fog

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* Astronomer at Lick Observatory.

when the sun is at a low altitude. Ordinarily the only phenomenon which is at all striking is the bright ring or halo of light in the center of which the apparently unenlarged shadow appears projected.

A short time ago, however, I was favored with the rare and truly imposing phenomenon of "The Specter of the Brocken." I was standing on the northwest corner of the Observatory grounds—in a fog through which the rays of the setting sun would, every now and then, find free passage — watching the phenomenon of the appearance and disappearance of my shadow in the fog which, apparently, completely filled the great cañon (out of which the northern slope of Mt. Hamilton rises quite abruptly) and hiding everything beyond. Suddenly the image seemed to grow to enormous proportions, and, in outline, it appeared to be standing on the familiar mountain which, on the other side of the cañon, rises to a height of more than a thousand feet, and distant from the Observatory about one mile. Nearly the whole of this mountain was now lit up by sunlight and visible through the fog (which was probably only a few yards from me) against which my shadow was projected. I raised my arm—the arm of the phantom image immediately stretched over an extent of familiar ground which from experience we know would require a good quarter of an hour to pass over on foot. While I was mentally trying to determine the scale of the image (which seemed to have a height much more than a thousand feet), it suddenly dwindled down to its natural size—the distant mountain was lost in the fog, and a few moments afterwards I was surrounded by the same envelope..

I very much regretted not having a camera with me at the time, as it would be interesting to know whether the same illusion would be reproduced on the photographic plate.

The psychological *modus operandi* of this particular case seems to be so simple that I suggest the following explanation:

The penumbral outline of the shadow cast by the sun is such that in assuming the outline to enclose a real object it becomes impossible to estimate the distance (and consequently the size) by means of the usual unconscious focal adjustment of the eyes. The subjective effect is such as to give nearly the same impression as would be produced by viewing a sharply defined distant object with the eyes focussed on a point in space but a few yards distant. The outlines of such an object would, of course, be blurred if viewed in this way, and there would be a constant tendency for the eyes to seek relief from the strain due to wrong focal adjustment. and such a sensation would most naturally be produced by the blurred outline of the actual shadow the moment a distant terrestrial object became visible in the same direction. The phantom image would at once be formed in the distant well known but dimly defined view, especially when, as in my case, one is not accustomed to seeing a human outline suspended in air over an immense cañon.

The scale of the phantom image will vary directly as the distance of the well known terrestrial object, and nearly inversely as the distance of the fog (shadow) from the observer.

I now venture to suggest that a somewhat similar explanation will account for the curious phenomenon which causes the moon to appear apparently much larger when rising or setting than it does when the altitude is considerable.

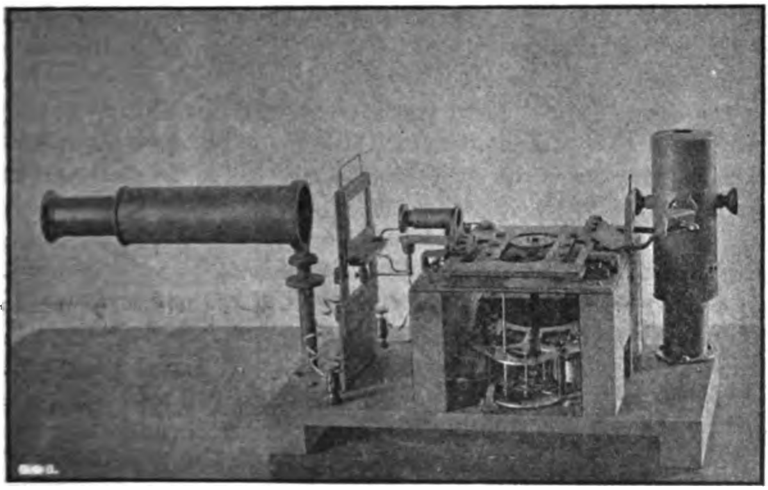
The outline of the moon is, of course, sharp and distinct, but, on account of insufficient illumination, terrestrial objects will apparently have more or less blurred or penumbral outlines, which tend to produce the subjective effect of causing these objects to be apparently so near that, compared with their usual distance, they appear to be out of focus for distinct vision. *The effect of apparently diminishing the known distance of terrestrial objects without increasing their angular magnitude, is, of course, such as to cause an apparent magnification of the moon's disc.*

When the moon is at a considerable altitude the direct comparison with distant terrestrial objects is not so readily made, but it is evident that on account of the increased illumination the outline of terrestrial objects will be much sharper, and, consequently they will appear to be more nearly in their normal positions.

Mt. Hamilton, Feb. 16, 1891.

A PERSONAL EQUATION MACHINE.

Doubtless most of our readers understand that, in noting the times of transit of a star across the lines of a transit instrument, all observers are liable to systematic as well as accidental errors. One observer will always note the time too early, another will always note it too late, and this difference between the true time and that which is observed is called personal equation. It frequently amounts to a considerable fraction of a second, even when a chronograph is used for recording the time, and it is not always the same with the same person. It varies with the physical condition of the observer, with the temperature, and, in some cases, with the apparent speed of the star across the field of the telescope; probably also with the brightness of the star, the illumination of the field of view, and the distinctness of the lines in the transit instrument.



One can easily see, therefore, how important it is, in the more delicate operations involving transits of stars, such as the determinations of longitude and of the fundamental right ascensions of stars, that there be an independent means of determining the absolute personal equation of each observer at the time when the observations are made.

The accompanying cut is a reproduction of a photograph of a personal equation machine recently constructed for Carleton College Observatory by Mr. E. Kahler, of Washington, D. C. It was designed by Professor J. R. Eastman, U. S. N., the first instrument having been constructed in 1875. It may be briefly described as an apparatus by which an artificial star is made to cross a reticule of lines corresponding to those in a transit instrument, alternating in direction from right to left and from left to right, automatically recording the time of transit of the artificial star across each line, and permitting the observer also to record the observed time of transit at the same time.

The light of the artificial star is produced by means of a lamp, shown at the right side of the cut. This light passes through a lens in the front of the lamp, then through a rectangular prism, turning a right angle to a diaphragm which is pierced with a small hole of any desired size, to represent a star of any magnitude. The ray of light thus transmitted passes across the top of the instrument through a sliding tube and lens, by means of which it is focussed upon a ground glass screen in contact with the reticule, seen in the center of the cut. The observer views the reticule and star through the tube at the left side of the cut. This tube contains no lenses, but may be adjusted to different lengths to suit different eyes. At the eye-end of the tube, a little 45° prism is placed on a lever, so that when desired it may be inserted in the line of sight in such a way that the star may be made to move apparently in any desired direction, enabling the observer to test the existence of an error depending on the direction of the star's motion.

The motive power is an ordinary clock movement which may be indistinctly seen in the cut. The minute's shaft is extended upward and carries at the top a pinion, the teeth of which have been cut away from a little more than half of the circumference. This pinion, turning between two racks, moves the frame carrying the diaphragm and lens, which produce the artificial star, alternately forward and backward. The seconds shaft is also extended so that fans of different sizes may be attached to it, regulating the motion of the artificial star to any desired speed.

In order to produce the automatic record, the wires of a chronograph circuit are connected, the one with the movable frame carrying the artificial star, the other with a fixed plate beneath the reticule. The under side of the fixed plate is of platinum and has a number of grooves corresponding to the lines of the reticule. The grooves are filled with shellac. An arm from the movable frame presses the point of an adjustable style against the under side of the fixed plate, thus closing the circuit with the chronograph except when the point of the style crosses the grooves. The observer makes his record by means of the observing key which is used in regular observations.

Several diaphragms are furnished with the instrument, so that we can represent stars of different magnitudes and also the planets. Several reticules also are furnished, with lines of different width and different intervals.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS

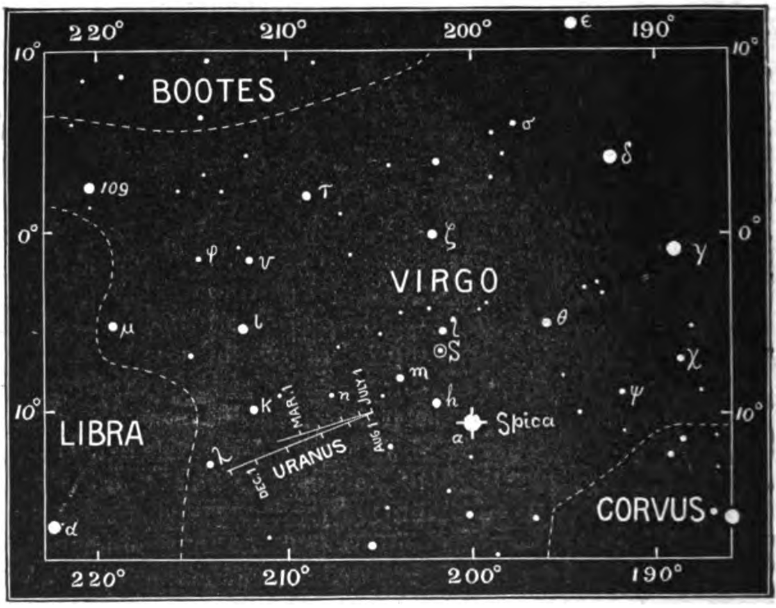
Mercury will be at superior conjunction March 23, so that during this month it will be hidden in the solar rays.

Venus is "morning star," rising about two hours earlier than the sun. She is now only a little more than half as brilliant as in January, the light number decreasing during the month from 125 to 91. The illuminated portion of the disk increases in the same time from 0.580 to 0.698. The diameter will be 21″ March 1, and 16″ April 1.

Mars can still be seen in the evening until half past nine. The bright red star which one sees towards the southwest in the middle of the zodiacal light at seven o'clock and later is the planet Mars. It is, however, too distant from the earth to be satisfactorily observed.

At the December meeting of the British Astronomical Association Mr. Green delivered a lecture on "The Canals of Mars," in which he criticised somewhat Schiaparelli's drawings, as lacking in accuracy from an artistic standpoint. In the course of his lecture he says: "I have thus, I think, shown conclusively that the larger forms in Schiaparelli's drawings differ considerably from the forms in which the same markings are represented by other observers, and also that they differ amongst themselves. I might add that I could have established my point just as readily from the drawings of De La Rue, Lockyer, Trouvelot, Terby, Knobel, Niesten, or Kaiser as from those which I have selected."

"Now, a very interesting question comes before us. What were the forms that the observer at Milan *did* see,—for he must have seen something,—which form the basis of these canals. A careful examination will partly answer this question. I have in my hand a drawing by Schiaparelli of the 1877 series, in which the 'Oculus' is on the meridian. From this, passing directly south, is a faint piece of soft shading. In the 1879 map this is drawn as two hard lines, and in 1882 with one sharp line, so that we have three methods of representing a single form. Now when I was at Maderia in 1877 I had some especially fine views of this portion of the planet, and had there been anything resembling these lines, I must have seen it. It may be objected that others have seen them, so that they must be there. That other observers have seen whatever forms the basis of these lines I do not for a moment doubt, but I feel thoroughly convinced they have not *drawn* what they have *seen*, or, in other words, have turned soft and indefinite pieces of shading into clear, sharp lines." [Journal of British Astronomical Association, December, 1890.]



Path of Uranus among the Stars in 1891.

Jupiter is now "morning star" rising about half an hour before the sun. In the latter part of the month it will be visible for a short time before sunrise each clear morning.

Saturn will be at opposition March 4, so that it is now in its most favorable position for observation. This is the bright yellow star which we see toward the east in the early evening, in the southeastern part of the constellation Leo. The diagram which we gave in our last number shows that Saturn is now apparently moving westward, and will continue to retrograde until May 1. The earth is now nearly 4° below the plane of the rings and this depression will increase until May 1 when it will be 5° 29′. The sun is about 3° below the plane of the rings. In a telescope of low power the rings can hardly be distinguished as such, but appear like a straight bar of light passing through the center of the planet, and extending out from it on each side.

Uranus may be observed after ten o'clock in the evening. We give this month a diagram showing the path of this planet among the stars of Virgo during the remainder of the year. The constellation Virgo rises in the southeast about nine o'clock. Uranus is about equal in brightness with the faintest stars shown in the cut.

Neptune is toward the west in the evening, between the Hyades and Pleiades. He is moving eastward now and will during the latter half of the month pass by, to the north of, the two eighth magnitude stars with which he has so long been in the same field of view.

MERCURY.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Mar. 25	0 25.9	+ 1 40	6 4 A. M.	12 14.1 P. M.	6 24 P. M.
Apr. 5	1 45.9	+ 11 55	5 59 "	12 50.6 "	7 42 "
15	2 47.0	+ 18 44	5 51 "	1 12.2 "	8 34 "
			VENUS.		
Mar. 25	21 36.0	− 14 08	4 18 A. M.	9 24.7 A. M.	2 31 P. M.
Apr. 5	22 25.9	− 10 25	4 9 "	9 31.2 "	2 53 "
15	23 10.5	− 6 29	3 59 "	9 36.5 "	3 14 "
			MARS.		
Mar. 25	2 39.2	+ 15 56	7 18 A. M.	2 27.2 P. M.	9 36 P. M.
Apr. 5	3 10.0	+ 18 15	6 55 "	2 14.6 "	9 34 "
15	3 38.3	+ 20 04	6 36 "	2 03.6 "	9 31 "
			JUPITER.		
Mar. 25	22 24.9	− 10 49	4 54 A. M.	10 13.7 A. M.	3 34 P. M.
Apr. 5	22 34.1	− 9 58	4 16 "	9 39.6 "	3 3 "
15	22 41.9	− 9 13	3 41 "	9 08.0 "	2 35 "
			SATURN.		
Mar. 25	10 57.5	+ 9 01	4 5 P. M.	10 44.1 P. M.	5 24 A. M.
Apr. 5	10 54.8	+ 9 17	3 18 "	9 58.2 "	4 39 "
15	10 52.9	+ 9 28	2 35 "	9 16.9 "	3 58 "
			URANUS.		
Mar. 25	13 53.9	− 11 05	8 21 P. M.	1 40.0 A. M.	6 59 A. M.
Apr. 5	13 52.3	− 10 56	7 35 "	12 55.1 "	6 15 "
15	13 50.7	− 10 47	6 54 "	12 14.2 "	5 35 "
			NEPTUNE.		
Mar. 25	4 11.2	+ 19 29	8 34 A. M.	3 59.0 P. M.	11 24 P. M.
Apr. 5	4 12.1	+ 19 33	7 51 "	3 16.8 "	10 42 "
15	4 13.5	+ 19 37	7 13 "	2 38.7 "	10 4 "
			THE SUN.		
Mar. 20	23 59.5	− 0 03	6 3 A. M.	12 07.6 P. M.	6 12 P. M.
25	0 17.7	+ 1 55	5 54 "	12 06.0 "	6 18 "
30	0 35.9	+ 3 52	5 45 "	12 04.5 "	6 24 "
Apr. 5	0 57.7	+ 6 10	5 34 "	12 02.7 "	6 31 "
10	1 16.0	+ 8 03	5 25 "	12 01.3 "	6 38 "
15	1 34.5	+ 9 52	5 16 "	12 00.0 "	6 44 "
			THE MOON.		
Mar. 20	9 03.9	+ 21 29	1 20 P. M.	9 10.9 P. M.	4 52 A. M
25	12 56.1	− 1 35	6 31 "	12 42.7 A. M.	6 40 "
30	17 06.6	− 23 52	11 56 "	4 33.4 "	9 03 "
Apr. 5	22 17.3	− 16 04	4 08 A. M.	9 23.4 "	2 36 P. M.
10	3 01.2	+ 15 24	5 48 "	1 46.5 P. M.	9 12 "
15	7 51.6	+ 24 57	10 08 "	6 16.7 "	2 20 A. M.

Phases and Aspects of the Moon.

			Central Time.			
			d	h	m	
First Quarter	1891	Mar.	17	3	10	A. M.
Apogee	"	"	22	3	40	P. M.
Full Moon	"	"	25	7	12	A. M.
Last Quarter	"	Apr.	2	12	30	"
Perigee	"	"	7	4	10	"
New Moon	"	"	8	2	57	P. M.

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N.P't. °	Duration. h m.
Mar. 16	121 Tauri	6.0	10 15	156	10 42.5	205	0 27
18	A Geminorum	5.7	8 17	95	9 44.1	288	1 27
29	ω^1 Scorpii†	4.6	10 14	62	10 50.0	350	0 36
29	ω^2 Scorpii†	4.6	10 27	96	11 27.0	316	1 00
Apr. 11	ω^2 Tauri‡	6.3	9 47	126	10 23.6	217	0 37

† Immersion below the horizon of Washington.

‡ Emersion below the horizon of Washington.

Minima of Variable Stars of the Algol Type.

[The times are given, to the nearest hour of Central Time, of only those minima which can be observed in the United States.]

U CEPHEI.

R. A. 0^h 52^m 32^s
Decl. +81° 17′
Period 2*d* 11^h 50^m

Mar. 19	10 P. M.
24	9 "
29	9 "
Apr. 3	9 "
8	8 "
13	8 "

ALGOL.

R. A. 3^h 01^m 01^s
Decl. + 40° 32′
Period 2*d* 20^h 49^m

Mar. 21	5 A. M.
24	2 "
26	11 P. M.
29	8 "
Apr. 13	4 "
15	midn.

R CANIS MAJ.

R. A. 7^h 14^m 30^s
Decl. — 16° 11′
Period 1*d* 3^h 16^m

Mar. 19	9 P. M.
27	8 "
28	midn.
Apr. 5	10 P. M.
13	9 "

S. CANCRI.

R. A. 8^h 37^m 39^s
Decl. + 19° 26′
Period 9*d* 11^h 38^m

Mar. 30	7 P. M.
Apr. 18	7 "

S ANTLIÆ.

R. A. 9^h 27^m 30^s
Decl. —28° 09′
Period 7^h 47^m

Mar. 16	11 P. M.
17	10 "
18	10 "
19	9 "
20	9 "
21	8 "
27	11 "
28	11 "
29	10 "
30	9 "
31	8 "
Apr. 9	10 "
10	10 "
11	9 "
12	8 P. M.

δ LIBRÆ.

R.A. 14^h 55^m 06^s
Decl. — 8° 05′
Period 2*d* 07^h 51^m

Mar. 21	midn.
28	11 P. M.
Apr. 4	11 "
11	10 "

U CORONÆ.

R. A. 15^h 13^m 43^s
Decl. +32° 03′
Period 3*d* 10^h 51^m

Mar. 16	2 A. M.
22	midn.
29	9 P. M.
Apr. 2	7 "

U OPHIUCHI.

R. A. 17^h 10^m 56^s
Decl. + 1° 20′
Period 0*d* 20^h 08^m

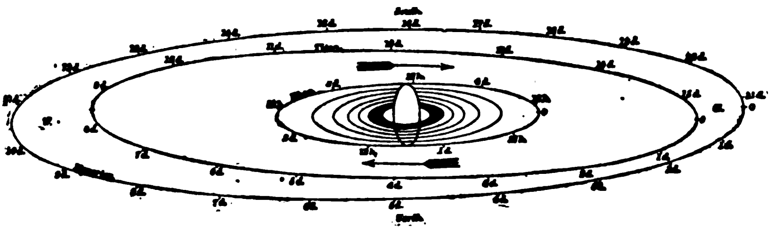
Mar. 16	midn.
21	5 A. M.
22	1 P. M.
26	2 A. M.
26	10 P. M.
Apr. 1	3 A. M.
1	11 P. M.
6	3 A. M.
6	11 P. M.
11	4 A. M.
11	midn.

Mr. Marth's Ephemerides of Saturn's Satellites.

[Reduced to Central Time; from Monthly Notices, Vol. LI. Nov. 1890; Di = Dione; En. = Enceladus; Mi. = Mimas; Rh. = Rhea; Te. = Tethys; Ti. = Titan; c = conjunction with the center of planet; f = conjunction with following end of ring; p = conjunction with proceding end: n = north; s = south of the major axis of the ring; e = eastern elongation: w = western elongation.]

March 6	8.1 p. m.	Te. fs
	9.9	Di. fs
	11.1	En. fs
	11.8	Rh.w
7	12.3 a. m.	Mi. pn
	3.9	Te. e
	11.7	Mi. fs
	11.7	Te. fn
	3.5 p. m.	En. pn
	5.1	Mi. fn
	6.7	Te. pn
	10.4	Rh. ps
	10.9	Di. fn
	11.0	Mi. pn
8	1.6 a. m.	En. ps
	2.6	Te. w
	3.7 p. m.	Mi. fn
	5.4	Te. fs
	6.0	En. fn
	7.2	Di. w
	9.6	Mi. pn
9	12.4 a. m.	En. pn
	1.2	Te. e
	3.0	Mi. ps
	2.3 p. m.	Mi. fn
	3.5	Di. fs
	4.0	Te. pn
	4.8	En. fs
	8.2	Mi. pn
	11.8	Te. w
10	1.6 a. m.	Mi. ps
	2.9	En. fn
	4.0	Di. e
	10.5	Tit. inf. n. 15″
	12.9 p. m.	Mi. fn
	1.5	Rh. pn
	2.7	Te. fs
	4.5	Di. fn
	6.8	Mi. pn
	7.3	En. ps
	10.5	Te. e
11	12.2 a. m.	Mi. ps
	12.3	Di. pn
	1.7	En. fs
	12.1 p. m.	Rh. w
	12.8	Di. w
	1.3	Te. pn
	5.4	Mi. pn
	6.1	En. pn
	9.1	Te. w
	10.8	Mi. ps
12	1.4 a. m.	Di. ps
	12.0 m.	Te. fs
	4.1 p. m.	Mi. pn
	7.7	Rh. fs
	7.8	Te. e
	8.6	En. fn
	9.5	Mi. ps
	9.7	Di. e
13	3.0 a. m.	En. pn
	3.4	Mi. fs
	8.6	Te. fn
	1.1 p. m.	En. ps
	2.7	Mi. pn
	6.0	Di. pn
	6.3	Rh. e
	6.4	Te. w
	7.4	En. fs
	8.1	Mi. ps
14	2.0 a. m.	Mi. fs
	2.3	Te. ps
	11.9	En. pn
	1.3 p. m.	Mi. pn
March 14	4.9	Rh. fn
	5.1	Te. e
	6.7	Mi. ps
	7.0	Di. ps
	10.0	En. ps
15	12.6 a. m.	Mi. fs
	12.9	Te. fn
	1.9	Rh. pn
	2.8	Di. fs
	12.6	Mi. fs
	12.9	Te. fn
	1.9	Rh. pn
	2.8	Di. fs
	2.4 p. m.	En. fn
	3.3	Di. e
	3.7	Te. w
	5.3	Mi. ps
	8.8	En. pn
	11.2	Mi. fs
	11.5	Te. ps
16	12.4 a. m.	Rh. w
	3.8	Di. fn
	11.6	Di. pn
	1.2 p. m.	En. fs
	2.4	Te. e
	3.9	Mi. ps
	9.8	Mi. fs
	10.2	Te fn
	11.0	Rh. ps
	11.3	En. fn
17	12.2 a. m.	Di. w
	12.7 p. m.	Di. ps
	1.0	Te. w
	2.5	Mi. ps
	3.7	En. ps
	8.4	Mi. fs
	8.5	Di. fs
	8.8	Te. ps
	10.1	En. fs
18	1.8 a. m.	Mi. fn
	3.8	Te. fs
	11.7	Te. e
	1.1 p. m.	Mi. ps
	2.5	En. pn
	3.7	Tit. sup. c s. 16″
	7.0	Mi. fs
	7.5	Te fn
	9.5	Di. fn
19	12.4 a. m.	Mi. fn
	12.6	En. ps
	2.5	Te. pn
	10.3	Te. w
	11.8	Mi. ps
	2.2 p. m.	Rh. pn
	5.0	En. fn
	5.7	Mi. fs
	5.8	Di. w
	6.1	Te. ps
	11.1	Mi. fn
	11.4	En. pn
20	1.1 a. m.	Te. fs
	12.8 p. m.	Rh. w
	2.1	Di. fs
	3.8	En. fs
	4.3	Mi. fs
	4.8	Te. fn
	9.7	Mi. fn
	11.8	Te. pn
21	1.9 a. m.	En. fn
	2.6	Di. e
	11.4	Rh. ps
	2.9 p. m.	Mi. fs
	3.2	Di. fn
March 21	3.4	Te. ps
	6.3	En. ps
	8.3	Mi. fn
	8.4	Rh. fs
	10.4	Te. fs
	11.0	Di. pn
22	11.5 a. m.	Di. w
	2.1 p. m.	Te. fn
	6.9	Rh. e
	9.1	Te. pn
23	12.0 m.	Di. ps
	12.7 p. m.	Te. ps
	5.5	Rh. fn
	7.7	Te. fs
	8.3	Di. e
24	11.4 a. m.	Te. fn
	4.6 p. m.	Di. pn
	6.4	Te. pn
25	1.1 a. m.	Rh. w
	2.2	Te. w
	5.0 p. m.	Te. fs
	5.6	Di. ps
	11.7	Rh. ps
26	12.8 a. m.	Te. e
	1.4	Di. fs
	5.0	Tit. inf. e. n. 16″
	1.9 p. m.	Di. e
	3.7	Te. pn
	7.3	Mi. pn
	7.8	En. pn
	11.5	Te. w
27	12.7 a. m.	Mi. ps
	2.5	Di. fn
	2.3 p. m.	Te. fs
	4.9	Mi. pn
	10.1	Te. e
	10.3	En. fn
	10.8	Di. w
	11.3	Mi. ps
28	1.0	Te. pn
	2.7	En. ps
	2.9	Rh. pn
	4.5	Mi. pn
	7.1	Di. fs
	8.8	Te. w
	9.1	En. fs
	9.9	Mi. ps
29	11.6 a. m.	Te. fs
	1.5 p. m.	Rh. w
	1.5	Rh. w
	3.1	Mi. pn
	7.4 p. m.	Te. e.
	8.1	Di. fn
	8.5	Mi. ps
	11.6	En. ps
30	12.0 m.	Rh. ps
	1.7 p. m.	Mi. pn
	4.1	En. fn
	4.4	Di. w
	6.1	Te. w
	7.1	Mi. ps
	9.0	Rh. fs
	10.4	En. pn
31	12.8 p. m.	Di. fs
	2.9	En. fs
	4.7	Te. e
	5.7	Mi. ps
	7.6	Rh. e
	11.6	Mi. fs
April 1	12.5 a. m.	Te. fn
	1.8 p. m	Di. fn.
	3.4	Te. w
	4.4	Mi. ps

April 1	5.2	p. m.	Rh. fn
	5.4		En. ps
	9.6		Di. pn
	10.3		Mi. fs
	11.2		Te. ps
	11.7		En. fs
2	2.0	p. m.	Te. e
	3.0		Mi. ps
	4.2		En. pn
	8.9		Mi. fs
	9.8		Te. fn
	10.6		Di. ps
3	1.8	a. m.	Rh. w
	2.3		En. ps
	2.3		Mi. fn
	12.7	p. m.	Te. w
	1.6		Mi. ps
	1.7		Tit. sup. c. s. 17″
	6.7		En. fn
	6.9		Di. e
	7.5		Mi. fs
	8.5		Te. ps
4	12.4	a. m.	Rh. ps
	12.9		Mi. fn
	1.1		En. pn
	3.2	p. m.	Di. pn
	5.5		En. fs
	6.1		Mi. fs
4	7.1	p. m.	Te. fn
	11.5		Mi. fn
5	2.1	a. m.	Te. pn
	4.3	p. m.	Di. fs
	4.7		Mi. fs
	5.8		Te ps
	8.0		En ps
April 5	10.1	p. m.	Mi. fn
6	12.1	a. m.	Di. fs
	12.8		Te. fs
	12.6	p. m.	Di. e
	3.3		Mi. fs
	3.6		Rh. pn
	4.4		Te. fn
	6.8		En. pn
	8.7		Mi. fn
	11.4		Te. pn
7	1.1	a. m.	Di. fn
	2.0	p. m.	Mi. fs
	2.2		Rh. w
	3.1		Te ps
	7.4		Mi. fn
	9.4		Di. w
	9.5		En. fn
	10.1		Te. fs
8	12.7	p. m.	Rh. ps
	1.7		Te. fn
	1.8		En. ps
	5.7		Di. fs
	6.0		Mi. fn
	8.1		En. fs
	8.7		Te. pn
	9.7		Rh. fs
	11.9		Mi. pn
9	12.4	p. m.	Te. ps
	12.6		En. pn
	4.6		Mi. fn
	6.8		Di. fn
	7.4		Te. fs
	8.1		Rh. e
	10.5		Mi. pn
	10.7		En. ps
April 10	2.6	a. m.	Di. pn
	3.2		Te. e
	3.1	p. m.	Di. w
	3.1		En. fn
	3.2		Mi. fn
	6.0		Te. pn
	6.7		Rh. fn
	9.1		Mi. pn
	9.5		En. pn
11	1.9	a. m.	Te. w
	5.8		Tit. inf. c. n. 18″
	4.7	p. m.	Te. fs
	7.7		Mi. pn
	11.9		Di. e
12	12.0	a. m.	En. fn
	12.5		Te. e
	3.3	p. m.	Te. pn
	4.4		En. ps
	6.4		Mi. pn
	8.2		Di. pn
	10.8		En. fs
	11.2		Te. w
13	2.0	p m.	Te. fs
	3.2		En. pn
	5.0		Mi. pn
	9.3		Di. ps
	9.8		Te. e
	10.4		Mi. ps
14	12.1	p. m.	Te. pn
	3.6		Mi. pn
	5.6		Di. e
	5.7		En. fn
	8.5		Te. w
	9.0		Mi. ps



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, MAY 17, 1891, AS SEEN IN AN INVERTING TELESCOPE.

(The Vertical Scale is Twice the Horizontal One.)

A new minor planet of the twelfth magnitude was discovered by Charlois, of Nice, February 11.4088, having right ascension $9^h\ 51^m\ 35^s.1$ and declination + 14° 53′ 38″. Daily motion is right ascension, — 13′, and declination, — 4′. Possibly No. (302).

A new minor planet of the twelfth magnitude was discovered by Millosevich, February 12.503 in right ascension $9^h\ 51^m\ 26^s$; in declination, + 16° 52′ 41″. Daily motion in right ascension, — 13′, in declination, — 3′.

A new minor planet of the thirteenth magnitude was discovered by Palisa, of Vienna, February 14.575, with right ascension $10^h\ 33^m\ 8^s$ and declination + 6° 46′. Daily motion in right ascension, — 22′, and in declination, — 8′.

Another asteroid of the eleventh magnitude was discovered by Charlois, of Nice, February 16.629, the right ascension being $9^h\ 41^m\ 32^s$, the declination, $+7^\circ\ 2'\ 24''$. Daily motion is $-12'$ in right ascension; in declination, $-5'$.

COMET NOTES.

Ephemeris of Comet 1890 II (*Brooks, March 19*). From Berberich's elements as given in A. N., Vol. 124, p. 301, I have computed the following ephemeris:

Gr. M. T.	App. R. A.			App. Dec.		Log r.	Log Δ.
	h	m	s	°	′		
March 1.5	10	50	48	+36	29	0.5653	0.4437
3.5		45	59	36	26		
5.5		41	15	36	24	0.5695	0.4510
7.5		36	37	36	19		
9.5		32	7	36	15	0.5736	0.4593
11.5		27	44	36	7		
13.5		23	29	36	1	0.5776	0.4684
15.5		19	23	35	52		
17.5		15	25	35	42	0.5817	0.4782
19.5		11	36	35	31		
21.5		7	56	35	20	0.5857	0.4886
23.5		4	26	35	7		
25.5	10	1	6	34	54	0.5896	0.4995
27.5	9	57	55	34	40		
29.5		54	53	34	26	0.5935	0.5106
31.5		52	0	+34	11		

O. C. WENDELL.

Harvard College Observatory, Feb. 14, 1891.

In an article in THE MESSENGER for February the periodic comets that are expected to return to perihelion during the present year are mentioned. I find that Tempel's comet, discovered in 1867, is included in the list.

In No. 2656 of the *Astronomische Nachrichten* Professor Gautier has given the result of his work on the orbit of this periodic comet, and explains the large perturbations it received from 1879 to 1885.

The following are the elements as determined by Professor Gautier:

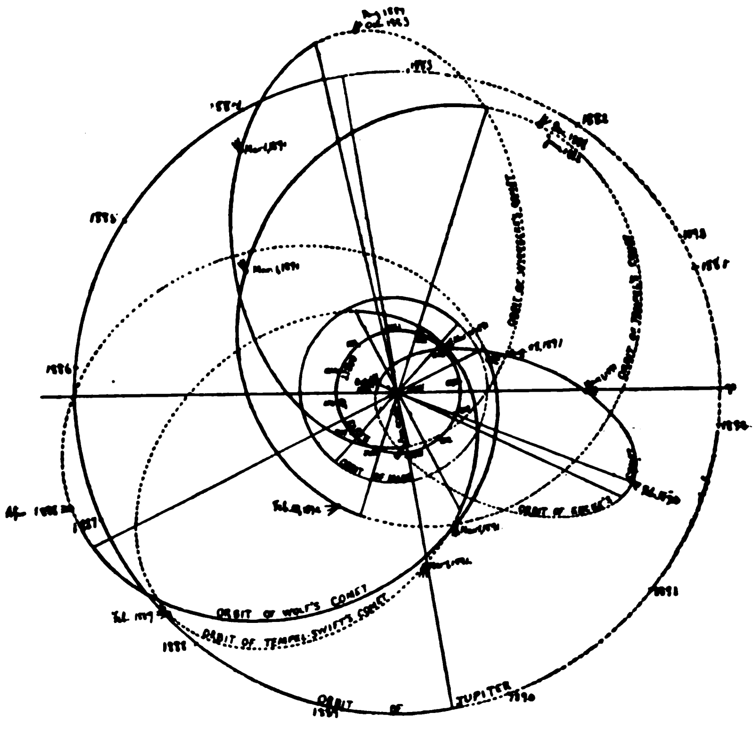
$T =$ 1879, May 7.4418 Berlin M. T.	$T =$ 1885, Sept. 25.7649
☊ $=\ 78^\circ\ 46'\ 53''$	☊ $=\ 72^\circ\ 24'\ 9''$
$\omega = 159\ \ 38\ \ 24$	$\omega = 168\ \ 57\ \ 41$
$i =\ 9\ \ 46\ \ 17$	$i =\ 10\ \ 50\ \ 27$
$\varphi =\ 27\ \ 32\ \ 29$	$\varphi =\ 23\ \ 53\ \ 57$
$\mu = 593''.140$	$\mu = 545''.3073$
$\log a =\ 0\ .517900$	$\log a =\ 0\ .542244$

By comparing these elements it wil be seen that the comet was greatly perturbed during the interval from 1879 to 1885, and that its return in the latter year was retarded about 148 days. If the perturbutions that have occurred from 1885 to the present time have been small the comet will not return to perihelion until the early part of 1892.

The error in predicting the return of the comet in April of this year has probably originated in using the elements for 1879, instead of those determined in 1885. GEO. A. HILL.

Washington, D. C., February 11, 1891.

Periodic Comets soon Due at Perihelion. We give this month a chart of the orbits of the periodic comets which are due at perihelion in 1891 and the early part of 1892, with the orbits of the Earth, Mars and Jupiter. The orbits are plotted as if they were in the plane of the ecliptic, but those portions which lie below the plane are represented by dotted lines. The places and dates of each comet's nearest perihelion and aphelion passages and also its place in orbit on March 1, 1891, are shown upon the chart. In calculating these places and dates we have used the best elements which we could find at hand, the authorities being Bossert, *Astr. Nach.* 114-95, Thraen, *Astr. Nach.*, 117-65; Gautier, *Astr. Nach.*, 111-241; von Haerdtl, *Astr. Nach.*, 126-171, and Young's General Astronomy 532. The place of the earth at the beginning of each month and that of Jupiter at the beginning of each year are shown on the chart.



An inspection of the chart shows that Tempel's comet was near to Jupiter in 1881 and 1882 and for two years must have suffered strong perturbations. Mr. Gautier calculated that the perturbations would retard the perihelion passage in 1885 about 148 days. The period would be changed from 5.98 years to 6.51 years. This comet was not detected in 1885 because, probably, of its unfavorable position. No serious disturbance of its path should have occurred since 1885, so that, if Gautier's elements are correct, it should be at perihelion in February, 1892. It will then be as unfavorably placed as in 1885.

The first to reach perihelion this year will be Wolf's comet 1884 III, due Aug. 28. It was at aphelion in 1888, but was so far behind Jupiter that but little change may be expected from his influence. It was observed for seven months in 1884 and, although not quite so favorably situated this year, ought to be easily found in June or July, as it was a rather bright telescopic comet.

Encke's comet will be the next to come to perihelion, Oct. 17, but will then be almost behind the sun. It may be seen in September and the first days of October.

In our hastily prepared note last month we inadvertently said that Temple-Swift's comet would probably not be detected. A glance at the chart shows that this comet will be very favorably situated in November, being opposite the sun, and approaching within about 10,000,000 miles of the earth. It was in 1880 a faint diffuse object, several minutes in diameter, and it was observed for fourteen weeks. It ought this year to be picked up in August and to be followed at least six months.

Winnecke's comet was quite near to Jupiter in 1882 and 1883 and its orbit was considerably changed at that time. Its perihelion passage in 1886 was considerably retarded. This comet is now about four times as far distant as the sun, yet it is possible that some of the great telescopes may be able to bring it to sight. In *Astr. Nach.* No. 3011, Dr. von Haerdtl has published an ephemeris for January of this year, which had previously been forwarded to Messrs. Barnard, Perrotin and Palisa, observers who have the use of giant telescopes. We have not heard yet that any of them have been able to detect the comet. At its perihelion passage in June, 1892, it will pass quite near the earth but at the the nearest approach will be involved in the rays of the sun so as not to be seen. For two months before perihelion it will be very favorably situated for northern observers.

A Magnificent Meteor. On Wednesday evening, Jan. 28, at 8 o'clock local mean time, a meteor of remarkable brilliancy was seen from the Observatory of the University of the Pacific. The path described was from the Pleiades to Mira in Ceti, where it divided into three parts. The brilliancy greatly exceeded that of the electric lights shining on the Alameda at the time. The coloration was that of magnesium. T. C. GEORGE.

College Park, California, Jan. 31, 1891.

Prominences in January.

Date.	Position Angles.
4th	135, 228, 327
7th	74, 123, 220, 309
10th	51, 55, 220
12th	47, 51, 71, 76, 138
(No examination beyond 140° on account of clouds.)	
13th	45, 60, 65, 75
15th	35, 128, 223, 313
19th	135, 228, 240
23d	33, 220, 230, 256
25th	30, 205, 227, 300
26th	25, 41, 57, 107, 134, 209, 215, 220, 290, 294, 312
27th	55, 105. 135, 215, 308
30th	37, 208, 313

Camden Observatory, Feb. 1, 1891.

Sun Spot Observations, Alta, Iowa. (Continued.)

DECEMBER, 1890.

1890.	Central Time.	No. of Visible		Definition.	REMARKS.
		Groups.	Spots.		
Dec. 16	12:00 m.	2	?	Poor.	Atmosphere too unsteady to count spots.
17	12:10 p m	2	?	Poor.	" " " " " "
18	11:25 a m	2	8	Good.	Larger groups near SW. limb surrounded by faculae. Other groups. 3 small spots 1 day E. of meridian.
19	11:20 a m	2	10	Fine.	New spots forming in groups on meridian.
20	11:40 a m	3	5	Good.	Group on W. limb with brilliant faculae is disappearing by solar rotation. New groups on E. limb [with large area, faculae.
22	11:25 a m	0	0	Good.	Apparently clear disc.
23	1:30 p m	0	0	Good.	2 groups faculae W.
25	12:10 p m	0	0	Good.	Clear disc.
26	11:25 a m	1	2	Poor.	Group NE.
27	11:30 a m	1	1	Fair.	Group vanishing.
28	2:00 p m	0	0	Good.	Small faculae by rotation E. limb. Spot formed in [faculae on E. limb.
29	11:50 a m	1	1	Fair.	Faculae NW.
30	11:30 a m	0	0	Bad.	Dense haze. Faculae on NW. limb.

DAVID E. HADDEN.

Alta, Iowa, Feb. 14th, 1891.

Sun Spot Observations, made by Caroline Furniss, student at Vassar College, with a three-inch Clark telescope.

DECEMBER, 1890.

d h m	Groups.	Spots.	Faculae.	REMARKS.
1 12 30	1	6	0	One large.
2 1 45	1	2	0	" "
12 11 30	0	0	0	
15 2 30	2	9	0	Eight in one group, south.
18 2 00	2	6	1	All small.
20 3 00	1	4	1	" "
22 3 00	0	0	0	
25 12 30	0	0	0	
28 3 00	0	0	0	

Carleton College Sun Spot Obserwrtions. (Continued from page 102.)

Date. 1891.	Groups.	Spots.	Faculae.	Observer.	REMARKS.
Jan. 24	3	15	1 gr.	C. R. W.	One conspicuous spot. New group with faculae NE.
" 30	2	18	1 "	H. C. W.	
Feb. 2	1	1	2 "	"	
" 9	1	1		C. R. W.	
" 10	2	21		"	New group with 17 spots.
" 11	3	20		"	New group near center with 8 spots.
" 14	3	10	1 gr.		
" 18	3	12		H. C. W.	One large group containing 8 spots. Other groups [very small.
" 21	2	12	1 gr.	C. R. W.	

NEWS AND NOTES.

Regular mailing day for THE MESSENGER, for each month, is the last day of the preceding month. If subscribers do not receive THE MESSENGER promptly after such mailing date, please notify the publisher and the wanting numbers will be supplied.

The new universal spectroscope constructed for the 16-inch telescope for Carleton College Observatory is now nearly completed. It will be ready for laboratory use in a few days. Mr. Brashear, of Allegheny, Pennsylvania, is the maker.

We have received an excellent article from Professor Lewis Boss, Director of the Observatory at Albany, N. Y., with title, "An Irrepressible Conflict." It is a brief history of the management of the United States Naval Observatory. It will appear in our next number.

Attention is called to the new advertisement of The E. Howard Clock and Watch Company of Boston and New York. We are glad to notice that this old and reliable company offers clocks with electrical attachments for use in transmitting time-signals for railway purposes. Particular notice of this fact is given to the officers of railway companies everywhere. If they desire to obtain their time from local observatories this can be done by the use of these clocks, which we know will give better service than that which the Western Union Telegraph Company can do through its Pond clock that is being industriously pushed in the large cities for this purpose.

Time for Railways. We have seen the working of this mongrel time system by the tri-partite arrangement between the U. S. Naval Observatory. the Western Union Telegraph Company and a certain clock company in New York for the last year, for we effected an arrangement whereby we could know of the reliability of the service in comparison with the Northfield time daily, and, as was expected, it proves unworthy of the confidence of those who must have accurate time in business. A jeweler as a time keeper in regulating watches, taxes a regulator as severely as an observatory does its time-piece in fundamental work, and the fact that any jeweler should be misled by the supposition that he is getting Washington time in any western city necessarily because the 'notice' on the clock case says so, is a great surprise to anyone who takes the trouble to find out what the facts are. The difficulty is not so much in the time itself when it is received by jewelers as it is in the reliability of the transmitting clock to give it when recieved on the wire. The Pond correcting or synchronizing apparatus, by which the work of setting the local clock is done, is one of the poorest that to our knowledge, has ever been put to public use. This is the main reason why local time by this system is so unreliable.

The Howard Clocks for local telegraphic signals and service for railways and jewelers will do away with the cause of bad service mentioned above, because they are better clocks and their synchronizers are reliable. As for the time it is a well known fact in observatories that the Western Union Telegraph Company appropriates the local time of local observatories to their own use whenever they care to do so and thus obviate the need of transmitting the Washington time long distances. Astronomers can very easily know when this is done, for they have means of proof, and we know it has been done repeatedly in the west, and local officers of the telegraph company admit it. But the practice of seizing the local time which is the property of local observatories still continues.

New Variable Star in Camelopardalis. [Communicated by Edward C. Pickering, Director of Harvard College Observatory.] The photometric measures of DM. + 62° 596 made at this Observatory were discordant and differed greatly from the magnitude 6.6 given in the Durchmusterung. This star is Dunér II, 7, whose approximate position for 1900 is in R. A. $3^h\ 33.2^m$, decl. + 26° 20′. Photographic charts of this region were therefore taken to determine whether the disagreement was due to errors in measurement, or to variations in the light of the star. The latter proved to be the case, since charts taken on Jan. 3, Feb. 13, April 1, April 5, April 11, April 16, Oct. 15, Oct. 17, Nov. 19, Nov. 25, Dec. 5, 1890, Jan. 16 and Feb. 1, 1891, give the approximate magnitudes 7.4, 7.5, 7.5, 7.3, 7.5, 7.5, $<$ 8.7, 8.1, 8.5, 8.5, 8.8, 8.1 and 7.8 respectively. A correction of -3.6 magnitndes has been applied to the photographic measures of this star to render them comparable with visual observations. The star DM. + 53° 2684, magn. 8.6, announced as a variable by the Rev. T. E. Espin in Circular No. 28 of the Wolsingham Observatory, has been measured on five charts. They were taken on Dec. 16, 1887, Sept. 1, Sept. 29, Dec. 7, 1890, and Jan. 15, 1891, and gave the approximate magnitudes 10.2, 10.7, 10.8, 10.4, and 10.0 respectively, thus confirming the variability of this star.

Harvard College Observatory,
Cambridge, Mass., Feb. 11, 1891.

M. FLEMING.

Saturn in 1891. Those who are interested in reading the continued article from the pen of Professor E. L. Trouvelot on the phenomena observed upon Saturn at the time of the passage of the sun and of the earth through the plane of its rings in 1877-1878, will find the most complete series of observations of certain features of the ball and rings of Saturn that we know of anywhere. They are so instructive and will be so useful to those who wish to make the system of Saturn during the present year the object of special study that the entire long paper has been translated from the French for THE MESSENGER. The concluding part of it will appear in the April number. Teachers of astronomy will find the article helpful.

Hathorn Observatory, Saratoga Springs, N. Y. Some fine drawings of Jupiter, as seen and drawn by F. J. del Corral, Nov. 16, 1890, have been shown us. The work shows much detail for a six-inch telescope, and the hand of the artist in its neat execution in India ink. We will give a fuller report of work at this Observatory next time.

Sunspot Observations. In view of the great number of sunspot observations that come to hand for publication, from month to month, and the very considerable space required for them by the different forms of observations chosen by different persons, it has been thought best, in the future to print this matter in another form, as an appendix to THE MESSENGER to be given once in three months. The data requested are dates of observation in central time, number of groups of spots, number of spots, definition, observers, and remarks. The first appendix will appear in June. If observers will send us all unpublished observations for this year to that date we will try to arrange them in suitable form for publication. It is hoped that great pains will be taken by all observers to obtain accurate data. We have noticed unexpected disagreement in some observations of the past.

Annals of Harvard College Observatory, Vol. 23, Pt. 1. This part of volume 23 of the Observations of Harvard College Observatory is devoted to the discussions of observations made with the Meridian Photometer during the years 1882-8, the report being made by Professor E. C. Pickering and assistant O. C. Wendell. The frontispiece is a fine, large picture of the Meridian Photometer, then follows a description of the instrument, detailed statement of the results of work, discussion of observations of standard circumpolars tars and atmospheric absorption and discordant observations. At the close of this part, the remarks on the comparison of photometric methods are very instructive. The experience of the observers in this line of work is shown in the fact that during the last twelve years 617,287 photometric measures of various kinds have been made.

New Theory of the Universe. In the February number of Lippincott's Magazine will be found an article by Charles Morris on "A New Theory of the Universe." The aim of the author is to present the new theory advocated by J. Norman Lockyer, generally known as the Metoritic Hypothesis. His statement in one paragraph is: "One striking result of the recent investigation appears to be the probable overthrow of that grand nebular hypothesis which has been of such intense interest to contemplative mankind, and which seemed almost as thoroughly based as the theory of gravitation."

In speaking of comets, the author makes the remark that they are not daughters of other systems that have escaped and come to us. "To be taken prisoner by a solar system is the end, not the beginning of a comet's career. Once captured it can never escape again. Every comet probably began its life as a rover; all may end as members of solar systems." These statements certainly show that the author has not rightly understood the writings of astronomers. If he has known it, he has forgotten the history of Lexell's Comet and others that might be mentioned, to say nothing of the families of comets belonging to the great planets. We do not think that astronomers are ready yet to admit that the nebular hypothesis is at all in danger from the valuable work of Mr. Lockyer. The meteoritic theory must be tested much more thoroughly than it has been so far, before a scientist will say, with authority, that the nebular hypothesis is in danger of being overthrown by it.

Special Studies in Mathematics and Astronomy. A three years' course of post-graduate studies in pure mathematics and practical astronomy has been undertaken at Carleton College, Northfield, Minn. A class of three members was formed in September last, and began regular work in Chauvenet's trigonometry. The first ten chapters of the plane trigonometry of that work and the first four chapters of the spherical part have been completed and a thorough written examination given on the same. In addition to this at least four hours per day, by each student, has been given to reductions of the observations by the Meridian Circle in the preparation of the regular publications of the Observatory, or, in other similarly useful and original work. For such work the student is paid twenty cents per hour from the reduction and publication fund belonging to the Observatory. On clear nights the students assist in observations, by recording, reading micrometers, and when in practice sufficiently by making the observations themselves. The class is now at work on Howison's Analytic Geometry, reviewing and completing Bowser's Calculus, and beginning Chauvenet's Practical Astronomy.

Co-operation among Amateur Observers. The plans recently developed by the British Astronomical Association for co-operation of amateur observers in the various fields of work open to them is certainly worthy of general attention and extended application. The plan of the society is to divide such work into sections and place at the head of each section some competent person to direct the work of all who become members of it. The society has already organized the following sections by name, with directions for each as given below:

Section.	*Director.*
Solar	E. Brown
Lunar	Thomas Gwyn Elger
Jupiter	W. R. Waugh
Colored Star	W. S. Franks
Variable Star	J. E. Gore
Double Star	Kenneth J. Tarrant
Meteoric	David Booth

Each person in charge of a section gives explicit directions to the observers and maps out work for them, the results of which are reported from time to time, and examined and given such place in permanent records as they deserve. It has occurred to us often that some such plan ought to be adopted and put into operation in various parts of the United States. From the many letters that we have received on this subject it would seem that a considerable number of observers in different lines of work would gladly co-operate and thereby make it possible soon to collect a volume of varied, useful observations that science can not hope to get from astronomers already employed in special work that consumes their whole time and energy. We have spoken of this matter and received some letters concerning it, but scarcely a number large enough to warrant a very general preparation for a movement of this kind. Correspondence is still desired.

Dr. F. Terby of the private Observatory of Louvain, Belgium, has kindly favored us with copies of seven different papers or abstracts of papers on astronomical subjects, prepared by himself recently.

Dr. James Croll. American scientists will be saddened to learn of the recent death of the distinguished writer, Dr. James Croll, F. R. S., who had reached the seventieth year of his age. It is said that Dr. Croll had been suffering a long time from a mortal malady but remained at his work almost to the last. Without the advantages of early scientific training, Mr. Croll had raised himself from a very humble social position to that of a recognized authority in his special subjects, notably those connected with the relation of climate to geological phenomena. As further reported in the *Scientific American* it appears that "some years ago by the influence of Sir A. Ramsey, Dr. Croll, then resident of Clasgow, was appointed an officer of the Geological Survey of Scotland. Although best known by his work on "Climate and Time," he was the author of several others such as "Climate and Cosmology," "Stellar Evolution," and the Philosophy of Theism. The originality of his views frequently brought him into controversy with scientific men who, differing from his opinions, learned to respect him as a doughty antagonist who had something to say and knew how to say it." Dr. Croll's investigations brought him into the discussions of certain questions in astronomy and, in this way THE MESSENGER more than once was chosen as the means of expressing his views to his American friends.

Vassar College Sunspot Observations. By a late private letter from Miss Mary W. Whitney, Director of the Observatory at Vassar College, Poughkeepsie, N. Y., we learn that students in astronomy of that college have made sunspot observations since 1882, and that the results of observation have been platted on squared paper for the purpose of finding the maximum of the present period. Miss Whitney has kindly shown us the sunspot curve so represented between the years 1884 and 1891, which fixes the maximum in January, 1884. We defer reproducing this interesting curve in the hope of having it extended backward to the date of 1882, and further if possible. This we have already asked for.

The New Naval Observatory is nearly ready for use, and in view of this fact the old question recurs to the minds of those interested in this line of scientific work, whether it is not now an opportune time to change the administration of the Observatory, and put it under competent civilian control. Has not the time come in the history of this government and this country, when scientific men should be called to places of large scientific responsibility and should be expected themselves to have the control of such positions and chiefly because of their peculiar fitness for such work? The reasons for such a course are so evident to anyone that it seems useless to argue the matter.

Wolsingham Observatory. We have been favored by a report for 1890 of work done at Wolsingham Observatory, Tow Law, Darlington, Ireland. It embraces search for stars with peculiar spectra. Seventy have been detected during the year, making a total number of 530. Work on the new edition of "Red Stars" has been completed and published. Other interesting matter is found in this brief report. T. E. Espin is Director.

Photographic Notes. At the meeting of the Royal Astronomical Society on January 9, Mr. A. Fowler made the following statement in regard to α Lyræ. "In the face of the facts brought forward by Professor Vogel, and the information I have received from Professor Pickering, I feel bound to acknowledge that α Lyræ cannot be a double star as I suggested November last. The facts with regard to my photographs, however, remain as I then stated them, and I have as yet no explanation to give of the phenomena."

Mr. Isaac Roberts' photographs seem to leave no room for doubt that the great nebula of Andromeda has a variable stellar nucleus; this variable can be studied in photographs of fifteen minute's exposure.

The Lick telescope has photographed the moon, Venus, Mercury and Vega in full daylight.

"Greenwich Spectroscopic and Photographic Results" for 1889 describes the position micrometer by which solar photographs are measured, also explaining the process of measuring. As to the number of such photographs available for 1889 the following statement is made: "Photographs were taken at Greenwich on 178 days, and Indian photographs on 166 days with Mauritius photographs on 16 days have been received from the Solar Physics Committee to complete the total of 360 days for which there are either Greenwich, Indian or Mauritius photographs of the sun available for measurement in 1889."

The Draper Catalogue of stellar photographic spectra contains the spectra of 10,351 stars. The total number of spectra measured for this catalogue was 28,266. The lens was a doublet with which 10° square could be covered. The plates used were the Allen and Rowell, and the Seed 21. In general each spectrum appeared on four plates. The number of spectra on a single plate sometimes exceeded 200.

"The dark part of the moon, when the moon's age is 2.9 days, can be photographed with the twelve-inch equatorial with a Seed 26 plate in twenty seconds, the complete outline of the dark part just showing with this exposure. With forty seconds and seventy seconds the dark part was conspicuous and details in it were clearly shown."—*Astronomical Society of the Pacific.*

The *Philadelphia Times* recently published an ingenious star puzzle and offered a gold prize for the best solution, with one hundred prizes of different kinds to the various grades of competitors. The puzzle seems to have greatly interested the young people.

M. Fleming of Harvard College Observatory will soon prepare an article for this publication on the mode of measuring the Harvard College Observatory photographs from which so many important new facts have been recently discovered.

Photographic Mosaics by Edward L. Wilson, of New York, is a neat publication of 288 pages, in paper cover, showing the annual record of photographic progress for the year 1890. The last year has been splendidly "redeveloped."

How to keep an Observing Book. Some good suggestions on how to keep a note-book are found in an article on practical work with the telescope in the "English Mechanic" for Jan. 23, 1891. They are as follows: For general work it is best to have a separate book for each class of observation. For the Observatory an ordinary account book is perhaps the most convenient. It should be on a table or desk, near the light shielded from the eyes but falling on the book. For delicate work, on colored stars, etc., a paper shade of light green or blue should be used which causes the light on the paper to be more purely white. The observations will often have to be written down quickly and in bad light. As soon as possible the observations should be entered in a large note-book. One should be kept for each subject, (1) for the sun, (2) for the planets, (3) for the moon, (4) for the stars and nebulæ and (5) one for casual observation. The note-book for the first three of these is best unruled and thus drawings may be made. On such pages may be found some of the most exquisitely colored sketches of Mars from the manuscript observations of the late Rev. T. W. Webb. No photograph can ever do justice to the beauty of the originals. Each of these sketches was numbered, and on the opposite page and following pages the description and dates are given; when the page of drawings is filled in, another is left, another going on consecutively, for the stars, etc., a ruled book is best. This should have a line ruled down from top to bottom, and each observation should be numbered in red ink, so that it can be at once referred to. At the head of each night's work the date and state of the air may be given.

Report of the Superintendent of the U. S. Naval Observatory. In his report for the year ending June 30, 1890 we notice the following statement under the head of Chronometers and Time Service: "The Observatory (meaning the U. S. N. Observatory) has been greatly hampered in this branch of its work by the lack of funds. In view of the great importance of the ball signals to mariners and others, there should be a system of return signals by which the errors in the dropping of the various time balls may be measured and given to the public. The system of corrected clocks might be advantageously extended to all the government offices using accurate and uniform time for the transaction of government business. An appropriation is greatly needed for these purposes."

"The fact that the government has never formally adopted a standard of time for the transaction of business has led to vexatious complications in land entries in territories in various ways and channels too well known to particularize. A standard of time is quite as important as one of weight or of measure, and the time destributed from the Observatory ought to be legalized by an act of Congress."

We would like to add to this recommendation that all postmasters and notaries public in the United States be included in the provisions of such an act that the general government may aid these officers in their official duty. Return signals also should be sent to the U. S. Naval Observatory daily at government expense so that the personal equations of these officers might be given to the public.

BOOK NOTICES.

The System of the Stars. By Agnes M. Clerke, Author of a Popular History of Astronomy during the Nineteenth Century. London: Messrs. Longmans, Green & Co., publishers; and New York, 15 East Sixteenth street. 1890, pp. 424.

Two books have been recently published that will be very welcome to astronomers generally, and it gives us pleasure to call attention to both of them in this issue of our publication. This volume, entitled "The System of the Stars," is a book of inestimable value. It is, indeed, as much a surprise, in point of success, as was that other notable book which appeared about five years ago, by the same author, titled "A Popular History of Astronomy during the Nineteenth Century." If it was a delicate task to write a history of the nineteenth century fifteen years prior to the end of it, in the midst of the marvelous advancement of science at the present time, much more is it difficult now to delineate the system of the stars, with its manifold differing lines of research, no one of which is yet more than fairly begun in systematic way. The undertaking is, indeed, a great one, so great that few scholars have tried to do more than to trace very general outlines for a system of the stars. The more the student turns over the momentous thought, the more the attempt seems to be a parallel of the distinguished Newton's thought who expressed himself as well employed in picking up pebbles on the shore, while the great ocean of truth unexplored lay before him. It is none the less a noble ambition that seeks to master these great questions in science, whether it be on the side of discovery, or in the art of apt and truthful expression of what is now known in the realms of the sidereal universe.

The purpose of the author in this book has been to present such facts about the starry universe as are known to astronomy, in such a plainly-worded and untechnical way that the popular reader may easily understand the whole range of the subject and think about it definitely and pleasurably for himself.

The first chapter opens by speaking of the stars generally, as they appear to the naked eye, their designations, sidereal natural history, the discoveries of nebulæ, and the desirability of continuous observation. This naturally leads to a consideration of the methods of sidereal research, in which star catalogues and instruments are the aids which the working astronomer must bring to hand. The heliometer, stellar light analysis, and spectroscopic determination of the movement of celestial bodies are made duly prominent, while stellar and nebular photometry and celestial photography for star charting and parallax are the newer methods that are growing rapidly in favor. The object of all methods of study is to learn something of the nature or characteristics of the heavenly bodies. Beginning with the Sirian and solar stars their spectra are studied and classified, and their physical distinctions noted, the stars with banded spectra discussed, and the meaning of flutings explained as at present understood. The physical nature of the various spectral classes of the stars is a theme of great interest, and large place is deservedly given to it. In chapter six we begin the theme of sidereal evolution, or the life history of the stars. In this connection the status of the red stars, the sun, stars past their prime, and the indicated line of evolution are considered; also the meteoric hypothesis and pre-nebular theories. Then follow chapters on temporary stars, variable stars of long period, variable stars of short period, the colors of the stars, double stars, variable double stars, stellar orbits and multiple stars. The chapter on the Pleiades is alone worth the price of the book to any reader who has interest in this branch of astronomy. The frontispiece to the volume is a large photographic chart of this group by MM. Paul and Prosper Henry, which contains, within a space of about 10 by 8 inches, 2,326 stars with nebulæ intermixed. Following this are star-clusters, the forms of nebulæ, the great nebulæ, the nature and changes of nebulæ, the distances of the stars, the translation of the solar system, the proper motions of the stars, the Milky Way, the status of the nebulae, the construction of the heavens, and tables of stellar data with a full general index. There are also six fine full page plates and fifty woodcuts as illustrations for the text which serve the purpose neatly and well. American teachers of astronomy will find this book a very useful one for reference.

Tycho Brahe, A picture of Scientific Life and Work in the Sixteenth Century. By J. L. E. Dreyer, Ph. D., F. R. A. S., Director of the Armagh Observatory, Edinburgh. Messrs. Adam & Charles Black, Publishers, 1890, pp, 405. Price $3.50.

Not a small number of our readers already know something of Dr. Dreyer's work as an astronomer and a writer on scientific subjects, and the knowledge that he has written a book setting forth the fact and work of the life of the noted Tycho Brahe will certainly draw favorable attention to it as a work of merit. The monographs and popular accounts of his life, that have already appeared from time to time have had for their object only to set forth various phases of the career of the great Danish astronomer, as Helfrecht and Brewster have done. The only scientific biography hitherto published, that we know of, is that by Gassendi, who obtained valuable materials for his work from Tycho Brahe's pupils, from the Danish savant Worm, and from a thorough study of the writings of the subject of his memoir, though much has appeared later that gives more of the details of his life that seems to have been overlooked, or not known, to Gassendi at the time of his writing. Dr. Dreyer has had ample opportunity to consult original sources for the materials of his account, and he seems to have spared no pains to give his readers a faithful rendering of Tycho's noble life.

The author first speaks of the revival of astronomy in Europe, by noticing the revival of science in Germany, early in the sixteenth century, the Greek astronomy that was prevalent, the new system of the world proposed, and in general, the state of astronomy in the sixteenth century. He next considers the family, childhood and education of young Tycho Brahe, and gives account of the construction of the large quadrant with which his early observations began. The new star of 1572 which he first noticed, that is still called Tycho Brahe's star, seemed to arouse his scientific energies, and set him at work with unwonted zeal. He wrote two books at different times in his life giving his opinion of the nature and supposed significance of this star, and the alleged appearance of other new stars. He gave some attention to astrology as was so common at this time and lectured somewhat on this theme. After a short period of travel he soon settled in his island home of Hveen, the seat of his Observatory and other buildings where so much of his valuable life was spent in assiduous devotion to the study of his chosen science. The detailed account of his work and the description of his Observatory and instruments with suitable illustrations are given fully and in attractive way in this book. The final chapter treats of the scientific achievements of Tycho Brahe and is an excellent summary of the victories won by this man for science in these early times which will make his name and fame household words forever. This book is the most important one for astronomical biography that has been published in late years.

A Treatise on Ordinary and Partial Differential Equations. By William Woolsey Johnson, Professor of Mathematics at the United States Naval Academy, Annapolis, Maryland. Messrs. John Wiley and Sons, Publishers, 15 Astor Place, 1889, pp. 368.

This book gives a treatment of the subject of differential equations complete enough for their general use in practical application, so far as this may be done without the use of the complex variable. Large space is given to geometrical illustrations in the use of rectangular co-ordinates, because the author thinks that the conceptions peculiar to the subject are more readily grasped by this mode of representation. Use is also made of singular solutions of ordinary differential equations and the concept of the peculiar feature in the partial differential equation. These points are important ones and make the book, in its general plan, a very desirable one for the student of mathematics who has only pursued a course of elementary study in calculus before undertaking special studies concerning the theory and use of differential equations. The author seems to have planned wisely in this regard, and he has written a book that will certainly meet a general want, in that it offers a plan of study adapted to the stage of advancement of students from the best colleges and scientific schools in which the subject of mathematics has the prominence it deserves.

The plan of this work comprises twelve chapters in which the following themes are discussed: Nature and meaning of a differential equation between two variables, equations of the first order and degree, equations of the first order and not of the first degree, equations of the second order, linear equations with constant co-efficients, linear equations with variable co-efficients, solutions in series, the hypergeometric series, special forms of differential equations, equations involving more than two variables, partial differential equations of the first order, and partial differential equations of higher order. Each of these chapters is divided into themes and discussed separately, and generally in so complete a way as to bring to mind easy and satisfactory conclusions. Take, for example, the chapter treating of equations of the first order, but not of the first degree. It is presented in three divisions, the first part considers decomposable equations, equations properly of the second degree, systems of curves corresponding to equations of the second degree, standard form of an equation of the second degree, singular solutions, the discriminant, cusp-loci, tac-loci and node-loci, followed bv two pages of illustrative examples.

We take pleasure in calling the attention of teachers and students of mathematics to this book, as one in which they will be interested, if they are prepared to read by previous thorough study of the elementary mathematics leading up to it.

THE SIDEREAL MESSENGER.

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 10, NO. 4. APRIL, 1891. WHOLE NO. 94

AN IRREPRESSIBLE CONFLICT.

LEWIS BOSS.*

FOR THE MESSENGER.

From the issue of the first volume of the publications of our government Observatory in Washington, the antagonism between "U. S. National "and "U. S. Naval" may be said to have begun. Secretary Bancroft had christened it "National"; but in the Observatory volume for 1845, which bore on its printed title-page the right name, "National," another was interpolated upon which was engraved the word "Naval." In the next few years the term "National" asserted its supremacy, until in 1854 the Secretary of the Navy, Hon. J. C. Dobbin, settled matters in these words: ... "My opinion is that it should be styled 'The U. S. Naval Observatory and Hydrographical Office.' ... It is a Navy affair, and its reputation is the property of the Navy. If it assume another name and character, *the next step will be to place a civilian at its head.*" The italics are mine. Secretary Dobbin was doubtless thinking of the memorable efforts of John Quincy Adams to establish a National Observatory, of his efforts to secure the interest of the Smithson fund for that purpose, and of the clear-sighted views of that great statesman, who said: "The express object of an Observatory is the increase of knowledge by *new discovery.*" (The italics are not mine in this case.) He might also have suspected or even have known that what little reputation the infant institution had gained during the first seven or eight years of its existence had been the merit of civilians like Coffin, Hubbard and Walker, whose lot at the Observatory had been far from a happy one—a fact which we are permitted to suspect had not altogether escaped the knowledge of Secretary Dobbin.

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* Director of Dudley Observatory, Albany, N. Y.

How vital to the reputation of the new Observatory had been the services of a few of the leading civilians employed there may be judged from the almost total eclipse of that reputation which occurred during the fifties, when only a small contingent of civilians like Yarnall and Ferguson remained in the atmosphere of the quarter-deck. One reads with amazement the "details" for the instruments in those earlier years,—the only astronomers of the institution serving at the foot of the lists, under the direction of lieutenants of the Navy. Is it any wonder that the "zones" which were observed in those years by direct order of Secretary Bancroft (March 6, 1846) are without a rival in that period, either for inadequacy in amount of observing, inaccuracy of the observations, or good-for-nothingness generally. Yet a line officer of the Navy, a trained "executive officer," was in charge of each instrument. And what .an inspiration to work lay in that order of Secretary Bancroft. Referring to the report of Lieut. Maury, your observations to further the interests of navigation are well enough, he said, but "The country expects also that the Observatory will make adequate contributions to astronomical science;" you must take up the observation of small stars where Bessel and Struve left off, and with the advantage of your more southern latitude, carry these to the southernmost practicable limit. It was a good program and the matter was particularly timely. It was a trumpet call calculated to inspire the heart of any astronomer who had feared that our government would not lend its open sanction to the work of original research. Had it been carried out with skill and effective zeal, what a monument to the credit of American astronomy might the results have been, instead of the reproach which they actually are. Unfortunately the president at that time concurred with Bancroft's wish and sent him abroad six months after the issue of the order that directed the National Observatory to work on the zones. Had he remained at his post until 1849, it is quite possible that Walker, or some equally capable, practical astronomer, would have been placed in charge of the Observatory, with results vastly different from those which have been experienced.

It is true that some respectable work was done at the

National Observatory during the first four years of its existence (but not on the zones). That of the next four years is practically worthless, except some of the work with the 9.6 inch equatorial. Afterward, until 1861 the astronomical history of the Washington Observatory is almost a blank except for the observations made by two or three civilian members of the staff, who kept the lamp of science burning under a bushel, as it were, during the whole of that lamentable period.

It is true, also, that Lieutenant Maury, in his capacity as chief of the Hydrographic Office, made those remarkable investigations in regard to the winds and currents of the ocean which will cause his name to be forever remembered among nautical men. But these investigations were no part of the work of an astronomical Observatory, and they form no part of its actual record. They prove how efficient a man can be in directing scientific work for which he has aptitude and special training and experience; and, by contrast, how ignominiously the same man may fail, even with the aid of able assistants, when he attempts to direct scientific work for which he has not been thoroughly educated and trained, and in which he has had no adequate practical experience.

How much better a practical astronomer can direct the labors of an Observatory was well illustrated in the period, 1861 to 1865, when Captain Gillis became superintendent of the Naval Observatory. Perhaps the best proof of his wisdom and efficiency was exhibited in his choice of new assistants, and in the rapid recognition of their special talents. Whatever confidence he may have had in the astronomical effectiveness of the versatile young officers of the Navy was probably destroyed by an inspection of the work which they had done for him, as his assistants in the U. S. Naval Expedition to Santiago de Chile. The good effects of his administration, reinforced by the favorable circumstances of the next two years, under the superintendency of the accomplished Admiral Davis, lasted for years after that time, and this constitutes the golden age of the Washington Observatory. Captain Gillis may not have been entitled to rank among the ablest astronomers which this country has produced, but he was nevertheless an astronomer, and felt an earnest and intelligent interest in the scientific reputation of our National institution.

It is not strange that about the time of his death, the old desire for a National Observatory should have flickered into life again. We see the evidences of this in the Act of Congress, approved March 3, 1865, by which the "rider" in the appropriation bill of 1848, providing that the superintendent should be a Naval officer, was repealed; and stands repealed up to the present time. With the history of this legislation, and with the plans and efforts by astronomers of that time to bring about a reform in the system of management at the Naval Observatory, we of the younger generation are not generally initiated, and it may not be worth while to inquire. But we do know that from that time to the present there has not been an hour when the astronomers of the country have felt that the National Observatory can be the representative of American astronomy that it ought to be, and that the public have the right to expect it to be, under any other than a responsible and competent scientific head.

Twice within the last dozen years the astronomers of the country have raised protests against the present system of management; and once their wishes came near realization in part, failing only for reasons which none of us care to recall to mind. In neither case was the issue direct, or the trial on merits satisfactory.

It was in 1865 that the rule of a line of distinguished Naval officers of high rank was inaugurated. During this period of nearly twenty years, no very serious complaint on the part of astronomers was heard during the incumbency of a superintendent. Men of great personal dignity of character, of national reputation, and who in long terms of professional service, some of it passed in the great struggle for national integrity, had deserved well of their country,—these men could not be seriously antagonized. *Silent leges inter arma.* It was in the interval between the administrations of Admirals Rogers and Rowan that the first well organized movement to place an astronomer in charge of the Observatory was made. But in 1885, astronomers felt no such personal check as had been implied by the incumbency of these distinguished Admirals, whom a grateful country delighted to honor.

The system had been a bad one for the true interest of astronomy in spite of the liberal and judicious executive management of those distinguished men. The Observatory has always been, since 1865, an astronomical mob, sometimes successful in attaining the most brilliant results by individual prowess; but always lacking in co-ordination of work, and wasteful of effort; excelling in theoretical rather than in practical astronomy; sending forth beautiful researches rather than refined and well digested results of observation; relying for excellence and its rewards upon the efforts of a few men working practically without any direction whatever, rather than upon the disciplined and well directed efforts of an entire staff.

It is true that much of the observing work of our national institution is good, and much of it is excellent and even unsurpassed. For the most part, the subordinates at the Observatory are as earnest, faithful and capable as are the men in similar relations in any other great national institution of the kind. But any one who is acquainted with the inner workings of that establishment knows the peculiar difficulties under which an astronomer must labor. Placidity and longevity are the stepping stones to material success, which no zeal, no eminence of acquirement can hasten, and no laziness nor incompetence delay. It is idle to assert that astronomers are not, like all the rest of mankind, to some extent influenced by the hope of material rewards. There is probably no class of workers more indifferent to the matter of pecuniary compensation than astronomers are; but he would be a rare and peculiar man indeed who would not hold and justly hold, that the material rewards of intellectual achievement must be to some extent proportioned to the quantity and quality of results produced. One would scarcely have the hardihood to deny, that in the human relations which astronomers, in common with all other men, are bound to form, that the hope of pecuniary reward even for the highest and most unselfish intellectual effort, is recognized as an incentive. Yet the young astronomer entering the corps of Professor of Mathematics, U. S. N., comparatively undeveloped and untried, sees his entire material future marked out for him in undeviating lines. The most ordinary good behavior, the most perfunctory attention to duty, will secure this future for him quite as certainly as will the genius of a Newton, or the colossal labors of a Herschel. To be sure the main incentives still remain,—the pride of achievement, and that which is the most powerful of all, the love of scientific investigation in and for itself; but these are not alone what governments must rely upon for securing the most uniformly effective and economical service from those whom it employs.

Probably the management of our Government Observatory by almost any competent astronomer would be more exacting in requirements than the management now is. It is not likely that any astronomer at the Naval Observatory, in recent years, could justly complain of overwork exacted from him, or of any lack of considerate courtesy from his superiors of the Naval line. But for the sake of illustration, one may easily imagine that the feelings of an astronomer on the Naval Observatory staff must be very much akin to those which the passengers on an ocean steamer would feel, if an astronomer who had passed all his life upon land were invested with supreme command on the bridge. The proposition needs only to be stated to an astronomer in order that its full force shall be appreciated. During the last decade there has been a distinct retrogradation at the Naval Observtory in the output of results as well as in *morale*. There is probably not a practical astronomer in the land who does not realize this fact. During the last year or two, there have been increasing indications that the old, irrepressible conflict is about to break out again with renewed force. The epoch of proposed removal from the old to the new site is rapidly approaching. Before, or soon after this is effected, arrangements must be made which will be likely to fix the character of the National Observatory for a long time to come. Whether anything will be accomplished to make this institution an object of pride to American astronomers and the country at large rests with astronomers themselves. The responsibility cannot be evaded. Now while astronomers universally recognize the righteousness of this cause, one constantly hears the time-serving caution: "The Navy is too strong." The writer himself does not claim exemption from having entertained this feeling. But it should be remembered that in all history the rightfulness of a cause is the strongest element for ultimate success. Organization, numbers, interest at court, superior finesse in inducing opponents to adopt arguments and propositions destructive of their own reasoning and in promoting divisions in the ranks of astronomers, may postpone a correct decision on the merits but cannot ultimately prevent it. The conflict is irrepressible.

Congress is a fair-minded tribunal when its attention can be directed to a subject like this. That has been emphatically proved by its action in reference to the antagonism between civilian and army surveys for geographical and geological purposes. The Army contended for its supposed prerogatives quite as sturdily as the Navy can hope to do in the case of the Naval Observatory. The Army could produce a score of weighty arguments in its favor in the former case where the Navy can produce one in the latter. And yet Congress made short work of the matter when its attention was once effectively drawn to the point.

The history of the transfer of the Weather Service to the Agricultural Department, under a civilian organization is another illustration of the manner in which Congress deals with this class of questions when it is made to understand the merits. The agitation in this case had to be kept up for a longer time than was necessary in the matter of the geological and geographical surveys, but the final result was the same, and the new organization, civilian throughout, will soon go into operation. Yet with its large *personnel*, and with the complicated business details of the Weather Service, the argument for military discipline and for the necessity and propriety of making mere executive capacity the chief function of its responsible head was ten times as strong in this case as it is in the matter of the Superintendency of the Naval Observatory. The Army had created the Weather Service and developed it to its present proportions with relatively far less assistance from professional men of science, than is the case with the Naval Observatory.

There is no other country in the world of great importance which has not at least one National Observatory under a responsible scientific management, and the director is usually a man of high astronomical attainments. The policy of the leading powers has provided for several such institutions under national patronage, every one of them in charge of a professional astronomer. There is, furthermore, nowhere except in this country a Naval Observatory which pretends to any rank as an astronomical institution. Ours is the only country in the world, and in all history, in which any footing has been secured for the doctrine that a National Observatory can be more advantageously managed by men who are not astronomers, and that astronomers are by nature incapable of exercising such a trust. This charge is an imputation on every American astronomer which should be resented, for it applies, if at all, to American astronomers alone. One needs only to glance at the roll of successful directors of large national astronomical institutions in other lands to see what a grievous insult to American astronomy our system with its implication is. Not to mention the present distinguished incumbents, who are almost invariably highly competent men in every respect, we have, among others, in the list of directors of the Royal Observatory at Greenwich, Flamstead, Bradley, Maskelyne, Pond and Airy; at the Cape, Maclear and Stone; at Paris in recent times, Arago, Le Verrier and Delaunay; at Berlin such men as Encke; at Vienna, Littrow; at Poulcova, the Struves. These are but few of the names that could be mentioned to combat the ridiculous proposition that astronomers cannot successfully manage a great National Observatory,—a proposition which is, perhaps, too much dignified by serious refutation.

It is a reflection upon the astronomers of this country, so long as the present system endures,—upon the country for lack of intelligence, or upon astronomers for incompetence, or in equal measure upon both. There is no escape from this conclusion.

Dudley Observatory, Feb. 23, 1891.

THE PROPER MOTION OF Σ 1321.

S. W. BURNHAM.[*]

FOR THE MESSENGER.

The components of the double star, Σ 1321, constitute a system similar to 61 Cygni, but one even more interesting in

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[*] Lick Observatory, California.

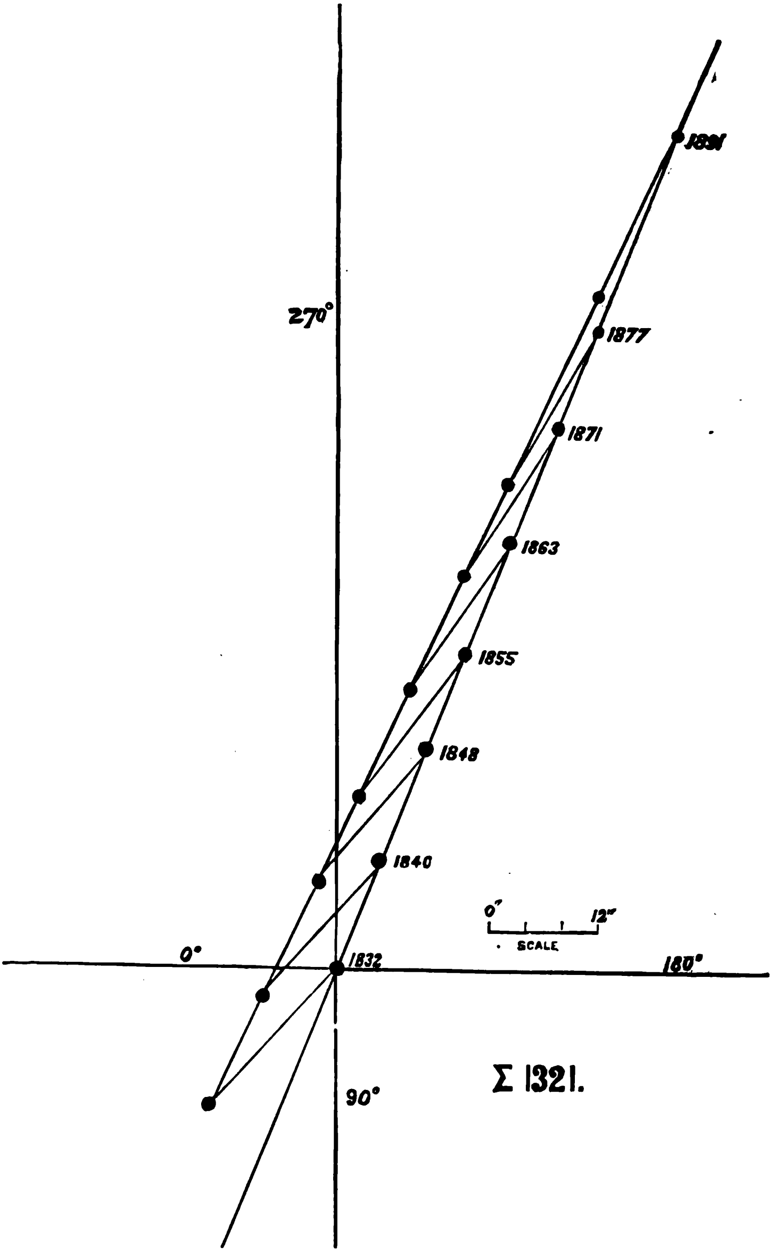
some respects, and particularly so far as the proper motion of the stars is concerned, although the movement in space is slower, and the stars much more distant as shown by the parallax observations. The parallax of the principal star of Σ 1321 is given by Kapteyn as 0″.087 (*A.N.* 2935), but this may be considered as subject to a relatively large correction, and perhaps only indicates that the star probably has a small parallax. The proper motion of this star according to Argelander is 1″.69 in the direction of 247°.5. For a long time it has been apparent from the measures of A and B that their relative motion was very small, the change in angle since the measures of Struve in 1832 being only 14° with diminution of about 0″.6 in the distance.

The original of the accompanying diagram was made on a scale of 8″ to the inch, and then reduced in the camera to the size here shown. A list of carefully selected observations by the best observers, at intervals of six or eight years, was made, and the measured angles and distances of B platted accurately to scale from the several positions of A along the line of its movement as determined by Argelander's proper motion. Thus we have a graphical representation of the two stars precisely as they were at the respective times.

The measures used are the following:

1832.96	48°.4	20″.10	Σ	3n
1840.32	50 .5	20 .18	*O*Σ	3n
1848.57	52 .2	20 .00	*O*Σ	4n
1855.17	53 .6	19 .59	De	4n
1863.12	55 .7	19 .73	De	5n
1871.24	57 .3	19 .67	Du	3n
1877.97	59 .2	19 .63	Hl	9n
1891.11	62 .4	19 .42	β	3n

The several positions of B fall almost exactly in line, so that there is no uncertainty as to the direction of its motion. This star is moving in the direction of 244°.5, and, therefore, makes an angle of exactly 3° with the path of A. The movement of B during this interval of nearly sixty years, as measured on this drawing, is a trifle over 0″.1 less than the assumed motion of A; and it is, therefore, safe to say that the two have the same proper motion, since the apparent difference is far below the ordinary errors of observation, and the chance of getting a less difference in stars of exactly the same proper motion would be exceedingly small.



Σ 1321.

Among the stars which are apparently only optically double, we have many examples where the known proper motion of the primary is also that of the companion, so that the two stars have remained unchanged with relation to each other, but I do not recall any other instance where these motions are practically the same, but in a slightly different direction. Other examples will doubtless be found when pairs with apparently the same movement are more fully observed.

I have previously shown with deference to 61 Cygni (SID. MESS., Jan., 1891) that the paths of the two stars make with each other an angle of 2°.0, while the difference in proper motion amounts to $0''.8$ annually, which is larger than any probable difference between the motions of Σ 1321 during the whole period of observation.

It will be seen from the diagram that the paths of these two stars will soon cross each other, but evidently there will be little change in the distance during the next century. The comparatively rapid change in the relative positions of the stars of 61 Cygni is the result, not of their greater proper motion, but of the inequality of the two motions.

PHENOMENA OBSERVED UPON SATURN AT THE TIME OF THE PASSAGE OF THE SUN AND OF THE EARTH THROUGH THE PLANE OF ITS RINGS, IN 1877-1878.*

E. L. TROUVELOT.†

IV. *The Anterior Part of the Ring Appears Narrower than its Posterior Part.*

We have observed another phenomenon, which, if it is not in direct relation with those which we have just made known, is nevertheless very interesting, for it indicates that there are still obscure points for us regarding the rings of Saturn. In fact, Dec. 6, 1878, we were able to prove with clearest evidence that the anterior part of the ring which passes before the globe (Fig. 7) was much narrower at A, against the eastern limb, than it was at P on the posterior part which received the shadow of the globe. At A, the ring was represented by a narrow luminous thread, perfectly

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* Continued from page 125. † Observatory at Meudon, France.

defined, which had scarcely a quarter of the size which it seemed to have at P. This observation made under the most favorable atmospheric conditions was immediately represented by the drawing of which Fig. 7 is a faithful copy.

December 7, 8, and 11 the same phenomenon was again observed. On the 12th it was still visible, but the thread of light representing the anterior ring was already much less narrow than on the preceding days. On the 14th it had resumed its normal form and the ring appeared perceptibly equal in size on the two opposite parts. It is perhaps worthy of remark that from Dec. 6 to 13, one saw no trace of the nebulous ring C on the globe, and that the opening of the eastern end was completely invisible, while one could easily distinguish that of the western end. Nevertheless the opening of the eastern end, invisible the 6th, 7th, 8th, 11th, 12th and 13th of December, was on the 14th as easily seen as it was at the opposite end.

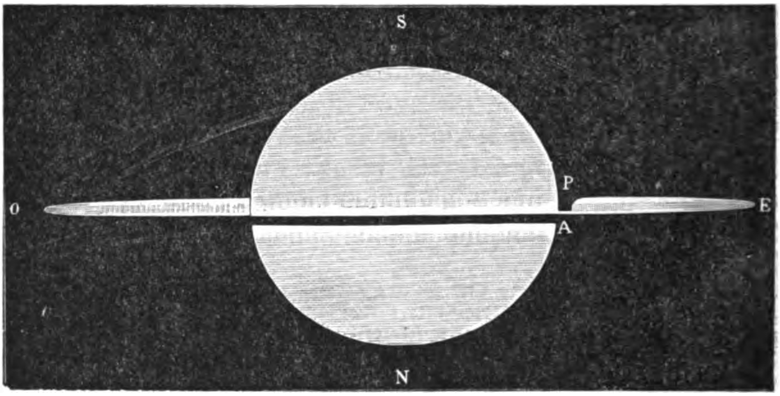


Fig. 7.

In the actual state of our knowledge of the rings of Saturn it is very difficult to explain this phenomenon. Should it be attributed to a partial and momentary super-elevation of the protuberant zone of which we have spoken, or is it indeed the result of an unknown cause which we have already had occasion to suspect? The observation does not furnish us any data for replying to these questions.

Dec. 6, 1878, the earth was at —1° 47′.3 above the plane of the rings (Fig. 1). If the phenomenon in question was due to the momentary elevation of a part of the protuberant zone, making a screen to the more distant parts, the phenomenon must be quite rare; for, from May 1 to Aug. 15, 1877, and from Nov. 10 to Dec. 6, 1878, our globe was less elevated above the surface of the rings than at this last date, and yet the 43 observations made during these two periods revealed noting of the kind; if the phenomenon existed it passed unperceived.

V. *Disappearance of the Rings of Saturn.*

As we have shown above, the illuminated part of the ring, gradually swallowed up by the shadow, was reduced to such fine proportions Feb. 5, 1878, the evening before the passage of the sun through the plane of the rings, that it was very difficult to recognize it. Feb. 6 the planet was observed at 6 P. M.

Had the sun already passed to the south side of the rings? I do not know, but I could not see the least trace of the luminous thread observed the evening before. At this time the conditions of observation were very bad, because of the proximity of the sun and of the horizon. Yet one could readily recognize the ring on the globe where it appeared like a rather dark, grayish band.

February 7, 11, 16, 18, 19 and 27 one could distinguish with more or less ease, two short and pale triangular appendices of which the base rested on diametrically opposite points of the limb, almost in the prolongation of the dark band which represented the obscure ring crossing the planet. This sort of handle, whose light was very pale, showed a very diffuse border which it was almost impossible to catch, and which one might attribute to the light reflected across the opening of the rings. On three different occasions, February 7, 16, and 19, I thought at certain moments I could catch some traces of a feeble thread of light discontinued at each side of the planet, but the impression was so fleeting that I cannot affirm whether I was dealing with a reality or an illusion.

Saturn was again observed February 9, 13, 24 and 26, then the first of March, but under such poor conditions that I could not obtain any results in which one could place confidence. After March 1st, the day when the earth passed through the plane of the rings, it became impossible to observe the planet, it was so near to the sun.

VI. *The Deformation of the Limb of Saturn.*

My observations show also the deformations of the limb of Saturn which were sometimes very apparent. For instance, on the 8th of May, 1877, the edge appeared quite strongly flattened on its southeastern part, which formed a straight line instead of a curve. Jan. 30, 1878, a similar flattening was seen on the south-southeast. Dec. 19, 1880, the limb seemed much flattened on all that part which is contiguous to the shadow of the globe on the rings. Jan. 25, 1878, the limb was much flattened in the polar regions especially the southern one.

Aside from these accidental and temporary deformations of the limb, the globe of Saturn seems also subjected to changes of form which last a longer or shorter time. In any case this globe has not the form of a regular ellipse, but rather that of a flattened spheroid. Feb. 5, 1878, when the ring, almost invisible, did not inconvenience the observation at all, it became evident that the globe of Saturn is a special spehroid of which Fig. 2 gives an idea. It is the "square shouldered" form of English observers, which is a curve with fine face. The real form of Saturn can not be discovered, of course, except toward the time when the earth is very near the plane of the rings, for the higher it goes the more does the form of the planet approach a circular figure.

For this same reason it is toward the time of the passage of our globe through the plane that we should measure comparatively the polar and equatorial diameters to obtain the flattening.

From these observations the conclusion is that we sometimes see on the limb of Saturn deformations which at times appear considerable; these deformations, which are always temporary, may be real or apparent. Any cause which would darken a certain extent of the materials which compose the edge of the planet would produce a deformation apparent and not real, like that which would result from the temporary displacement of the matter composing the limb. Although we see nothing which can be opposed to one of these explanations more than to the other, yet we are rather inclined in favor of the first, which seems to us most probable, in which the deformation is apparent and not real. In fact, we have sometimes observed deformations quite remarkable, Oct. 28, Nov. 11, 16, 18, 19 and Dec. 28, 1880, when the southern polar cap presented itself to our sight under the characteristic form of a very flat cone, and it was only after several observations of the same phenomenon that we were able to convince ourselves that this conical form was only apparent and due to the darkening of the two arcs reaching out to the limb.

VII. *The disc of Saturn has not a Uniform Luminous Intensity.*

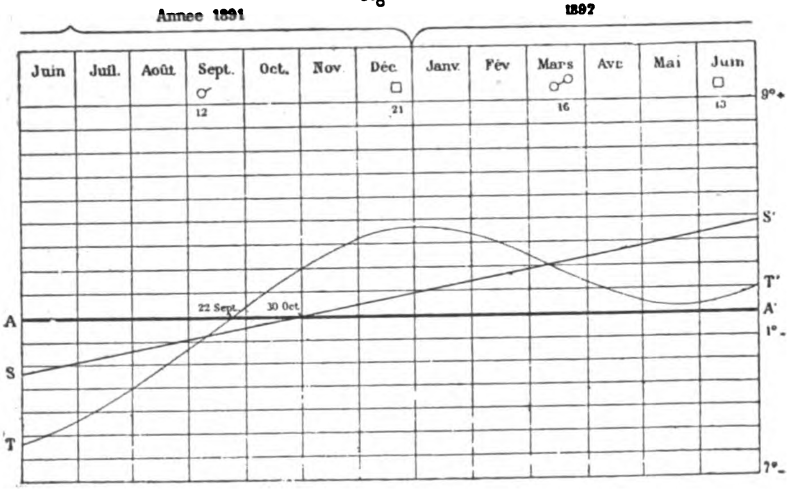
The opinion already expressed that the globe of Saturn, unlike that of Jupiter, shines with greater brilliancy toward its periphery than toward its more central parts, has not been confirmed by our observations. In fact, while these observations do not once mention that the edge of Saturn is more luminous than the other parts of the disc, they show, on the contrary, that on Sept. 25, Dec. 18, 28 and 29, 1877, as well as Oct. 28, Nov. 24, and 26 and Dec. 6, 14, 22 and 28, 1878, this edge like that of Jupiter, was notably less luminous than the other parts of the globe.

These observations show also that on Sept. 25, 1877, Oct. 28, Nov. 24 and Dec. 12, 22 and 28, 1878, the half of the limb most distant from the sun appeared considerably darker than that which was turned toward the sun. If the last phenomenon did not indicate the beginning of a phase, it was at least the forerunner, and probably was nothing else but the kind of penumbra which on the planets always accompanies their phase. The observation of Sept. 25, 1877, was made only 17 days after the opposition of Saturn, while that of Oct. 28, 1878, was made 38 days after the following opposition; also the darkening of the penumbra was much less pronounced, especially for the second date, than it was on Nov. 24 and Dec. 14, 22 and 28 when the planet was much nearer quadrature, where the phases become the most accentuated.

VIII. *Remarks and Suggestions on the Observations to be made on Saturn in 1891-1892.*

The approaching passage of the earth and the sun through the plane of the rings will not take place under conditions the most favorable for the delicate operations which relate to the simultaneous observation of the protuberant belts belonging to the north and south surfaces of the ring, for Saturn will be at that time too near the sun, and aside from that the passages of the two bodies are too distant the one from the other.

Fig.8



Apparent path of the sun and of the earth with reference to the plane of the rings. AA′ plane of the rings; SS′ position of sun; TT′ position of earth.

In examining the diagram (Fig. 8), one can easily see that the protuberant belt of the ring B, if, as we have supposed, it is true that this belt exists, cannot show simultaneously its opposite sides in 1891 because of the opaque screen formed by the ring A, which will prevent the solar rays from lighting one of them and consequently it will remain invisible. In fact, when, toward the middle of September, the elevation of the earth will not be more than — 0° 20′, the opposite surface as well as its protuberant zone will both be still in darkness, the height of the sun at that date being still — 0° 42′. Sept. 22, when our globe will cross the plane of the rings, the sun will be 0° 35′ south of the ring, a height more than sufficient for the ring A to intercept the sun's rays and prevent the zone from receiving them. It will be just about the same after the passage of the earth to the north of the plane of the ring.

When the sun will have lowered on the southern surface enough to lighten the northern protuberant belt, the earth will be too much elevated above the northern surface to allow anyone to see the southern belt hidden by the screen A.

On the other hand, when the sun in its turn passes through the plane of the rings, Oct. 30, the earth will be much too high, about 2°, for the protuberant part B to be visible. There is then little probability that this interesting phenomenon can be proved in. 1891 unless the shadow of the ring, enlarged by the protuberant zone will permit us to arrive at the same result when the sun has become very oblique.

But it will not be the same for the other phenomena, which we have explained in sections one, two and three which can be examined at leisure before and after the crossing of the two bodies through the plane of the rings, although the proximity of the sun may inconvenience the observations somewhat, especially at the time when they offer the greatest interest, *i. e.*, at the moment when the illuminated surface will become very small.

The phenomenon of the swallowing up of the illuminated part of the ring by a shadow can be observed from the middle of July to the beginning of September; for after the 10th, the elevation of the earth above the southern surface of the ring becoming inferior to that of the sun, the shadow will become invisible to the observer until Oct. 30, the day of the passage of the sun through the plane of the rings. After this last date one can observe at leisure the retreat of the shadow on the ring and the gradual enlargement of the lighted surface until toward the middle of February 1892. As to the decrease and increase of brightness of the opposite surfaces of the ring, the southern surface can be observed from Jan. 13 to Sept. 22, 1891; and the northern from Nov. 1 of the same year to Aug. 21, 1892. In the months of

April, May and June 1892, the earth and the sun will be situated, with regard to the northern surface of the ring, very nearly as they were for the southern surface in 1878 (Fig. 1) that is to say, at this time our globe approaches very near the plane of the ring, while the sun is at quite a distance from it. One could at this time ascertain whether phenomena of the same kind as those which were observed Dec. 6, 7, 8, 11, and 12, 1878, are visible. The conditions will be the most favorable possible for this kind of observations, in the first place because Saturn will be near quadrature, the time when the shadow of the globe on the ring and that of the ring on the globe reach their maximum of development, and also because, in 1892, our globe will approach much nearer the ring than in 1878. In fact, while on the 6th of December the earth was situated at —1° 47′.3, on the 20th of May, 1892, it will be at + 0° 22′.2; only, on May 20, the time when our globe will be the nearest to the surface of the ring, the shadow cast by the latter upon the globe will be perhaps a little too much separated from the exterior edge of the ring A; which condition would be less favorable for judging of the size of the anterior part of this ring. In any case, the observations made in the month of May 1892 can not fail to be extremely interesting, for the eye of the observer skimming over the surface of the rings, lighted then by a sun elevated nearly 3°, cannot fail to notice very interesting things about the structure of the rings as well as con-

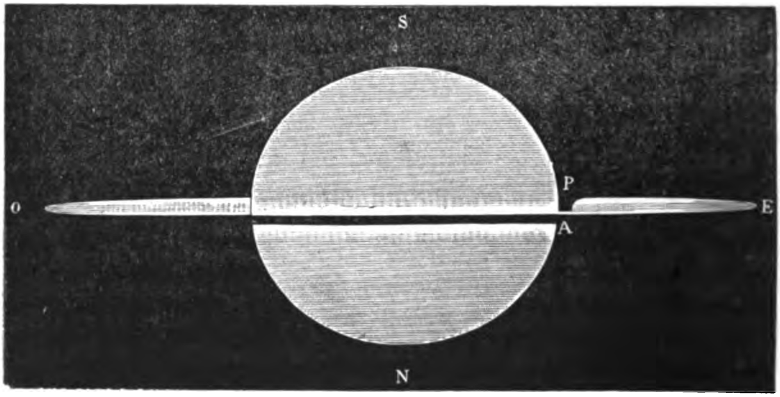


Fig. 9.

cerning the cause of the encroaching shadow which we observed in 1877-1878.

Fig. 9 is a projection of the rings and represents them as they ought to appear May 20, 1892 if their surface were flat.

In order to observe with profit, toward the time of the passages of the sun and the earth through the plane of the rings, we advise observers to prepare in advance projections of the rings of Saturn according to the apparent elements of the rings given in the *Nautical Almanac* for the date of each contemplated observation; in this way it will be easy to know whether the observation agrees with the projection. Since certain phenomena can be seen in broad daylight, Saturn can be observed at the most favorable moment of the day when there is any advantage in doing it.

THE ORIGIN OF THE STELLAR SYSTEMS.

T. J. J. SEE.*

FOR THE MESSENGER.

In the February number of THE MESSENGER I have pointed out what I am convinced is the physical meaning of the high excentricities of the stellar orbits. The mathematical investigation therein referred to seems to show that tidal friction is an amply sufficient cause to account for the great excentricities, but to complete the syllogism we ought to show that no other possible cause can be assigned as the source of the observed phenomena. The array of multitudinous resources revealed in the Cosmos is such that in general it is difficult to set rigorous bounds to the possibilities of nature. Fortunately, however, in this particular case the circumstances surrounding the question at issue are such as to justify the belief that in general no other cause than tidal friction can be assigned to account for the excentricities observed in the binary orbits. Some astronomers may conceive that the excentricities indicate the fortuitous origin of these systems from separate stars. A little reflection, however, will make it clear that such an hypothesis is

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untenable. For such a chance orbit would be in general hyperbolic; and it is easy to show that should the orbit in some cases even be elliptic, its absolute dimensions would very far exceed those of binary orbits hitherto computed. Professor Lockyer in his "Meteoritic Hypothesis" has suggested that double stars originate through the approach of separate swarms of meteorites. But this suggestion, to my mind, is even more unsatisfactory than the foregoing, since it not only encounters the same difficulties, but must in addition explain how the smaller swarm would escape disintegration under the action of the chief swarm. For the smaller swarm would enter on an orbit highly elliptic or hyperbolic. In case the orbit is elliptic the disintegrating action of the larger swarm, in a comparatively short time, will scatter the meteorites of the smaller swarm along the whole length of its orbit—reduce it [as the sun reduces a comet] to a train of meteoric dust. Moreover, the observed excentricities of the stellar orbits are in general hardly sufficiently high to support this hypothesis.

Again, it has been suggested that an explosion in the process of separation has rendered the orbit of the detached body so highly excentric. This suggestion of explosions is purely an hypothesis, and we are not able to affirm that such phenomena really take place, except probably in our sun. But granting that they really take place in nebulæ, it seems very difficult to see how such explosive action could divide a nebula into two nearly equal masses. It seems more probable that the meteorites of a nebula under such conditions would merely be scattered in every direction, and that the parts would almost immediately fall back together. But even should the detached parts not immediately reunite to the largest remaining body they would revolve around it as meteoric swarms in excentric orbits, and it is impossible to conceive how, under the disintegrating action of the chief mass, they could ever be gathered into individual small bodies, much less could they be agglomerated into a second large mass.

All the foregoing hypotheses seem, therefore, to encounter fatal objections. I will now venture an hypothesis which demands nothing extraordinary, and rests, moreover, on a dynamical basis.

A homogeneous fluid sphere devoid of rotation is always in equilibrium, however its particles may be arranged with respect to one another. If this sphere be endowed with a slow rotation about any axis, it becomes a spheroid; here again we may suppose the particles exchanged with one another without any disturbance of the equilibrium. We may regard this homogeneous spheroid as made up of infinitely thin layers, all having the same ellipticity. If the rotation of the spheroid is quickened its ellipticity increases, and the ellipticities of all the strata increase equally rapid. The particles of a heterogeneous fluid sphere devoid of rotation are in equilibrium when and only when they are so arranged that the density decreases from the center to the surface. Such a sphere is composed of successive infinitely thin layers of a uniform density, but the layers decrease in density from the center to the surface.

If now the sphere be endowed with a slow rotation, it passes into a spheroid, and all its layers become spheroidal. But in this case of heterogeneity the layers do not, as in the case of homogeneity, retain the same ellipticity in passing from the center to the surface. The ellipticities increase, as is mathematically established by Laplace in the second volume of the *Mecanique Celeste.* Thus the ellipticities of the layers of a heterogeneous fluid spheroid in equilibrium follow a law the reverse of the densities. Sir John Herschel has observed that certain nebulæ actually appear to confirm this law. Since the ellipticities were zero when the body was devoid of rotation, it is clear that acceleration of axial velocity will cause them all to increase until a certain limit is reached. But all the ellipticities will not increase equally rapid; the ellipticities of the outer, less dense, layers will gain ever more and more rapidly upon the denser and less elliptic layers at the center. The divergence in the ellipticities thus increases as the rotation proceeds. With a given velocity of rotation the divergence increases with increase of heterogeneity. This being established, let us now consider some other figures of equilibrium. Throughout this discussion we are supposing the law of attraction to be Newtonian gravitation. In the figures of equilibrium hitherto determined, owing to mathematical difficulties at present insurmountable, nearly all investigators have presupposed the fluid to be homogeneous. Among the figures established on this hypothesis is the Jacobian ellipsoid of three unequal axes; and the spheroid may be regarded as a particular case where two of the axes of the ellipsoid are equal. This Jacobian ellipsoid set rotating in equilibrium about its shortest axis is rigorously stable.

M. Poincaré has discussed the dynamics of the Jacobian ellipsoid with particular care [*Acta Math.* Vol. VII]. He finds that as the rotational velocity of the ellipsoid increases the ellipsoid gradually flattens out, and finally passes into the accompanying very remarkable figure.

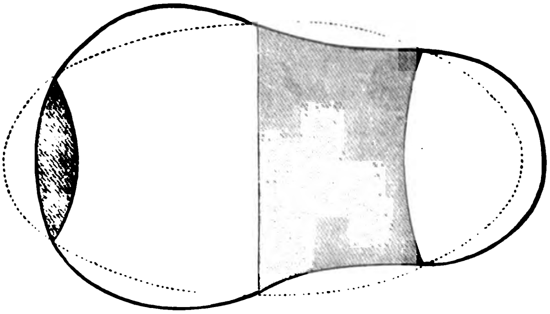

FIG. 1. SECTION OF M. POINCARÉ'S FIGURE OF EQUILIBRIUM. THE SHADED PORTION FALLS WITHIN THE ELLIPSOID.

Fig. 1 represents a section of M. Poincaré's figure through the shortest and longest axes (corresponding respectively to similar axes in the ellipsoid). This furrowing of the Jacobian ellipsoid parallel to its smallest section indicates, as M. Poincaré points out, a tendence of the body to split up into two comparable masses. At the stage represented in Fig. 1 the equilibrium is rigorously stable. M. Poincaré expresses disappointment in the conclusion of his excellent memoir that his investigation did not throw much light upon Laplace's Nebular Hypothesis. Professor Darwin undertook a somewhat similar investigation independently, and completed it after the publication of M. Poincaré's paper. He sought to determine the figure which two homogeneous spherical fluid masses would assume under their mutual attraction when set in synchronistic orbital motion about their common center of gravity so close together that their surfaces nearly touched. His result is given in Fig. 2—equal masses.

In Fig. 2 the whole sections are given—one through the axis of rotation, the other perpendicular to it. For details and an admirable discussion of this remarkable dumb-bell figure of equilibrium, see *Phil. Trans.* 1887.

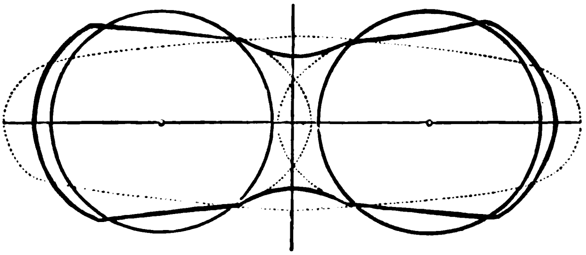

Fig. 2 (*a*). Section of Mr. Darwin's Dumbbell Figure of Equilibrium Perpendicular to Axis of Rotation. Dotted Section Jacobian Ellipsoid of Same Mass and Moment of Momentum. Scale one-third of the Original.

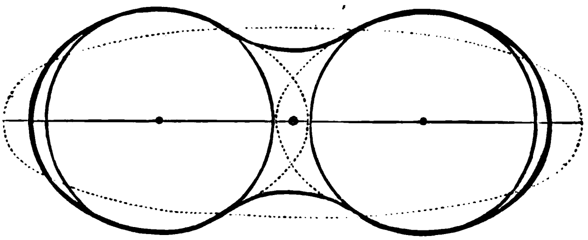

Fig. 2 (*b*). Section Through Axis of Rotation.

At the conclusion of his work Mr. Darwin, like M. Poincaré, remarks that but little help is gained towards understanding Laplace's Hypothesis. He adds that both his results and those of M. Poincaré's seem to show that the mass separated should bear a very much larger ratio to the parent mass than is observed in the planets and satellites of the solar system. He states that the mass separated can not bear a less ratio [in case of homogeneity] than about one-thirtieth. He agrees with M. Poincaré that when the equilibrium of the Jacobian ellipsoid breaks down, the body splits up into two comparable masses.

Now let us examine the significance of these mathematical results in our study of the origin of the binary stars. Before we proceed further let the reader compare the above figures with Sir John Herschel's drawings of double nebulæ, published in *Phil. Trans.* for 1833. Compare M. Poincaré's figure with the figures numbered by Sir John Herschel respectively 68, 69, 70, 71, 72, 73, 74 [representing the nebulæ numbered: 1252, 1202, 604, 1146, 444, 2197, 1408]; and I think it will be impossible to escape the conclusion that the foregoing mathematical results are exemplified in the heavens. Nebulæ absolutely homogeneous of course do not exist; yet there are abundant reasons for thinking that in many cases the departure from homogeneity is not very marked. If the nebula is not heterogenous to a considerable degree we may take the figures of M. Poincaré and Professor Darwin to represent substantially what would occur as gravitational contraction proceeds. And we may consider the figure of a nebulae undergoing development momentarily, but not secularly, stable, owing to the continual dissipation of its energy and the contraction consequent therefrom. Hence we see that if the nebula be homogeneous the mass-ratio which will obtain between its parts when it splits up will be a very large fraction, perhaps one-half, one-third, or one-fourth, or smaller, and possibly under certain conditions unity. The above mathematical investigations seem to show that in general the masses would not be exactly equal, but always comparable—*i. e.* always of the same order. If the heterogeneity be not very considerable, when the parent nebula splits up, this same relative mass-ratio will.be nearly maintained. There is reason to believe that many of the nebulæ are not very heterogeneous, and we ought therefore to expect a separation into comparable masses. This theoretic inference accords with the great number of double nebulæ and double stars actually observed in the heavens. The greater the heterogeneity the greater the divergence in mass-ratio from that obtaining in case of homogeneity. This clearly follows from what we have said elsewhere concerning the concentration of density about the center of the parent nebula, and the increase in the ellipticities of the strata as we pass to the surface. For the part thrown off will be taken chiefly from the peripheral regions of the parent mass; and even should the volume detached retain the same ratio to the parent volume as in the case of homogeneity, still the mass would bear a much smaller ratio to the parent mass, owing to the inferior density of the part detached. But in fact it is easy to see that both the mass and the volume split off will be less in case of heterogeneity. If the nebula be very heterogeneous the part detached ought to bear a very small mass-ratio to the central body. With respect to the planetary system this conclusion would seem to indicate that when the planets were formed our original nebula was very heterogeneous. Under this hypothesis our remarkable system is seen to be a particular case—an exception to the general process of cosmic evolution by which nebulæ develop first into double nebulæ, and then into systems of binary stars. Thus far the mass-ratio of the components of stellar systems has been determined satisfactorily from measurements in but few cases. But if we take the binary stars as a class we shall not err greatly in supposing the mass-ratio to correspond with the amount of light we receive, and this can be determined from the magnitudes of the stars.

In particular cases this method of inferring the relative masses of stars of a system from their magnitudes would doubtless fail. And in general the value thus deduced would probably be a little too small; still, it would at least give a rough approximation to the truth. It now remains to examine the orbit which the detached mass would pursue when first split off. From the very nature of nebular contraction we may with safety assume that acceleration in angular velocity proceeds slowly and steadily—there are no sudden jerks or stops. This being the case it is certain that separation takes place very slowly; and we may unhesitatingly affirm that in general many revolutions are performed while the splitting process is in progress. Sudden acceleration in angular velocity being impossible, we see that the orbit the detached mass begins to pursue must be nearly circular. Were the orbit highly excentric the action of the larger body would soon reduce the smaller mass to a train of meteoric dust; and when once strewn out into a girdle it could never condense into a star. But the mass split off being set revolving in an orbit nearly circular, the action of the larger body could not spread the smaller swarm out into a meteoric ring; and, condensation forthwith proceeding, it would escape disintegration when the orbit eventually became expanded and highly excentric from the secular effects of tidal friction. When just separated [as is apparently the case in Herschel's figure 68] the masses doubtless rotate and revolve in synchronism. But the dissipation of the energy of either mass soon permits gravitational contraction, and this causes the axial angular velocity to surpass the orbital angular velocity, and then tidal friction begins to operate. Under these conditions tidal friction increases both the major axis and the excentricity of the orbit. And in general these elements will continue to increase until the rotations of both stars are reduced to synchronism with the orbital revolution. When this state is reached, we have the maximum of excentricity; afterwards the excentricity is again very slowly reduced to zero by the secular action of libration. Such a rigid state would probably not be reached until both bodies have become entirely dark, since the angular velocity will continue to accelerate as long as contraction takes place. When finally this state is reached, however, the stars will show always the same faces to each other, and the system will continue to revolve as though rigidly connected forever, unless acted upon by external forces, or ethereal or meteoric resistance. These suggestions of secular dynamic instability have a particular interest also when applied to systems of the Algol type, where the bodies are not only both very large, but also very close together, and therefore the tides in all probability enormous. From what we have said it will appear that astronomers have hitherto greatly underestimated the importance of tidal friction as a formative agency in the history of the universe. It has certainly left a distinct impress upon the orbits of the stellar systems, and even in the case of the solar system it has exercised some influence. I do not therefore hesitate to rank tidal friction as one of the most important agencies operative in the development of the various systems of the Cosmos.

In conclusion I beg to add that this and my former article constitute only a very brief outline of the general conclusions at which I have arrived by the investigation mentioned. An investigation which explains satisfactorily the great excentricities of the stellar orbits, the large mass-ratio of the components, and intimately connects binary systems with double nebulæ, constitutes a coherent theory, of which the probability, to my mind, closely approaches certainty.

It is difficult to see how either M. Poincaré or Professor Darwin could have felt disappointed, had he realized the full significance of his splendid dynamical researches as applied in the Universe at large, and not merely as reflected by the solar system. It appears to me that more light will be thrown upon the general process of cosmic development, if, instead of studying the Universe in general through the solar system, we base our general deductions on a study of the double nebulæ and stellar systems. Thus we may hope eventually not only to attain to a safer scientific basis for stellar cosmogony, but we may also even approach the formation of the solar system from anew point of view—from the sidereal heavens. On first sight it appears doubtful whether the planets and satellites were separated, as Laplace, supposed, in the form of rings; a separation in the form of lumps or bulky masses seems in general more probable. Finally, whatever may prove to be the value of the ideas I have herewith advanced, it is but proper to state that whilst I began the investigation and arrived at the main conclusions independently, nevertheless in the exact mathematical investigation I have profited by a study of Professor Darwin's extensive tidal researches, and therefore I should be ungracious, if not, indeed, in some measure unjust, if I did not acknowledge my especial indebtedness to Professor Darwin for some methods of research employed in his excellent memoirs.

UNIVERSITY, BERLIN, PRUSSIA,
February 7th, 1891.

THE SPIRIT LEVEL.

A. HALL.*

FOR THE MESSENGER.

In connection with the interesting remarks of Professor Safford on observations with meridian circles I should like to call attention to the use of the spirit level.

In the description of the prime vertical instrument at Pulkowa W. Struve estimates the probable error of a single level determination as ± $0''.02$. On beginning observations

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* U. S. Naval Observatory, Washington, D. C.

with a similar instrument at the Naval Observatory thirty years ago it appears to have been assumed that this estimate was correct, and that the error of level could be perfectly corrected by means of the spirit level. The level was investigated in 1862, and again at the close of the work in 1867; and apparently it was an excellent instrument. On reducing the observations the results from the single wires on any day were generally in good agreement, but the results for different days were more discordant than one would expect. Discordances of this kind, however, are usual, but in this case they led me to suspect that the level had not always given the true position of the axis of rotation. This idea has been confirmed by the subsequent examination and use of a number of spirit levels, and I now think that the accuracy ascribed to this instrument has been exaggerated. It is only occasionally, I think, that one finds a spirit level in which the motion of the bubble corresponds exactly and readily to a small change of level. We ought not therefore to investigate a spirit level on a certain date, and at a certain temperature, and then assume that its action remains the same for a long time, and for all temperatures. I am inclined to question the practice of putting a level in a certain position and then to continue readings without touching it. It would be better to subject the level to a variety of changes. In fact this instrument should be used like any other, with the idea of eliminating constant errors that can arise from any defect or roughness that may cause the bubble to stick at a given position. It would hardly be worth while to observe the declination of a star on certain divisions of a circle for many years without examining the errors of graduation, and it would be better in any case to shift the circle so as to bring new conditions to bear in the determination of the star's position. This is only a step toward transferring constant errors to the class of accidental ones, something that should always be done if possible.

An example of trusting too much to the spirit level may be seen in the new determination of longitude between Paris and Greenwich.

March 10, 1891.

NEW METHOD FOR THE SIMULTANEOUS DETERMINATION OF LATITUDE AND AZIMUTH.

JOSEPH S. CORTI.*

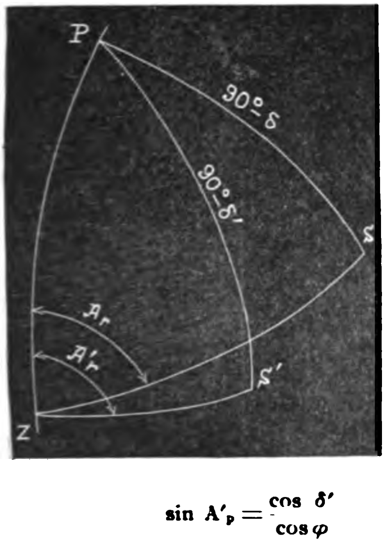
In this method we measure the difference between the azimuths of *at least two stars* when they are at their greater elongation, and we compute with that value and the declinations of both stars, the azimuth of each of them and the observer's latitude.

In order to get at the final formulæ let us consider separately the two following cases:

I. Both stars are on the same side of the meridian at their greater elongation.

II. One star is on one side of the meridian, and the other on the opposite one.

CASE I.



Let PZ be the meridian, S the position of one of the stars, of declination $\delta = 90° - PS$, at its greatest elongation PS its hourly circle and ZS its vertical circle.

Calling A_p the angle made by the vertical circle of the star with the polar side of the meridian; then $PZS = A_p$.

Also for the star S',

$PS' = 90° - \delta'$; $PZS' = A'_p$.

And $ZP = 90° - \varphi$, φ being the latitude of the observer's place.

The spherical triangles ZPS' and ZPS have their angles S' and S right; then:

$$\sin A'_p = \frac{\cos \delta'}{\cos \varphi} \qquad (1)$$

$$\sin A_p = \frac{\cos \delta}{\cos \varphi} \qquad (2)$$

Subtracting (2) from (1)

$$\sin A'_p - \sin A_p = \frac{\cos \delta' - \cos \delta}{\cos \varphi} \qquad (3)$$

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[*] Professor of Geodesy at the National Engineering School of San Juan (Arg. Rep.)

NOTE.—Ar and A'r in both cuts should read A_p and A'_p.

adding (2) to (1)

$$\sin A'_p + \sin A_p = \frac{\cos \delta' + \cos \delta}{\cos \varphi} \cdot \qquad (4)$$

and, finally, dividing (3) by (4)

$$\frac{\sin A'_p - \sin A_p}{\sin A'_p + \sin A_p} = \frac{\cos \delta' - \cos \delta}{\cos \delta' + \cos \delta}$$

Changing the sums and differences of sines and cosines into products in the last formula, we have:

$$\frac{2.\sin \frac{A'_p - A_p}{2} \cos \frac{A'_p + A_p}{2}}{2.\sin \frac{A'_p + A_p}{2} \cos \frac{A'_p - A_p}{2}} = \frac{-2.\sin \frac{\delta' + \delta}{2} \sin \frac{\delta' - \delta}{2}}{2.\cos \frac{\delta' + \delta}{2} \cos \frac{\delta' - \delta}{2}}$$

$$\therefore \frac{\operatorname{tg} \frac{A'_p - A_p}{2}}{\operatorname{tg} \frac{A'_p + A_p}{2}} = -\operatorname{tg} \frac{\delta' + \delta}{2} \operatorname{tg} \frac{\delta' - \delta}{2} \cdot \qquad (5)$$

Knowing the declinations of both stars the second number of (5) will be known and one of the quantities

$$\frac{A'_p - A_p}{2} \text{ or } \frac{A'_p + A_p}{2}$$

may be computed, should the other one be had by measurement.

In our Case I, the angle SZS′, that is, the difference between the instrumental azimuths of the observed stars, is just the value of $A'_p - A_p$, then from (5)

$$\operatorname{tg} \frac{A'_p + A_p}{2} = -\operatorname{tg} \frac{A'_p - A_p}{2} \operatorname{cotg} \frac{\delta' + \delta}{2} \operatorname{cotg} \frac{\delta' - \delta}{2} \qquad (6)$$

after which we may compute $\frac{A_p + A_p}{2}$.

Thence:

$$\left. \begin{aligned} A'_p &= \frac{A'_p + A_p}{2} + \frac{A'_p - A_p}{2} \\ A_p &= \frac{A'_p + A_p}{2} - \frac{A'_p - A_p}{2} \end{aligned} \right\} \qquad (7)$$

With each of these two values we may compute the latitude by:

$$\cos \varphi = \frac{\cos \delta}{\sin A_p} \text{ or } \cos \varphi = \frac{\cos \delta'}{\sin A'_p} \qquad (8)$$

Before considering Case II let us find the most favorable circumstance for the determination of $\frac{A'_p + A_p}{2}$ by (6) and for that of φ by (8).

Taking to simplify:

$$\Sigma = \frac{A'_p + A_p}{2} \text{ and } \Delta = \frac{A'_p - A_p}{2},$$

e. g. (6) may then be written down

$$\operatorname{tg} \Sigma = - \operatorname{tg} \Delta \operatorname{cotg} \frac{\delta' + \delta}{2} \operatorname{cotg} \frac{\delta' - \delta}{2}.$$

An error whatever on Δ will give an error on Σ, but no doubt, it will do nothing to $\frac{\delta' + \delta}{2}$ nor to $\frac{\delta' - \delta}{2}$; then in the last formula the two contangents will be constants, and Δ and Σ variables depending one from the other.

By differentiation of the last formula we have

$$\frac{d\Sigma}{\cos^2 \Sigma} = \frac{- \operatorname{cotg} \frac{\delta' + \delta}{2} \operatorname{cotg} \frac{\delta' - \delta}{2}}{\cos^2 \Delta} . d\Delta,$$

$$\therefore d\Sigma = - \frac{\cos^2 \Sigma}{\cos^2 \Delta} \operatorname{cotg} \frac{\delta' + \delta}{2} \operatorname{cotg} \frac{\delta' - \delta}{2} d\Delta,$$

Which shows that an error whatever, $d\Delta$ on the difference between the instrumental azimuths of the observed stars, will give us on Σ an error equal to the former multiplied by a factor

$$- \frac{\cos^2 \Sigma}{\cos^2 \Delta} \operatorname{cotg} \frac{\delta' + \delta}{2} \operatorname{cotg} \frac{\delta' - \delta}{2};$$

and as this factor will be smaller, the *greater* the difference $' - \delta$, then the most favorable circumstance for the computation of Σ is that in which

$$\delta' - \delta = \text{maximum} \qquad (9)$$

The value of A_p once found, *e. g.* (8) will give us the latitude by

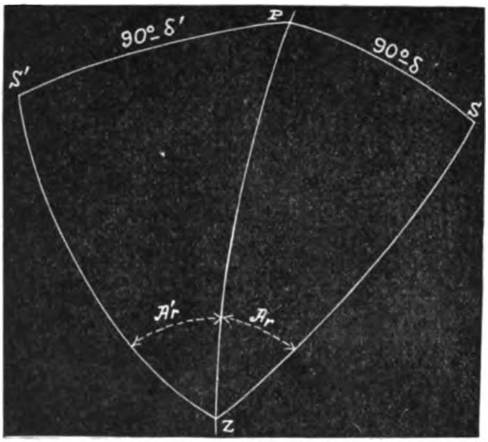
$$\cos \varphi = \frac{\cos \delta}{\sin A_p}.$$

Differentiating this equation in which A_p and φ are variables and δ constant,

$$- \sin \varphi \, d\varphi = \frac{- \cos \delta \cos A_p}{\sin^2 A_p} . dA_p$$

$$\therefore d\varphi = \frac{\cos \delta}{\sin \varphi} \operatorname{cotg} A_p \operatorname{cosec} A_p \,.\, d\, A_p,$$

which shows that an error on A_p gives on φ an error so much smaller, the farther the star will be from the meridian at the moment of its greatest elongation, that is to say, for a given place the best star will be the nearest one to the equator.



CASE II.

Let, as before, P and Z be the celestial pole and the zenith, S and S′ the stars observed at their greater elongation.

If δ, δ' and A_p, A'_p be the declinations of the stars and the angles made by their verticals with the polar side of the meridian, then

$$PS = 90° - \delta; \quad PS' = 90° - \delta';$$
$$SZP = A_p; \quad S'ZP = A'_p;$$

and also $PZ = 90° - \varphi$, φ being the latitude of the observer's place.

The spherical triangles SZP and S′ZP, rectangles at S and S′ will give

$$\frac{\text{tg}\,\frac{A'_p - A_p}{2}}{\text{tg}\,\frac{A'_p + A_p}{2}} = -\,\text{tg}\,\frac{\delta' + \delta}{2}\,\text{tg}\,\frac{\delta' - \delta}{2} \qquad (5)$$

In this case angle S′ZS = difference between instrumental azimuths of the observed stars $= A'_p + A_p$; then from (5)

$$\text{tg}\,\frac{A'_p - A_p}{2} = -\,\text{tg}\,\frac{A'_p + A_p}{2}\,\text{tg}\,\frac{\delta' + \delta}{2}\,\text{tg}\,\frac{\delta' - \delta}{2} \qquad (10).$$

from which we will get the values of A_p and A'_p by (7), and φ by (8)

Let us find for this case also the most favorable circumstance for the computation of $\frac{A'_p - A_p}{2}$ by (10).

Taking, as in case I, $\Sigma = \frac{A'_p + A_p}{2}$ and $\Delta = \frac{A'_p - A_p}{2}$, *e. g.* (10) may be written down

$$\text{tg}\,\Delta = -\,\text{tg}\,\Sigma\,\text{tg}\,\frac{\delta' + \delta}{2}\,\text{tg}\,\frac{\delta' - \delta}{2},$$

where the only variables are Σ and Δ.

Differentiating

$$\frac{d\varDelta}{\cos^2\varDelta} = -\frac{d\Sigma}{\cos^2\Sigma}\operatorname{tg}\frac{\delta'+\delta}{2}\operatorname{tg}\frac{\delta'-\delta}{2}$$

$$\therefore\ d\varDelta = -\frac{\cos^2\varDelta}{\cos^2\Sigma}\operatorname{tg}\frac{\delta'+\delta}{2}\operatorname{tg}\frac{\delta'-\delta}{2}.\ d\Sigma,$$

which shows that an error whatever, $d\Sigma$, on the difference between the instrumental azimuth of the observed stars, will give on $\varDelta$ an error equal to it multiplied by a factor

$$-\frac{\cos^2\varDelta}{\cos^2\Sigma}\operatorname{tg}\frac{\delta'+\delta}{2}\operatorname{tg}\frac{\delta'-\delta}{2}.$$

and as this factor will be smaller, the *smaller* the difference $\delta'-\delta$, then the most favorable circumstance for the determination of $\varDelta$ is that in which

$$\delta'-\delta = \text{minimum}. \qquad (11)$$

EXAMPLE.

At San Juan (Argentine Rebublic) we have observed three stars at their greatest elongation, the 1st of May of the present year, with the following readings observed by a 6 in. theodolite reading to 10″ of arc:

EAST OF THE MERIDIAN.

Star.	Declin.	Instrum. reading.
β Triangulis Australis:	− 63° 5′ 25″;	230° 9′ 55″
α Triangulis Australis:	− 68° 49′ 22″;	237° 9′ 42″.5

WEST OF THE MERIDIAN.

α Navis (Canopus):	− 52° 38′ 25″;	307° 37′ 57″.5

Fixed staff; Instrumental reading 79° 11′ 30″

To compute the azimuth we may arrange the following pairs of observations:

1st. α and β Triangulis Australis on the same side of meridian (Case I).

2d. α Triangulis Australis to the east and Canopus to the west (Case II).

3d. β Triangulis Australis to the east and Canopus to the west (Case II).

We do not take into account the 1st pair, for its data do not satisfy condition (9), and computing (10), (7) and (8) for the other two, we have what follows:

Value of A_p:

by 2d pair for α T. A.	25° 4′ 38″.2	
" " " " Canopus		45° 23′ 36″.8
" 3d " " β T. A.	32° 4′ 23″.2	
" " " " Canopus		45° 23′ 39″.1
and taking the mean for Canopus		45° 23′ 37″.9

Starting from these values the azimuth of the fixed staff will be

$$\left.\begin{array}{ll}\text{by } \alpha \text{ Trian. Austr.} & 3^\circ\,2'\,50''.7\\ \text{" } \beta \text{ " "} & 3^\circ\,2'\,45''.3\\ \text{" Canopus} & 3^\circ\,2'\,49''.6\end{array}\right\}\text{mean: } A = 3^\circ\,2'\,48''.5$$

and the latitude

$$\left.\begin{array}{ll}\text{by } \alpha \text{ Trian. Austr.} & -31^\circ\,32'\,0''.5\\ \text{" } \beta \text{ " "} & -31^\circ\,32'\,4''.2\\ \text{" Canopus} & -32^\circ\,31'\,2''.2\end{array}\right\}\text{mean: } \phi = -31^\circ\,32'\,2''.3$$

Should we have not rejected the 1st pair of observations, we would have had two values of A_p for each star, and taking the mean for each, the computation would have given

$$A = 3^\circ\,2'\,56''.8;\quad \phi = -31^\circ\,32'\,12''.8.$$

ON THE ORIGIN OF GAPS IN THE ZONE OF ASTEROIDS.

DANIEL KIRKWOOD.

FOR THE MESSENGER.

In regard to the physical constitution of the asteroid zone between Mars and Jupiter it is known by astronomers—(1) that well defined gaps occur in the arrangement of the mean distances; and (2) that these blanks or chasms coincide with the respective distances at which the periods of minor planets would have a simple commensurability with the period of Jupiter. These coincidences, then, are either accidental, or the original asteroids have been eliminated by the dominating mass of Jupiter. The laws of probability compel our rejection of the former alternative.* We must therefore admit a relation of some nature between Jupiter's influence and the observed vacant spaces. What, then, was the *modus operandi* of Jupiter's power?

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* The Asteroids, p. 46.

In the nebular hypothesis the sun's centrifugal force was not the only agent in separating planetary masses from the central body. The tide-producing power of previously formed planets, especially of Jupiter, was also effective. It is easy to see that the process of asteroid formation was more active in sections of commensurability than in spaces intervening. Those bodies were not only separated from the sun, in part, by the influence of the "giant planet," but again eliminated by his agency from the planetary cluster. Was the latter process a slow and gradual one—a *secular* variation, or did the maximum activity at critical epochs, issue in the sudden extinction of new members by their passing, in perihelio, beneath the solar surface? That the latter was nature's method, as we have more than once intimated,* seems, we think, not wholly improbable.

In the first stages of Jupiter's planetary existence its diameter was probably several millions of miles. It is hence not impossible that some original asteroids may have been lost in its mass. A more probable result, however, would be their re-absorption into the sun itself. Let us suppose an asteroid separated in a tidal protuberance, at the distance, say, of 4.481. Its period would be four-fifths of Jupiter's. The initial eccentricity would doubtless be considerable. If but 0.15, the present average of known asteroids, its perihelion distance would have been 3.8; in other words the point of nearest approach to the sun's centre would have been sixty million miles beneath its surface. We see, therefore, that the separate existence of the asteroid could have been but temporary. Again, let us suppose an original asteroid in the maximum chasm, with a period equal to half that of Jupiter. Its mean distance from the sun's centre would be 3.2776. With a primitive eccentricity equal to that of the earth's orbit, (0.017) the perihelion point would be 5,000,000 miles beneath the surface of the solar mass. Similar reasoning would obviously apply to other simple cases of commensurable motion. Only those asteroids whose primitive perihelion distances were greater than the radius of the contracting solar volume could permanently maintain a planetary existence. In this view of

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* See the author's "Asteroids" pp. 38-47.

the subject the chasms of the zone originated with the zone itself, and were not produced by Jupiter's *secular* perturbation. It must be remarked however, that the present observed eccentricity of many asteroids could not have obtained from the beginning, as was shown by the writer in the work already quoted.[*]

Intimately connected with this question of the asteroids is that of the eccentricity of Jupiter's orbit; its origin; the increased intensity, in perihelio, of Jupiter's perturbation on the solar nebula, the forming asteroids, etc., etc.—all questions within the domain of physical science. More facts however, are needed for their discussion.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at greatest elongation east of the sun, 20° 01′, April 18. It will then be visible to the naked eye an hour and a half after sunset. One should look for the planet a little to the north of the west point of the horizon. The northern declination of the planet makes this month a very favorable time for daylight observations of Mercury, the best time for them being after the middle of the afternoon.

Mercury will be at the descending node of its orbit May 9, at 3^h A. M., central time, and at inferior conjunction with the sun May 9, at $8^h\ 41^m$ P. M. As this conjunction occurs so near the node, the planet will cross the disk of the sun. The transit will only be partially visible in the United States. At Washington the times of the phases will be as follows:

Ingress, exterior contact,	May 9	11^h	55^m	$29^s.3$	Greenwich mean time.
Ingress, interior contact,	9	12	00	25 .0	
Least distance of centers 12′ 32.4″	9	14	23	54 .5	
Egress, interior contact,	9	16	47	02 .3	
Egress, exterior contact,	9	16	52	45 .7	

The point of first contact at ingress will be 115° 31′ E., and that of last contact at egress will be 168° 15′ W. from the north point of the sun's disk.

At places in the eastern part of the United States the transit will begin very near the time of sunset so that no observation of value can be made. The following are the standard times of external contact at ingress, as calculated for several of the observatories by Professor George W. Coakley (see page 40):

Observatory.	External Ingress.	Standard.
Harvard College	$6^h\ 54^m\ 32^s.55$	Eastern.
New York City	6 54 25 .81	"
Washington	6 54 18 .64	"
Chicago	5 54 19 .73	Central.
Carleton College	5 54 26 .68	"
Lick	3 54 17 .99	Pacific.

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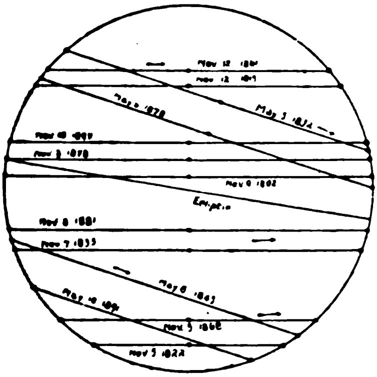
[*] Asteroids, p. 47.

For any other place the time of ingress may be found by means of the following formula, in which ρ denotes the radius of the earth at the place, the geocentric north latitude, ω the longitude *west* from Washington, and L the longitude of the nearest standard meridian from Greenwich.

$$T = 11^h\,55^m\,29.3^s - L + 71.66^s\,\rho \sin \phi$$
$$- 157.88^s\,\rho \cos \phi \cos (20^\circ\,16'\,55.5'' - \omega).$$



The time of internal contact at ingress will in every case be about five minutes later than that of exterior contact. The diameter of the planet at the time of transit will be 12.0″, so that it will be easily seen with a small telescope but will not be visible to the naked eye. The accompanying cut showing the path of Mercury across the disk of the sun during each transit in this century is copied from *L'Astronomie* for January, 1891.

Venus is "morning star" but is receding behind the sun so that she can not be readily seen. Venus and Jupiter will be in conjunction April 7, at $3^h\,25^m$ P. M., central time, the distance between the two planets being then only 13′.

Mars may be seen in the west each evening until nine o'clock. He is now among the faint stars of Aries and will during this month move eastward into Taurus between the Pleiades and Hyades.

Jupiter is "morning star" with Venus. The conjunction of the two planets, April 7, has been mentioned above. After that date Jupiter will be the more westerly of the two, both being brighter than any of the stars in the morning sky. It is rapidly coming into good position for observation.

Saturn is on the meridian now at about ten o'clock in the evening, and doubtless most lovers of astronomy have already had many excellent views of the planet. The rings are inclined at an angle of only five degrees to the line of sight so that their width is greatly foreshortened, yet in moments of good definition one can distinguish the three rings with a telescope of moderate power. We would call especial attention to the suggestions of Professor Trouvelot (page 171) as to what observations may and should be made this year upon the ring system of Saturn.

Uranus will be at opposition April 19, rising then at about sunset. The best hours for observing this planet will be from ten to two o'clock when it will be not far from the meridian at an altitude of about 35°. We refer those who wish to look it up with small telescopes to the diagram in our last number (page 142) showing the path of Uranus among the stars.

Neptune is too low in the west in the evening to be well seen.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Apr. 25	3 18.6	+ 21 08	5 32 A. M.	1 04.7 P. M.	8 38 P. M.
May 5	3 15.5	+ 19 09	4 59 "	12 22.1 "	7 46 "
15	2 56.2	+ 14 55	4 19 "	11 23.6 A. M.	6 28 "
			VENUS.		
Apr. 25	23 54.6	− 2 11	3 46 A. M.	9 41.1 A. M.	3 36 P. M.
May 5	0 38.5	+ 2 17	3 33 "	9 45.6 "	3 58 "
15	1 22.8	+ 6 46	3 20 "	9 50.5 "	4 21 "
			MARS.		
Apr. 25	4 07.0	+ 21 36	6 18 A. M.	1 52.8 P. M.	9 28 P. M.
May 5	4 35.7	+ 22 48	6 01 "	1 42.3 "	9 24 "
15	5 05.0	+ 23 40	5 46 "	1 32.0 "	9 18 "
			JUPITER.		
Apr. 25	22 48.5	− 8 35	3 07 A. M.	8 35.9 A. M.	2 05 P. M.
May 5	22 55.2	− 7 57	2 31 "	8 03.3 "	1 35 "
15	23 01.2	− 7 22	1 50 "	7 29.9 "	1 04 "
			SATURN.		
Apr. 25	10 51.5	+ 9 35	1 54 P. M.	8 36.2 P. M.	3 18 A. M.
May 5	10 50.7	+ 9 38	1 14 "	7 56.1 "	2 38 "
15	10 50.6	+ 9 37	0 35 "	7 16.6 "	1 58 "
			URANUS.		
Apr. 25	13 49.0	− 10 38	6 12 P. M.	11 33.2 P. M.	4 54 A. M.
May 5	13 47.5	− 10 29	5 31 "	10 52.4 "	4 14 "
15	13 46.0	− 10 21	4 49 "	10 11.6 "	3 34 "
			NEPTUNE.		
Apr. 25	4 14.8	+ 19 40	6 35 A. M.	2 00.7 P. M.	9 27 P. M.
May 5	4 16.2	+ 19 44	5 56 "	1 22.8 "	8 49 "
15	4 17.5	+ 19 48	5 18 "	0 45.0 "	8 12 "
			THE SUN.		
Apr. 25	2 11.7	+ 13 16	5 00 A. M.	11 57.9 A. M.	6 56 P. M.
May 5	2 49.8	+ 16 19	4 45 "	11 56.6 "	7 08 "
15	3 28.9	+ 18 56	4 33 "	11 56.2 "	7 20 "
			THE MOON.		
Apr. 20	11 55.7	+ 5 44	3 20 P. M.	10 00.3 P. M.	4 29 A. M.
25	15 53.2	− 19 48	8 46 "	1 37.6 A. M.	6 22 "
30	19 53.7	− 24 58	12 48 A. M.	5 21.7 "	9 46 "
May 5	0 43.2	− 0 04	3 44 "	9 50.7 "	4 10 P. M.
10	5 28.9	+ 24 51	6 12 "	2 16.1 P. M.	10 26 "
15	10 06.1	+ 17 16	11 01 "	6 32.8 "	1 52 A. M.

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m.
Apr. 18	*i* Leonis	5.7	11 08	134	12 22.7	302	1 15
22	65 Virginis	6.1	6 12	104	7 15.4	319	1 04
22	66 Virginis	6.0	7 00	115	8 11.5	313	1 11
25	λ Libræ*	5.1	10 08	107	11 20.1	313	1 12
May 2	τ^1 Aquarii†	5.8	14 42	20	15 21.4	301	0 39
12	ϰ Geminorum†	3.6	10 39	130	11 25.7	256	0 46
14	B.A.C. 3206	6.3	8 35	142	9 42.6	273	1 08

* Immersion below the horizon of Washington.

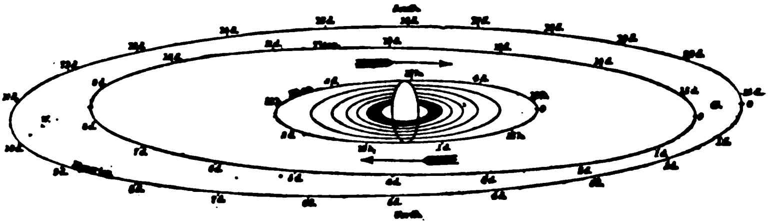
† Multiple star.

Mr. Marth's Ephemerides of Saturn's Satellites.

[Reduced to Central Time: from Monthly Notices, Vol. LI Nov. 1890; Di = Dione; En. = Enceladus; Mi. = Mimas; Rb. = Rhea; Te. = Tethys; Ti. = Titan; c = conjunction with the center of planet; f = conjunction with following end of ring; p = conjunction with preceding end: n = north; s = south of the major axis of the ring; e = eastern elongation: w = western elongation.]

April 15	12.1 a. m.	En. pn
	1.9 p. m.	Di pn
	2.2	Mi. pn
	4.3	Rb. pn
	5.5	En. fs
	7.1	Te. e
	7.6	Mi. ps
16	2.9	Rh. w
	2.9	Di. ps
	5.8	Te. w
	6.2	Mi. ps
	7.1	En. ps
	10.7	Di. fs
17	1.5	Rh. ps
	4.4	Te. e
	4 8	Mi. ps
	5.9	En. pn
	10.5	Rh. fs
	10.7	Mi. fs
	11.8	Di. fn
18	12.2 a. m.	Te. fn
	3.1 p. m.	Te. w
	8.1 " "	Di. w
	9.1	Rh. e
	10.9	Te. ps
19	11.4 a. m.	Tit. sup c. s. 18″
	1.7p. m.	Te. e
	4.4	Di. fs
	7.7	Rh. fn
	9.5	Te. fn
20	12.4	Te. w
	5.5	Di. fn
	9.2	Te. ps
21	1.8	Di. w
	2.2	En. fn
	5.2	Mi. fs
	6.8	Te. fn
	8.5	En. fn
22	10.6	Mi. fn
	1.0	En. fs
	3.8	Mi. fs
	5.5	Te. ps
	9.2	Mi. fn
	10.6	Di. e
	11.0	En. fn.
23	12.5 a. m.	Te. fs
	4.1 p. m.	Te. fn
	6.9	Di. pn
	11.1	Te. pn
24	2.8	Te. ps
	5.1	Rh. pn
	8.0	Di. ps
	9.8	Te. fs
25	1.4	Te. fn
	3.7	Rh. w
	4.3	Di. e
	4.8	En. fn
	5.1	Mi. fn
	8.4	Te. pn
	11.0	Mi. pn
	11.2	En. pn
26	2.3	Rh. ps
	3.6	En. fs
April 26	3.7 p. m.	Mi. fn
	7.1	Te. fs
	9.6	Mi. pn
	11.3	Rh. fs
27	1.6	Di. ps
	2.3	Mi. fn
	5.8	Te. pn
	6.1	En. ps
	8.2	Mi. pn
	9.4	Di. fs
	9.9	Rh. e
28	4.4	Te. fs
	4.9	En. pn
	6 8	Mi. pn
	8.5	Rh. fn
	10.5	Di. fn
29	3.1	Te. pn
	5.5	Mi. pn
	6.8	Di. w
	7.5	En. fn
	10.9	Mi. ps
	10.9	Te. w
30	1.7	Te. fs
	3.7	Di. fs
	4.1	Mi. pn
	6.3	En. fs
	7.5	Mi. ps
	7.5	Te. e
May 1	4.2	Di. fn
	8.1	Mi. ps'
	8.2	Te. w
	8.8	En. ps
2	6.7	Mi. ps
	6.8	Te. e
	7.6	En. pn
3	5.3	Mi. ps
	5 5	Te. w
	5.9	Rh. pn
	9.3	Di. e
	10.1	En. fn
	11.2	Mi. fs
4	2.6	En. ps
	3.9	Mi. ps
	4.2	Te. e
	4.5	Rh. w
	5.7	Di. pn
	8.9	En. fs
	9.9	Mi. fs
5	9.7 a. m.	Tit. sup c. s. 18″
	2.8 p. m.	Te. w
	3.1	Rh. po
	6.7	Di. ps
	8.5	Mi. fs
	10.6	Te. ps
6	1.5	Te. e
	3.0	Di. e
	3.9	En. fn
	7.1	Mi. fs
	9.3	Te. fn
	10.3	En. pn
	10.7	Rh. e
7	2.7	En. fs
	5.7	Mi. fs
May 7	7.9 p. m.	Te. ps
	9.3	Rh. fn
	11.1	Mi. fn
	11.9	Di. w
8	4.3	Mi. fs
	5.2	En. ps
	6.6	Te. fn
	8.2	Di. fs
	9.7	Mi. fn
	11.6	En. fs
9	3.0	Mi. fs
	4.0	En. pn
	5.3	Te. ps
	8.4	Mi. fn
	9.2	Di. fn
10	12.3 a. m.	Te. fs
	3.3 p. m.	Te. fn
	5.5	Di. w
	6.6	En. fn
	7.0	Mi. fn
	10.9	Te. pn
11	1.9	Di. fs
	2.6	Te. ps
	5.4	En. fs
	5.6	Mi. fn
	9.6	Te. fs
	11.5	Mi. pn
12	2.4 a. m.	Di. e
	1.2 p. m.	Te. fn
	2.9	Di. fn
	4.2	Mi. fn
	6.7	Rh. pn
	7.9	En. ps
	8.2	Te. pn
	10.1	Mi. pn
	10.7	Di. pn
13	2.3 a. m.	En. fs
	2.4	Tit. inf c. n. 18″
	2.8 p. m.	Mi. fn
	5.3	Rh. w
	6.7	En. pn
	6.9	Te. fs
	8.7	Mi. pn
	11.8	Di. ps
14	2.1 a. m.	Mi. ps
	2.7	Te. e
	3.9 p. m.	Rh. ps
	5.5	Te. pn
	7.4	Mi. pn
	8.1	Di. e
	9.2	En. fn
15	12.8 a. m.	Mi. ps
	12.9	Rh. fs
	1 4	Te. w.
	1.7 p. m.	En. ps
	4.2	Te. fs
	4.4	Di. pn
	6.0	Mi. pn
	8.0	En. fs
	11.4	Mi. ps
	11.5	Rh. e
	12.0 midn.	Te. e

Two new minor planets of the thirteenth magnitude have been discovered since our last issue, No. 307 by Millosevich at Rome, March 1, and No. 308 by Charlois at Nice, March 5. No. 307 was in R. A. $10^h\ 47^m\ 29^s$, Decl. $+ 11° 37'$; and No. 308 in R. A. $10^h\ 1^m\ 26^s$; Decl. $+ 19° 42'$. Both were moving north and west.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, MAY 17, 1891, AS SEEN IN AN INVERTING TELESCOPE.

(The Vertical Scale is Twice the Horizontal One.)

Phases and Aspects of the Moon.

			Central Time.			
			d	h	m	
First Quarter	1891	Apr.	15	7	40	P. M.
Apogee	"	".	19	5	24	A. M.
Full Moon	"	"	24	12	05	"
Last Quarter	"	"	1	7	51	"
Perigee	"	"	5	2	36	"
New Moon	"	"	8	12	15	"
First Quarter	"	"	15	1	04	P. M.

Minima of Variable Stars of the Algol Type.

[The times are given, to the nearest hour of Central Time, of only those minima which can be observed in the United States.]

U CEPHEI.

R. A. $0^h\ 52^m\ 32^s$
Decl. $+81° 17'$
Period $2d\ 11^h\ 50^m$

Apr. 18	8 P. M.
23	7 "
28	7 "
May 3	7 "
8	6 "
13	6 "

R CANIS MAJ.

R. A. $7^h\ 14^m\ 30^s$
Decl. $-16° 11'$
Period $1d\ 3^h\ 16^m$

Apr. 21	8 P. M.
22	11 "
29	7 "
30	10 "
May 8	9 "

S ANTLIÆ.

R. A. $9^h\ 27^m\ 30^s$
Decl. $-28° 09'$
Period $7^h\ 47^m$

Apr. 21	10 P. M.
22	10 "
23	9 "
24	8 "
25	8 "
May 3	10 "
4	9 "
5	9 "
6	8 "
15	10 "

δ LIBRÆ.

R.A. $14^h\ 55^m\ 06^s$
Decl. $-8° 05'$
Period $2d\ 07^h\ 51^m$

Apr. 18	10 P. M.
25	9 "
May 2	9 "
9	9 "

U CORONÆ.

R. A. $15^h\ 13^m\ 43^s$
Decl. $+32° 03'$
Period $3d\ 10^h\ 51^m$

April 16	4 A. M.
23	1 "
29	11 P. M.
May 6	9 "

U OPHIUCHI.

R. A. $17^h\ 10^m\ 56^s$
Decl. $+1° 20^m$
Period $0d\ 20^h\ 08^m$

Apr. 16	5 A. M.
17	1 "
17	9 P. M.
22	1 A. M.
22	9 P. M.
27	2 A. M.
27	8 P. M.
May 2	3 A. M.
2	11 P. M.
7	4 A. M.
7	12 midn.
12	5 A. M.
13	1 "
14	9 P. M.

COMET NOTES.

Ephemeris of Comet 1890 II (Brooks, March 19). From Bidschoff's elements as given in A. N. Vol. 124, p. 301, I have computed the following ephemeris:

Gr. M. T.	App. R. A.			App. Dec.		Log *r*	Log *Δ*
	h	m	s	°	′		
April 1.5	9	50	38	+ 34	4	0.5965	0.5193
3.5		47	59	33	48		
5.5		45	30	33	32	0.6006	0.5312
7.5		43	11	33	16		
9.5		41	0	33	1	0.6042	0.5427
11.5		38	57	32	44		
13.5		37	2	32	28	0.6080	0.5545
15.5		35	16	32	11		
17.5		33	38	31	54	0.6117	0.5663
19.5		32	7	31	38		
21.5		30	44	31	21	0.6154	0.5779
23.5		29	28	31	4		
25.5		28	18	30	47	0.6191	0.5894
27.5		27	14	30	30		
29.5		26	16	30	14	0.6228	0.6008

The theoretical light at the end of April is 0.12, that at discovery being unity.

O. C. Wendell.

Harvard College Observatory, March 14, 1891.

Ephemeris of Wolf's Periodic Comet 1884 III. We take from the *Astronomical Journal* the following ephemeris for the return of this periodic comet, computed by Dr. Berberich and communicated to the *Journal* by Mr. E. E. Barnard:

EPHEMERIS FOR BERLIN MIDNIGHT.

1891	App. R. A.			App. Decl.		log *Δ*	Brightness.
	h	m	s	°	′		
May 3	22	31	40	+ 13	03.9	0.3593	1.32
7		40	19	14	00.6		
11		49	04	14	57.4	0.3401	1.51
15	22	57	54	15	54.2		
19	23	06	51	16	50.9	0.3204	1.73
23		15	59	17	47.3		
27		25	04	18	43.1	0.3001	1.98
31		34	21	19	38.1		
June 4		43	45	20	32.0	0.2793	2.27
8	23	53	17	21	24.7		
12	0	02	57	22	15.8	0.2580	2.62
16		12	45	23	05.0		
20		22	40	23	52.0	0.2362	3.00
24		32	44	24	36.6		
28		42	56	25	18.4	0.2139	3.45
July 2	0	53	15	25	57.3		
6	1	03	42	+ 26	32.2	0.1911	3.96

Variation corresponding to — 1d in the period
May 11 + 96^{s}, + 1′.4.
June 20 + 133^{s}, — 2′.3.

NEWS AND NOTES.

We suggest to subscribers that it is not the safest way to remit dues to THE MESSENGER, by currency or postal notes, though the latter is a very common way, and the former frequent. If letters are lost or destroyed in railway accidents the remittances are liable to be a total loss to somebody. If post office orders, bank drafts or checks are used the probability of loss is considerably diminished.

Publication No. 2 of Carleton College Observatory is nearly ready for distribution. This number consists of the observations and the reduction of the same for the determination of the three following longitudes:—

I. The longitude of Carleton College Observatory, re-determined, as based on Washington directly.

II. The longitude of Iowa College Observatory at Grinnell, Iowa, also based on Carleton College Observatory.

III. The determination of the longitude of the point where the 103° meridian west of Greenwich intersects the Northern Pacific Railroad, as an initial point for the government survey of the Sioux Reservation. The basis of this determination was Carleton College Observatory.

"*The Irrepressible Conflict*" is the title of the leading article of this issue. The manner in which Professor Boss has presented the general theme in this paper will quicken the interest of the friends of astronomy in the United States, and we hope sufficiently arouse the attention of the public mind generally to a matter that needs radical reform.

The Origin of Stellar Systems. Mr. See, of the University of Berlin, has favored THE MESSENGER by two important papers on the "Origin of the Stellar systems," which, we think, will be read generally with much interest. If we had had, in this issue, space at command, we would have presented some valuable tables from which Mr. See derives some of his data for support of the new theory. We notice, however, that the tables referred to have already appeared in connection with a similar paper published by the author in *Observatory*, for February of this year.

We are sorry also that our crowded pages have, for this month, shut out a large amount of useful amateur matter that we had planned to present. We are now ready to take up the work of which we have previously spoken as adapted to the opera-glass and the small telescope for our numerous friends who desire to do something in this way systematically. The more we have thought of this useful branch of work, the more it has seemed to us that we ought to publish this matter separately and in suitable and convenient form for the use of those interested. Further consideration may lead us to do it and to undertake the work in that form quite soon.

Polar Snow Caps and a Solar Belt on the Moon. A suggestive article is found in the *English Mechanic* of March 13, 1891, on the probability of polar snow caps and a solar belt on the moon, written by S. E. Pearl, of India. It is assumed that the axis of the moon has changed about 30° in early ages of lunar development, occasioning thus a new tidal equator, By drawing the north pole towards us about 30°, it is noticeable that Maria Imbrium, Serenitatis, Crisium and Smythii lie truly in a line of a great circle and form a chain, in such a manner and at such a place as seem to preclude the possibility of accident. In regard to this fact Mr. Pearl says: "This great chain of *Maria*, therefore I take to be the remains of the great solar belt about the former old (tidal) equator; the remains of the belt of solar influence, the least areas left liquid ere the polar caps united. The enormous littoral ranges are the snow ramparts raised during the long, final struggle around these vast lagoons, repeating exactly on a large scale the features we see in all the other circular formations called craters and walled plains. In case any of your readers may doubt the possibility of the change in the lunar axis of 30°, I may say that when starting this part of the investigation, I laid the case before Professor C. H. Darwin, and ve hery kindly, at once, replied that 'the shifting of the axis of rotation is undoubtedly a mechanical possibility. A large shift, such as you postulate, is far more likely to occur in the case of a body with slow rotation, as in the case of the moon, than in the earth.' "

No. 14, Vol. III, Publications of the A. S. P. is at hand. It contains 83 pages of useful current matter of unusually wide range. It is one of the strongest numbers that the society has issued.

A Remarkable Meteor. By kindness of C. C. Hutchins, of Brunswick, Maine, we have a brief account of a remarkable meteor which was seen near Kingsfield, Maine, on the morning of the 23d of last month. The peculiarities of this meteor were its great size and its vivid light. Its course is said to have been from southwest to northeast, as far as Franklin County, Maine., where it exploded. The noise of the explosion was heard for many miles and shook buildings like an earthquake. It left only a dense cloud of smoke behind, no fragments reaching the earth, so far as known.

Rev. P. B Fisk, of Morrisville, Vt., by private letter, also sends an account of the Maine meteor. He says the explosion took place over eastern Maine, from three to five minutes past 4 o'clock A. M. February 23. Before 4 o'clock, Mr. Fisk was awake, and the full moon shone brightly, and he saw a light like that of a meteor which indicated that it had passed southward and to the east. He was probably 100 miles west of the place where the meteor exploded in Maine.

Dr. Hosmer A. Johnson, of Chicago, died February 26, 1891. He was President of the Chicago Astronomical Society from 1882 to 1889. At the time of his death he was Vice-President, and Professor E. Colbert, of the Chicago *Tribune*, President.

Nebulous System of Orion. By private letter of March 10, C. C. Hutchins says that a portion of the vast nebulous system of Orion is easily visible in a small telescope. Just over and in the same field with ζ Orionis his 6½-inch comet seeker shows a very extensive nebulosity with a mottled light like that of the outlying portion of the great nebula. This is visible out at least half a degree square and is seen to have a great dark rift dividing it into two unequal portions. This same nebulous patch has been seen at Northfield since Mr. Hutchins called our attention to it. The broad, dark rift, in its general course, is concave to the star, and seems to have short, faint branches on either side. The mottling of the nebulous mass is distinctly seen. We used the 8¼-inch Clark equatorial with a power of 50. On December 26, 1889, Dr. H. C. Wilson photographed this region with an ordinary camera attached to a telescope. The lens of the camera was 2½ inches, and the time of exposure was two hours and forty minutes. Two negatives of the same field were taken at different times but the date of the second one was not preserved. Both show the dark rift and portions of the nebulosity above referred to. They were not, however, before observed, simply because the plates were not studied. Some of our books of reference are not now at hand, and hence we can not be sure that this large nebula is not on record. If it is, we do not remember it and we are sure we have never seen it before. This an excellent field for the small telescope and the amateur to try his powers of observation.

Wolshingham Observatory. A star 8.4, red, III type, not in D. M. was observed here January 31st, February 1st and 2d, at $5^h\ 32^m\ 37^s$, + 31° 57′ ('55). This star is perhaps variable.

Circular No. 29.

The variability of Es—Birn. 146 = D. M. + 68.398 has been ascertained. Period and limit unknown. T. E. Espin.

Circular No. 30.

Rousden Observatory, England. C. E. Peck, of Rousden Observatory, England, favors The Messenger with a report of astronomical work done during the year 1890. It has consisted chiefly of transit observations and observations of variable stars, a list of which is given. This is the fifth year that variable star work has been carried on regularly.

A Remarkable Solar Halo.—Yesterday at 1 P. M. I witnessed an exhibition of the above phenomenon quite unlike any I had ever seen or read of. The sky had been unusually clear, and I was congratulating myself on the anticipated cloudless night, but at the above hour I was surprised to note the sun shining but dimly, and, looking out of a west window, to see the sky nearly covered with a thin haze, and, in the northwest, at an elevation of about 45°, a segment of a luminous curve. From the lawn, the segment was found to be part of a complete circle, but the sun instead of occupying its center, as is generally the case, was at its southern circumference, the northern limit being, by estimation, contiguous to the pole star. The diameter of the circle must, therefore, have been 90°. The luminous band was about half a degree in width and without color. Lewis Swift.

Warner Observatory, Rochester, N. Y., March 18, 1891.

Star Studies by the Opera-Glass. We were very sorry not to be able this month to begin the star-studies by the opera-glass as we had expected to do. Mr. G. P. Serviss, of New York, will have some matter ready for the next MESSENGER. He has been unavoidably delayed in its preparation so far.

Charles A. Bacon, director of Smith Observatory, Beloit, Wis., is industriously at work on an illuminated globe for the aid of teachers and students in the study of the constellations. Something of the plan of the globe and the method of using it will be given by Mr. Bacon in the next issue of this periodical.

Publications of the Leander McCormick Observatory of the University of Virginia. We are in receipt of Part 5, Vol. 1, of the above named publications, with title Durchmusterung, — 23°. This is a neatly printed catalogue of 6671 stars, all belonging to *one* degree of south declination numbered 23, and is a continuation of the Bonn Durchmusterung. The work was begun at the Cincinnati Observatory, and the instrument employed was a 4-inch equatorial by Alvan Clark & Sons. The instrument used at the Leander McCormick Observatory, where the work was completed, was made by Kahler and was of the same size. The observers were Professor Stone, F. P. Leavenworth, H. C. Wilson, H. V. Egbert and John Jones.

Comets Captured by Electricity. Several copies of the *Examiner* (San Francisco, Cal.), bearing date March 8, have been received from friends in different parts of the West, calling attention to a new mode of discovery of comets by the aid of electricity, and other ingenious appliances, expected to work automatically and constantly. In a word the machine is of such a kind (according to the *Examiner's* report) that if it be set its telescope will sweep the sky automatically and automatically record the observation of cometary bodies and those only. All the observer has to do is to start his machine and it will do the work alone, and he can go about other business or sleep if he chooses. We have the impression that this sensational story, with its strong head-lines, is a hoax, or a tremendous scientific blunder. It is easy to believe this, because the *Examiner* has a wonderful capacity for blundering in scientific matters. We remember our own experience with that paper two years ago. Its manager had asked the favor of some facts about the eclipse. The facts were given, and they elicited an editorial that was the most wonderful piece of blundering known to us in the whole range of newspaper possibilities. The errors were so obvious that no one paid any attention to them. This, probably is another illustration of the *Examiner's* progressive science.

Theology by Starlight is an apt and forceful interpretation of the Word now spoken from on high, by Newton M. Mann, who has written much and well for these pages for years past. The author believes that

> "One sun by day, by night ten thousand shine
> To light us up into the Deity."

Photographic Notes. "M. Prosper Henry calls attention to the fact that the co-efficient of refraction is not the same for photographic rays as for visual. . . . At Z. D. 80° visual and photographic refractions would differ by about 5″; and generally in photographic work, all visual refractions would be increased in the ratio of 1.0156 : 1. The measures from which this result was obtained were made by placing a grating in front of the object glass of a telescope, and thus obtaining short spectra of stars." —*The Observatory.*

Journal de l'Industrie Photographique suggests a method for developing photographic plates in full light. Developing, washing and fixing are carried on in boxes having red glass sides; plates are transferred from box to box by means of taps.

Mr. Gabriel Lippmann has brought before the Paris Academy of Sciences photographs of the spectrum in which all the colors appear with their exact tones. The photographs are permanent, exposure to light and air producing no apparent effect upon them. The following statements are made by M. Lippmann in the *Photographic Times* of March: "The sensitive coat (on the photographic plate) must be continuous; that is to say, that the sensitive matter must be distributed in a state of division as it were infinite, in a transparent support such as gelatine, albumen, or collodion. In general the bromides of commerce form much too heavy an emulsion for employment. The sensitive coat must be placed against a reflecting surface. For this purpose it is fixed during the exposure in a hollow frame containing mercury, which forms a plane mirror in contact with the sensitive coating. The exposure is made, then the development, finally the fixing, followed by washing in the ordinary manner with hyposulphite of soda, or cyanide of potassium. The plate has been exposed dry and the colors appear there when it again becomes dry. The theory of the experiment is very simple—the incident rays forming the image in the camera interfere with the rays reflected by the mercury; there results in the interior of the sensitive coat a series of fringes of interference, that is to say, of maximums of light separated by entirely obscure minimums. Only the maximums imprint the plate; the photographic operations terminated, they are marked by a series of transparent coats of silver reduced, separated by the interval itself which separated two maximums, that is to say, equal to a half length undulation. . . . Seen by transparency the cliché is negative, that is each color is replaced by its complementary color—green by red, red by green, etc. I have already found that the colors of the cliché may remain with impunity exposed either to the light of day or to the concentrated rays of a powerful electric arc."

The English of the above translation is not very choice; but we prefer to let it stand as it is.

At the Lick Observatory Jupiter was photographed on thirty-three nights between July 14 and November 3, 1890.

Mr. Isaac Roberts concludes from photographs taken on ten different nights that the nucleus in the Great Nebula in Andromeda is variable.

Photography of the Solar Prominences. A useful paper on the photography of the solar prominences will be found in *Technology Quarterly*, Vol. 3, No. 4, November 1890, from the pen of George E. Hale, Kenwood Physical Obsrevatory, Chicago, Ill.

Barnard's Photograph of the Milky Way.—In No. 492, Vol. 21 of the *Photographic Times* of New York (Feb. 20) will be found a reproduction of a photograph of a portion of the Milky Way by E. E. Barnard, of Lick Observatory, and a descriptive article accompanying the same. The negative was taken Aug. 1, 1890, with a six-inch portrait lens, and the position of the center of the picture is right ascension 17^h 55^m, and south declination 28°. The exposure was three hours and seven minutes. The important feature that is claimed for the superiority of the Lick photographs of the Milky Way is that they show the structure of it better than any other means of study. It is believed by astronomers that a better knowledge of the Milky Way will give the key to the structure of the Universe, and this is the place to begin severe and exhaustive study. By the use of the telescope with high power the details of a field large enough to give knowledge of the structure are lost. The massing of stars, the cloud-like forms and wonderful nebular structure almost wholly disappear. It is on this account that the portrait lens of larger field has been tried with surprising results when the best quality of sensitive plates have been used in long exposures. It will be of interest to our readers to know that copies of one of these beautiful pictures can be obtained from the *Photographic Times*, 423 Broome St., New York City, at the small price of 25 cents per copy.

Edmund J. Spitta's Recent Papers. We are sorry that we have been unable to find space for some valuable papers by Edmund J. Spitta of England which the author has had the kindness to send us recently. We mention the titles of them that American readers may avail themselves of copies from other sources.

"Some Experiments relating to the method of obtaining the Co-efficient of Absorption of the wedge photometer."

"Some experiments relating to the photometric comparison of points of light with objects of sensible area," and

"On the appearance presented by the satellites of Jupiter during transit, with a photometric estimation of their relative albedoes and of the amount of light reflected from the different portions of an unpolished sphere."

Baron D'Engelhardt's Private Observatory. We have recently received two fine volumes of observations made by Baron D'Engelhardt in his private Observatory at Dresden. The first volume was published in 1886, and contains descriptions of the Observatory and instruments and observations of comets, planets, nebulae and star-clusters made with a twelve-inch equatorial and filar micrometer. It is illustrated by four large engravings of the building and instruments. The second volume was published in 1890, and contains the results of four years' observations, all made by the Baron himself with the twelve-inch Grubb refractor, comprising observations of the satellites of Saturn, comets, asteroids, the Bradley stars, a list of twenty-one double stars selected by O. Struve, a number of comparison stars for Comet 1862 III, and 203 nebulae and star-clusters. All of these are micrometrical measurements of a good degree of accuracy and afford a large amount of very valuable material for the study of the motions of the heavenly bodies.

Some Thoughts on Subjects Astronomical is the title of a recent pamphlet of 58 pages by John Romains, S. S. C. Scot. of Scotland. It is a résumé of the important facts of astronomy stated in a clear and direct way, and well suited to popular readers.

Annual of the Royal Observatory of Brussels. The Annual for 1891 of the Royal Observatory of Brussels, by F. Folie, Director, has been received.

Annual of the National Observatory of Tacubaya, Mexico, has reached our table. This is volume XI and is for 1891. This work is under the Directorship of Felipe Valle.

BOOK NOTICES.

The Geometry of Position, by Robert H. Graham, author of Graphic and Analytic Statics. London and New York, Messrs. Macmillan & Co., Publishers, 1891, pp. 192.

So far as we know there is no work in English devoted to this interesting science of the geometry of position, as it is called by French and German writers, unless we except Salmon's *Conic Sections* and *Higher Plane Curves,* which present, in certain chapters, a similar set of problems. The analytic method used by Salmon, it is claimed, is ill-suited to make prominent the useful aspects of the subject, or, to illustrate fully the beauty and elegance of projective geometrical methods. Carnot published a work on the geometry of position at the beginning of this century. Since that time this branch has been developed by Poncelet, Standt, Steiner, Cremona and others, and the graphic idea has grown in prominence. On this account the study of geometry of position has been made compulsory in the Federal Polytechnic of Zürich, in Strasburg University and other continental institutions. The tendency of later writers seems to be to make the study of the geometry of position an introduction to lessons on graphic studies. The author's experience in reading Culman's *Graphic Statics* is in the same direction, and hence he was led to prepare the work before us, for the advantage of students who wish preparation in such studies.

An idea of the plan of the work may be gathered from the subjects discussed. They are six in number, with titles as follows: Anharmonic Pencils and Ratios, Projective Conics, Reciprocal Figures, Centers of Gravity, Ellipses of Inertia and Kerns and the Elastic Line. Each theme is followed by several pages of examples illustrative of the line of discussion followed. There is much other useful history to be found in the books referred to and in the full preface of this work, showing how the geometry of position has come to occupy the prominent place in some lines of study, that it has recently acquired. So far as appears from a cursory examination of this book, it fills a much needed place in the relations already indicated, and probably will interest American students of mathematics who have given, or wish to give attention to such themes.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 10, No. 5. MAY, 1891. WHOLE No. 95

HOW TO MAKE GOOD MERIDIAN OBSERVATIONS.

TRUMAN HENRY SAFFORD.*

FOR THE MESSENGER.

SECOND ARTICLE.

Transit Observations for Local Time.

With a portable transit of two inches (French) in aperture local time can be determined with all the accuracy needful. If there are any exceptions they apply only to the highest class of telegraphic longitude work; in which, however, an aperture of 2½ inches (French) is amply sufficient.

With the smaller instrument mentioned a power of 70 is easily applicable; and if everything is in good order, and the chronographic method is used, the probable error of a time determination from six stars need not exceed ± $0^s.04$ or ± $0^s.05$, all elements included, even variability of personal equation. So that the employment of larger instruments is not necessary; their use may be, up to a certain point, a convenience.

But the excellence of the striding or hanging level must not only be guaranteed by the maker's reputation, but by careful investigation. Levels are apt to change their curvature, either really or apparently; and very embarrassing consequences may ensue. This Observatory has a Troughton & Simms level belonging to a disused instrument, which is more than half a century old. But when put on the level trier which I use for students' practice, it never fails to exhibit its admirable qualities as completely as when it was first made; certainly I know no better level tube of that age. If it were to be used in the Observatory, exposed to air currents, I should have it mounted in a newer way; but that does not detract from the conclusion that the tube itself is unharmed by its long existence.

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* Professor of Astronomy, Williams College, Williamstown, Mass.

Sometimes I have met the suggestion, both in print and conversation, that observations for time might be reduced without any reference to the vertical. This is so absurd as to be hardly worth mentioning. Of course the fallacy lies (as one can show either by geometry or analysis) in the fact that we thus get the clock-correction for an unknown meridian, distant from the place of observation by $i \sec \varphi$ in longitude, or, in other words, about 100 linear feet for every second of arc in the level correction. A least square solution shows this by the nullity of the last divisor. The computer who mentioned the possibility of such a least square solution which would give a clock correction without leveling, had probably made such errors in his computation that his last divisor came out unequal to zero. The very skillful astronomer who suggested this as possible in a published memoir was in all probability merely thoughtless. But some levels, as before indicated, break down utterly. This is possibly a consequence of physical or chemical changes inside the tube. In some cases impurities in the ether dissolve particles of the glass, loosen other particles, and they make the bubble sluggish by adhesion; and the cases in which I have noticed bad levels have been comparatively very numerous. In reducing observations (not my own) for latitude by the zenith telescope I have sometimes found that the apparent level-corrections seemed to have nothing at all to do with the observations. That is, the vertical axis of the instrument was probably pretty accurately adjusted; but as the instrument was turned about the level bubble moved by jerks, or in some very irregular way, so that the axis itself was steadier than the level; at least the omission of the level-corrections improved the latitude. The latest German zenith telescopes have two attached levels. In this case if one breaks down the probable errors of the latitudes will at once show which is the defective one.

But for an ordinary transit-level, a simple level-trier affords an excellent and readily applied control. The larger instruments need more complicated level-triers; or else the dismounting of the glass tube. Professor Bruns of Leipsic has had constructed a large and fine level-trier (at a good deal of expense, I presume) by which to test the level of his meridian circle without taking it apart; but this is hardly practicable in ordinary cases.

The first maxim, then, of the observer who is determining absolute time is to look sharply after the level.

A portable transit of any size ought to be reversed smoothly enough not to change its azimuth. In such cases the collimation can be obtained in two nearly independent ways. The close polars will give it, without much dependence on the accuracy of the clock, on the assumption that reversal does not change the azimuth, and the stars near the zenith will give it, without much dependence on the stability in azimuth, on the assumption that the clock rate is regular.

If the instrument is but newly put up at a distant station, it is safer to rely upon a good time-piece than upon its fixity; the freshness of the cement in the piers is sometimes apt to lessen the stability.

The continental astronomers usually determine the collimation (for longitude observations) by reversal on a slow-moving star; taking some wires in the one position, and some in the other. This requires very good spider-lines, such as are inserted by the Repsolds; or a glass-scale finely cemented to the instrument; it also assumes great stability; and the assumption is usually warranted.

On the other hand the Coast Survey officers depend almost entirely upon the time stars for their collimation; and do not assume the identity of the azimuths before and after reversal. I have elsewhere given reasons for thinking it best to observe few stars below pole or south of the equator in determining longitude.

About one star near the pole to three or four near the zenith gives for our latitudes, the best practical balance, and the maximum of weight in proportion to the time spent in observing. If stars near the zenith only are observed for time, the result of the final solution is apt to show a diminished weight owing to uncertainty in azimuth, or, in other words, it becomes difficult to make the best selection of stars for the purpose.

Every complete time determination where exact results are required should be made partly in each of the two reversed positions of the instrument; and it is a good rule to select such combinations of stars that if it clouds up before reversal the evening's work will not be lost from want of either polars or time-stars in the one position; as the collimation can usually be obtained, if need be, by interpolation or reversal on a terrestrial mark.

The security of a time determination to a few hundredths of a second depends, however, mainly upon exact and critical knowledge of the particular instrument. This can best be obtained by experience with it. A great many longitude observations in this country have been far less accurate than they need have been, from want of this precaution. A little experience may here illustrate the principle. In determining the longitude of Evanston, Wyoming, for the purpose of establishing the southwest corner of the territory, I had an instrument of rather light construction and poorly mounted. But it had just been employed in the prime vertical to determine latitudes on the parallel of 41° at about six stations; and the very skillful observer who had used it, and who was to take one end of the longitude work, exchanging stations with myself in the middle of the series, had learned its peculiarities and how to counteract them. The chief trouble was that the plank, not very well seasoned, on which the instrument rested "curled up" in the day time from the heat of the air, and at night gradually became flatter. Hence we took care to divide our stars into small groups of three or four, a polar and two or three time stars, and to reverse and adjust the level between groups; working as rapidly as possible. This threw the greater strain upon the star catalogues. I had, fortunately arranged the prime vertical list according to Bessel's method, east and west stars alternately, but not waiting for the west transit of the same star observed in the east; so that the method used in the prime vertical where the same instrumental peculiarity had shown itself, was quite adequate to the problem. Both the latitudes and the longitude were found quite needlessly accurate, as the contractor's topographical work was far from carefully done. The astronomical work was nearly as good as if the transit had been far better. This happened nearly twenty years ago. Since that time the improvements in portable instruments, and (probably) the actual stock of good transits in the country have rendered it unnecessary to employ bad ones any longer.

There are many extant transits whose true place is in the class-room to exemplify the general form of the instrument, or properly hung up in an astronomical museum of antiquities.

In teaching practical astronomy the first instrument employed is usually the portable transit. It is, on the whole, quite as well to use a rather small one; Bessel's Repsold transit, with which he determined latitudes in his arc of the meridian, has an aperture of 21 lines French, or less than 2 inches English. Such an instrument has to be very delicately handled; and if the pupil is worth teaching at all, he will thus gain in the carefulness of his manual work, and be also very apt to get as good results as if he had a larger transit to practice with. In this way he learns to use the larger instruments with equal care and delicacy; and so to get excellent results.

I also think very highly of the eye-and-ear method as a means of training, and usually require pupils to use that some months before employing the chronograph. The careful reduction of eye-and-ear and chronographic observations on different stars will serve to indicate how far the pupil has acquired constancy of personal equation.

The first thing to be learned in transit practice is to perform the series of operations involved in "taking time" in proper order and without hurry. Then follows the exact judgment of fractions (in eye-and-ear work) or of the instant of transit in chronographic; then the insertion of level readings and reversals at the right time; and lastly practice for the purpose of making the personal equation (which greatly depends upon sub-conscious mental processes) more nearly constant. Novitiate astronomers are usually too anxious about their single wires, and need to be especially cautioned that this is not the critical matter. The pupil will probably have learned the preliminaries of measurement (estimation of tenths, etc.) in the physical laboratory, or with the level and level trier. The instructor must at first arrange the programme of stars. But above all things let the student avoid hurry; let him go slowly at first and increase his pace by well-arranged exercises, little by little.

A PAIR OF ANCIENTS.

C. C. HUTCHINS.

For The Messenger.

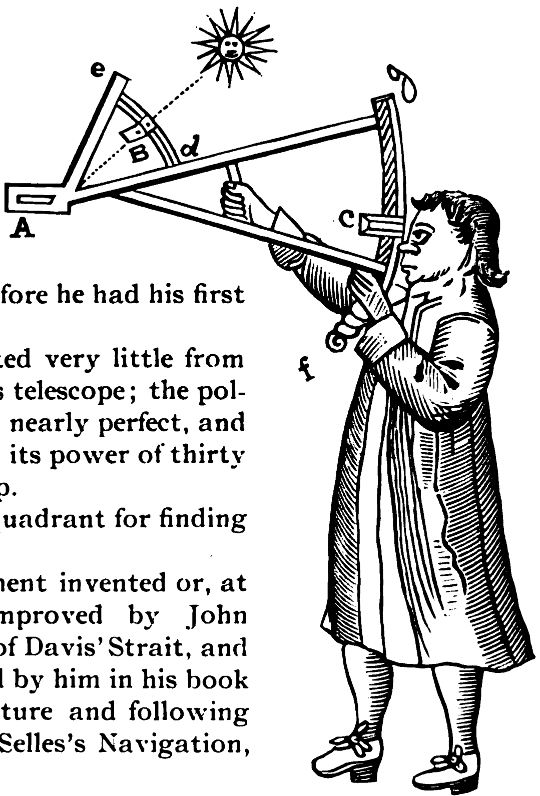
I have among my possessions two astronomical instruments whose age fairly entitles them to a measure of respectful notice. The first is a telescope—a Gregorian reflector; about eighteen inches long by two and a half in diameter. The tube is of heavy brass covered with black leather, now much worn, and on the eye-tube is engraved: "A^{s}. Mann, Ludgate Street, London, 1749.

It seems to have been just such an instrument that the elder Herschel loaned and used in his earliest observation; but it was twenty-five years later than the above date before he had his first telescope.

Age has detracted very little from the powers of this telescope; the polish of its mirror is nearly perfect, and the definition with its power of thirty is beautifully sharp.

The second is a quadrant for finding latitude at sea.

It is the instrument invented or, at least, greatly improved by John Davis, discoverer of Davis' Strait, and was first described by him in his book of 1594. The picture and following description from Selles's Navigation, 1699.



The Figure of the Quadrant and Manner of Observation.

The parts of this instrument are principally three Vanes, and two Arches, which Arches together contain 90 degrees, and give it therefore the denomination of a quadrant.

Of the three Vanes. That which in time of observation respects the horizon, in this annexed figure represented by A, is called the horizon-vane; that which gives the shadow noted by B, is named the shadow-vane; and that through which you are to look for both shadow and horizon, distinguished with C, is called the sight-vane.

Of the Arches. The lesser noted with *de*, is named the sixty-arch because it contains but 60°, it is of small radius (advisedly so contrived) for the more apt placing of the Vane B thereon, that the shadow thereof falling upon the horizon-vane A, at this short distance might become the stronger and the more perspicuous to the eye of the observer. The greater Arch, here denoted by the letters *fg*, is called the thirty-arch, etc.

Rude as this device seems, it was the best in existence until as late as 1740, when it was superseded by Hadley's quadrant.

The instrument in my possession is made of rosewood and boxwood, is of very fine workmanship, tastefully carved. With its aid, after a little practice, I have been able to get the sun's altitude correct within one or two minutes; so that with fairly good solar tables the navigator should have been sure of his latitude within five miles.

THE ORBIT OF β DELPHINI (β 151.)

S. W. BURNHAM.[†]

FOR THE MESSENGER.

This pair has been under observation since 1873. The duplicity of the large star was discovered with the 6-inch telescope in August of that year, but the measures commence in 1874, and with the exception of 1879, when the distance was about minimum, it has been measured every year since. It was very soon apparent from the measures that this pair was in rapid motion, and likely to prove an interesting binary.

Three orbits have been computed for this pair; the first by Dubjago in 1884, who found a period of 26.07 years; the second by Gore in 1885 with a period of 30.91 years; and

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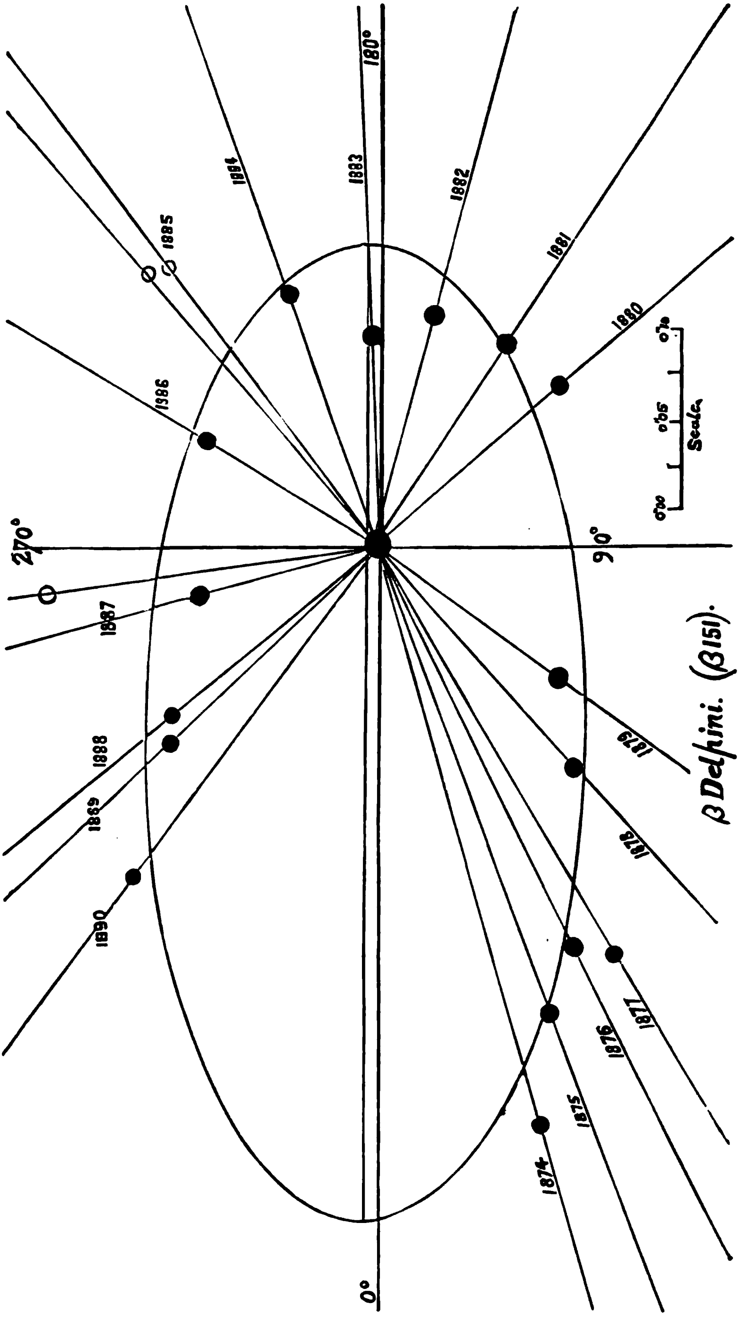
[*] Astronomer at Lick Observatory.



β Delphini. (β151).

the third by Celoria in 1888 giving a period of 16.95 years. It is evident that the last period is considerably too short, as the time has already elapsed, and the companion has still some fifty degrees of position-angle to pass over to reach the place it occupied in 1874.

I have platted the best available measures, and after repeated trials, drawn an ellipse through these observed positions which would best represent them, and make the areas described substantially proportional. The observations are fairly accordant when the closeness and difficulty of the pair is considered, and the corrections necessary are comparatively small.

The ellipse shown gives a period of about 28½ years, and that certainly cannot be far from the actual time of rotation. The measures of the next few years will give additional data for a very accurate determination of the period; and during this time it will be easy to measure. The distance will not be less than 0″.6.

LICK OBSERVATORY, March 19.

IS IT PROBABLE THAT ANY PLANET OF THE SOLAR SYSTEM ROTATES ON ITS AXIS IN THE SAME TIME AS ITS PERIOD OF REVOLUTION AROUND THE SUN?

PROFESSOR GEORGE W. COAKLEY.*

FOR THE MESSENGER.

It is known that the moon rotates on her axis in the time in which she makes a sidereal revolution around the earth, and that the cause of this identity of the rotation and revolution periods is the elongation of the moon's diameter pointed towards the earth. This elongation is supposed to have been produced by the earth's attraction at the time when the moon was in a fluid condition, and is entirely similar to the tendency towards such an elongation produced by the tidal action of the moon and sun upon the waters of the earth.

Recently Professor Schiaparelli, the distinguished Italian astronomer has announced that the planets, Mercury and Venus, appear to rotate on their axes in their periods of rev-

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* University of the City of New York.

olution around the sun. If this is the case it must be due to a tidal elongation of the diameters of these two planets towards the sun, produced by his attraction on their figures of equilibrium in the same way as the earth has acted on the moon.

To test the *probability* of such an action of the sun on the figures of equilibrium of these planets, the following approximate computations have been made with regard to the earth's tidal disturbing forces on the moon when in a fluid state, and of the similar tidal forces of the planets Jupiter, Saturn, Uranus and Neptune on their satellites, and then of the tidal forces of the sun on the earth and on Jupiter when they were fluid, and lastly of the tidal forces of the sun on the planets, Venus and Mercury, in a similar condition of fluidity.

An approximate computation of these several tidal forces will be sufficient for this purpose, as was ascertained by the more exact process employed in the paper, "On the Stability of the Rings of Saturn published in Nos. 80 and 81 of THE SIDEREAL MESSENGER. The numerical data for the several planets and satellites will be taken from the "Text-Book of General Astronomy," by Professor Charles A. Young, of Princeton College.

Let $a =$ the mean distance of a satellite from its primary planet, or the mean distance of a planet from the sun; and let $r =$ the radius of the satellite, or the radius of the planet. Also let $m =$ the mass of the planet attracting its satellite, or the mass of the sun attracting a planet. The masses will all be expressed in terms of the earth's mass, as the unit, and the radii and distances in miles. The unit of attractive force will then be the value of the acceleration that might be produced by the earth at one mile from its center, if the whole mass of the earth were concentrated at this center.

The attraction of a planet for its satellite, or of the sun for a planet, at its center, will be expressed by $\frac{m}{a^2}$.

At the nearest point of the satellite to its primary, or of a planet to the sun, the attraction will be $\frac{m}{(a-r)^2}$; and at the farthest point of the satellite, or planet, it will be $\frac{m}{(a+r)^2}$

Let f_1 = the difference of attraction on the nearest point, and on the center of the satellite or planet; and let f_2 = the difference of attraction on the center and on the farthest point of the satellite or planet. The disturbing force, f_1, tends to draw away the nearer portions of the satellite, or planet, from the center; and the force, f_2, tends to draw away the center from the farthest portions of these bodies; or, what is equivalent, the force, f_2 *acts as though* it REPELLED these remote portions from the center.

Regarding both these forces as positive quantities, it is evident that

$$f_1 = \frac{m}{(a-r)^2} - \frac{m}{a^2}, \quad f_2 = \frac{m}{a^2} - \frac{m}{(a+r)^2}.$$

Hence

$$f_1 = \frac{2mr}{a^3} \cdot \frac{1 - \frac{1}{2} \cdot \frac{r}{a}}{(1 - \frac{r}{a})^2}, \quad = f_2 \frac{2mr}{a^3} \cdot \frac{1 + \frac{1}{2} \cdot \frac{r}{a}}{(1 + \frac{r}{a})^2}.$$

Let $\beta = \frac{r}{a}$; then

$$f_1 = \frac{2m\beta}{a^2} \cdot \frac{1 - \frac{1}{2}\beta}{(1-\beta)^2} = \frac{2m\beta}{a^2} \cdot (1 + \tfrac{3}{2}\beta + \tfrac{4}{2}\beta^2 + \tfrac{5}{2}\beta^3 + \text{etc.})$$

$$f_2 = \frac{2m\beta}{a^2} \cdot \frac{1 + \frac{1}{2}\beta}{(1+\beta)^2} = \frac{2m\beta}{a^2} (1 - \tfrac{3}{2}\beta + \tfrac{4}{2}\beta^2 - \tfrac{5}{2}\beta^3 + \text{etc.})$$

The first power of β within the parentheses will be a sufficient approximation for the investigation proposed, as $\beta = \frac{r}{a}$ is always a small fraction. Hence the above formulæ may be written:

$$\left. \begin{aligned} f_1 &= \frac{2m\beta}{a^2} (1 + \tfrac{3}{2}\beta) \\ f_2 &= \frac{2m\beta}{a^2} (1 - \tfrac{3}{2}\beta) \end{aligned} \right\}, \qquad \text{(A).}$$

The first inference from these formulæ is, that f_1 is always greater than f_2;or that the nearer portions of the satellites or planet are always *pulled forward* more than the remoter portions are *pushed back*. The center of gravity of the attracted body must therefore be transferrd to some point within the hemisphere nearest to the attracting body. The *transference of the centre of gravity* towards the attracting body, together with the *amount of elongation* of the diameter towards the source of attraction, are the causes of the co-incidence of the periods of rotation and of revolution.

Let us now see how large these forces, f_1 and f_2, are in the case of a fluid moon attracted by the earth, and in the cases of the satellites of Jupiter, Saturn, Uranus and Neptune, and in the cases of the sun's attraction of the different planets.

In the case of the earth and our moon, $r = 1081$ miles = the moon's radius, and its mean distance, $a = 238{,}840$ miles, according to Professor Young. Taking the earth's mass as a unit, $2m = 2$.

$$\begin{aligned}
\therefore r &= [3.033826] \\
a &= [5.378107] \\
\hline
\therefore \beta &= [\bar{3}.655719] = 0.00452604, \quad \tfrac{3}{2}\beta = 0.00678906 \\
2m &= [0.301030] \\
\hline
2m\beta &= [\ \bar{3}.956749] \\
a^2 &= [10.756214] \\
\hline
\frac{2m\beta}{a^2} &= [\bar{13}.200535] \\
1 + \tfrac{3}{2}\beta &= [\ 0.002939] \\
\hline
f_1 &= [\bar{13}.203474]
\end{aligned}$$

$$\begin{aligned}
1 - \tfrac{3}{2}\beta &= [\bar{1}.997042] \\
\frac{2m\beta}{a^2} &= [\bar{13}.200535]. \\
\hline
f_2 &= [\bar{13}.197577]
\end{aligned}$$

$$\left.\begin{aligned}
\text{Hence } f_1 &= \frac{0.159763}{10^{12}} \\
f_2 &= \frac{0.157604}{10^{12}}
\end{aligned}\right\}$$

$$f_1 - f_2 = \frac{0.2159}{10^{14}}$$

f_1 and f_2 are, approximately, the measure of the earth's tidal disturbing forces on the moon's figure of equilibrium; and their difference, $f_1 - f_2$, is the excess of the earth's attraction on the nearer hemisphere over that on the remote hemisphere, and measures approximately the degree of transference of the moon's centre of gravity towards the earth. These forces, approximately, produce the elongation of the moon's diameters directed toward the earth, the displacement of its center of gravity, and thereby the co-incidence of its periods of rotation and revolution.

The same formulæ applied in like manner to Jupiter and his first satellite, with the data from Professor Young's Astronomy, $r = 1250$ miles, $a = 261000$ miles, $m = 316$, or $2m = 632$ times the earth's mass, give

$$f_1 = \frac{0.44750}{10^{10}}, \quad f_2 = \frac{0.44114}{10^{10}}, \quad \text{and } f_1 - f_2 = \frac{0.636}{10^{12}}$$

Hence it appears that in the action of Jupiter on his first satellite, his disturbing forces, f_1 and f_2, on its figure of equilibrium are more than 280 times those exerted by the earth on our moon, and the difference of his forces, for displacing the satellite's center of gravity, is more than 290 times the similar action of the earth on the moon.

If the earth's action on our moon, when it was fluid, was great enough to impress on our satellite a form that should cause its rotation and revolution periods to coincide, much more could Jupiter produce such an effect on his first satellite.

For Jupiter's second satellite Professor Young's data are $r = 1050$ miles, $a = 415000$ miles, $2m = 632$. Hence, by the same formulæ,

$$f_1 = \frac{0.93198}{10^{11}}, \quad f_2 = \frac{0.92600}{10^{11}}, \quad f_1 - f_2 = \frac{0.598}{10^{13}}$$

Here, also Jupiter's disturbing forces on his second satellite's figure of equilibrium are about 58 times as great as those exerted by the earth on our moon, and their difference is about 28 times that of the earth for displacing the center of gravity of this satellite. The second satellite of Jupiter ought, therefore, to have also a coincidence of its periods of rotation and revolution.

For the third satellite, the data are $r = 1775$ miles, $a = 664{,}000$ miles, $2m = 632$. Hence by the formulæ,

$$f_1 = \frac{0.38472}{10^{11}}, \quad f_2 = \frac{0.38165}{10^{11}}, \quad \text{and } f_1 - f_2 = \frac{0.307}{10^{13}}$$

Here the forces f_1 and f_2 are about twenty-four times those exerted by the earth, and their difference about fourteen times the corresponding difference in the case of the earth and moon. Hence Jupiter's third satellite should also rotate upon its axis and revolve around the planet in the same time.

For Jupiter's fourth satellite, $r = 1480$ miles, $a = 1117000$ miles, and $2m = 632$. Hence, by the formulæ,

$$f_1 = \frac{0.58965}{10^{12}}, \quad f_2 = \frac{0.58743}{10^{12}}, \quad \text{and } f_1 - f_2 = \frac{0.222}{10^{14}}$$

A glance at the corresponding values for the earth and moon shows that these values, f_1 and f_2, for Jupiter and his fourth satellite, are between three and four times as great, while the difference $f_1 - f_2$ is nearly the same, though a little larger than in the case of our moon. Hence all of Jupiter's satellites ought, for the same reason as our moon, to rotate on their axis in their several periods of revolution around him.

For Saturn's satellites, taking his mass $m = 94.9$ that of the earth, as given by Professor Young, and the other data from his Astronomy, the same formulæ give similar results for the first six satellites; the disturbing actions on their figures of equilibrium, and their differences being in each case larger than those of the earth's action on our moon. Hence the first six satellites should rotate in their periods of revolution about the planet. For the seventh satellite of Saturn the formulæ and data give the results,

$$f_1 = \frac{0.58260}{10^{13}}, \quad f_2 = \frac{0.58213}{10^{13}}, \text{ and } f_1 - f_2 = \frac{0.47}{10^{16}}$$

Hence the forces, f_1 and f_2, exerted by Saturn on his seventh satellite are more than one-third of those exerted by the earth, and their difference is about one-forty-sixth the corresponding difference in the case of the earth and moon.

For Saturn's eighth satellite, the results are

$$f_1 = \frac{0.15111}{10^{13}}, \quad f_2 = \frac{0.15092}{10^{13}}, \quad f_1 - f_2 = \frac{0.19}{10^{16}}$$

The values of f_1 and f_2 are about one-fifteenth of those exerted by the earth on our moon, and the difference, $f_1 - f_2$, is about one one-hundred and fourteenth of the corresponding difference for the earth and moon.

These two last satellites of Saturn must therefore be left in doubt whether they have such a figure of equilibrium impressed upon them as to cause a coincidence of their periods of rotation and revolution.

For the first satellite of Uranus, with the mass $2m = 29.4$ that of the earth, the formulæ and data give

$$f_1 = \frac{0.42668}{10^{11}}, \quad f_2 = \frac{0.42402}{10^{11}}, \quad f_1 - f_2 = \frac{0.266}{10^{13}}$$

The forces f_1 and f_2 are more than twenty-five times as great, and their difference more than twelve times that for the earth and moon.

The remaining three satellites of Uranus exhibit also a greater value of the forces f_1 and f_2 and also their difference, above those for the earth and moon. Hence it is probable that these satellites all rotate on their axes in their several periods of revolution around the planet.

The same law also holds good for the single known satellite of Neptune, since the computed values of f_1 and f_2 and $f_1 - f_2$ are larger than for the earth and moon. The satellites of Mars have not been examined because the values of their diameters can be considered as little better than mere guesses.

This investigation makes it highly probable that all the satellites of the solar system, if we except those of Mars, and the last two of Saturn, which are doubtful, rotate on their axes in the periods respectively of their revolutions about their primary planets.

If it be supposed that when the planets were in a fluid state, the sun may have impressed upon them an elongated form in his own direction, as the earth has done on the moon, it will be interesting to inquire what the forces f_1 and f_2 and their differences $f_1 - f_2$ would be in such cases, and to compare their values with those produced by the earth in disturbing the moon's figure of equilibrium. To consider first the case of the sun's action on the earth. According to Professor Young, the radius of the earth is $r = 3959$ miles, $a = 92900000$ miles = the earth's mean distance from the sun. The sun's mass compared with that of the earth as a unit, gives $2m = 662200$. Hence, by the formulæ (A),

$$f_1 = \frac{0.32701}{10^{14}}, \quad f_2 = \frac{0.32696}{10^{14}}, \quad f_1 - f_2 = \frac{0.5}{10^{18}}$$

These values of f_1 and f_2 are about the one-forty-eighth or one-forty-ninth part of those exerted by the earth on the moon, and their difference is less than one-four thousandth of of the corresponding difference for the moon. These results are very much smaller than the action of Saturn and his two most distant satellites. They may be regarded as the measure of the sun's impotence to produce such a change of the earth's figure of equilibrium as to compel a coincidence of the two periods of rotation and revolution. It is unnecessary to try the case of Mars and the sun, since r being less and *a* being greater than in the earth's case, it is certain that f_1, f_2, and $f_1 - f_2$ will be less for Mars than for the earth. But since *r* is much larger for Jupiter than for any of the planets, it will be interesting to compare the disturbing forces of the sun on Jupiter's figure with those exerted on the earth and with those of the earth on the moon.

For Jupiter Professor Young gives $r = 86500$ miles, $a = 483300000$ miles. Hence, by the same formulæ,

$$f_1 = \frac{0.50754}{10^{15}},\ f_2 = \frac{0.50727}{10^{15}},\ f_1 - f_2 = \frac{0.27}{10^{18}}$$

These values are smaller than in the case of the sun's action on the earth. Hence it is not surprising that the earth and Jupiter do not obey the equality of the periods of rotation and revolution. It would be useless to test the cases of the planets beyond Jupiter, because *r* being less, and *a* being greater for these than for Jupiter, it is certain that the forces f_1 and f_2, and their difference, will be progressively less for these more distant planets.

For Venus, $r = 3850$ miles, $a = 67{,}200{,}000$ miles, according to Professor Young. Hence, by similar computations to those for the earth and Jupiter, it will be found that

$$f_1 = \frac{0.84019}{10^{14}},\ f_2 = \frac{0.84005}{10^{14}},\ f_1 - f_2 = \frac{1.4}{10^{18}}$$

The earth exerts on our moon values of f_1 and f_2, about 19 times as great as these of the sun on Venus; and the difference $f_1 - f_2$, in the case of the earth and moon is about 1500 times as great as the corresponding difference for the sun and Venus. These effects of the sun on Venus are, however, all of them between two and three times as great as those which the sun exerts on the earth. There is therefore, little probability that the sun's disturbing forces on the figure of equilibrium of Venus could cause the periods of rotation and of revolution of that planet to coincide.

For Mercury, Professor Young gives $r = 1515$ miles, $a = 36{,}000{,}000$. Hence by the same formulae

$$f_1 = \frac{0.21504}{10^{13}},\ f_2 = \frac{0.21501}{10^{13}},\ f_1 - f_2 = \frac{3}{10^{18}}.$$

Compared with the disturbing forces of the earth on the moon, those of the sun on Mercury are less than one-seventh the values of the former, and the difference of the forces, $f_1 - f_2$, on Mercury, is less than one-seven-hundredth of that produced by the earth on the moon. But compared with the sun's action on the earth the f_1 and f_2 on Mercury are a little more than six and a half times those exerted by the sun on the earth. The difference, $f_1 - f_2$, of the sun's action on Mercury is also six times his action in this respect on the earth. It may be doubted perhaps whether the action of the sun on the planet Mercury would be sufficient to control his figure of equilibrium, and the position of his center of gravity, in such a manner as to cause his period of rotation to be identical with that of his revolution about the sun. The observations of the distinguished Italian astronomer are doubtless correct and valuable, but they may perhaps be susceptible of of a different interpretation.

AN ELEMENTARY METHOD FOR CALCULATING TRANSITS OF VENUS AND MERCURY.

MILTON UPDEGRAFF.*

FOR THE MESSENGER.

The convenient and accurate method of Lagrange for computing transits of Venus and Mercury is the one usually employed, and the results of its application to the coming transit of Mercury on May 9th are given on page 414 of the American Ephemeris, and also on pages 365-6 of the *Berliner Astronomisches Jahrbuch* for 1891. In each of these books are given the times of the contacts for the center of the earth and convenient formulæ for computing the times of contact for any place on the earth's surface. But the development of the general formulæ by Lagrange's method is a rather abstruse mathematical process, and it is the object of this paper to show a way of calculating transits of Venus and Mercury which may be understood by any student possessing a knowledge of elementary astronomy, plane trigonometry and algebra. This can best be done by applying the method to the transit of Mercury on May 9th of this year.

We have first to extract the necessary data from the daily

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ephemerides of the sun and Mercury given on page 75 and 222 of the American Ephemeris for 1891. The places of the sun and Mercury are given for Greenwich mean noon, and Greenwich time will be used in the computation. By a casual inspection of the right ascensions and declinations of the sun and the planet for May 7th, 8th and 9th, it will be seen that these bodies are moving in opposite directions and approaching each other in both co-ordinates. It is evident that they will be nearest together at some time on May 9th. We next determine with accuracy the time when the sun and Mercury are in conjunction in right ascension. To do this the following method will be employed which may be found in a less extended form in Loomis' Practical Astronomy, page 210.

The right ascensions of the sun and Mercury are taken out of the ephemeris for a few days before and after May 9th and set in adjacent columns as below:

Date 1891	R. A. of Mercury	R. A. of Sun	Sun — Mercury	1st Diff.	2nd Diff.	3d Diff.	4th Diff.
	h m s	h m s	m s	m s	s	s	s
May 7	3 12 23.48	2 56 35.76	+15 47.72				
				−5 51.88			
" 8	3 10 24.31	3 0 28.47	+ 9 55.84		−5.05		
				−5 56.93		+ 2.42	
" 9	3 8 20.66	3 4 21.75	+ 3 58.91		−2.63		+ 0.01
				−5 59.56	−1.415	+ 2.43	
" 10	3 6 14.95	3 8 15.60	− 2 0.65		−0.20		−0.09
				−5 59.76		+ 2.32	
" 11	3 4 9.61	3 12 10.02	− 8 0.41		+ 2.12		
				−5 57.64			
" 12	3 2 6.95	3 16 5.00	−13 58.05	*a*	*b*	*c*	*d*

The difference of right ascensions of the sun and Mercury are taken for each day and are set down in the fourth column. These differences of right ascension are equi-distant values of a function and we wish to determine at what time it is zero. We know that it must be zero at some time on May 9th, since on that day it passes from plus to minus. We now take the various orders of differences as for interpolation, but instead of desiring to find the value of the function for a certain time we wish to find at what time the function has a certain value. For this purpose we may use any of the algebraic formulæ for interpolation and will adopt Bessel's, which is

$$a_t = a_0 + tb + \frac{t\,(t-1)}{2}c + \frac{t\,(t-1)\,(t-\frac{1}{2})}{2.3}d, \text{ etc.}$$

Now $a_t = 0$, and neglecting all terms except the first two we have for a first approximation $t = -\frac{a_0}{b}$.

Neglecting only the last term we have as a second approximation $t = \frac{a_0}{b - \frac{c}{2} - \frac{c}{2} \cdot \frac{a_0}{b}}$, and making use of the last term

$$t = \frac{-a_0}{b - \frac{c}{2} + \frac{d}{12} + t\left\{\frac{c}{2} - \frac{d}{4}\right\} + t^2\frac{d}{6}}$$

In using this last formula the value of t used in the denominator is the value given by the second approximation. The values of b, c and d are the differences between the horizontal lines in the table and $a_0 = + 3^m\ 58^s.91$.

By the third approximation the value of t is 0.664844 days $= 15^h\ 57^m\ 22^s.5$, which is the time of conjunction in right ascension on May 9th. The following data are interpolated from the Ephemeris for this time using 2d and 3d differences when necessary:

R. A. of sun and Mercury,	3*h* 6*m* 57.2*s*	Hourly motions	+ 2′ 26″.22, — 1′ 18″.51
Declination of Mercury	+ 17° 18′ 0″.5	Hourly motion	— 1 6 .68
Declination of sun	+ 17 32 1 .3	Hourly motion	+ 39 .53
Eq. Hor. Parallax of sun	8 .75	Semidiameter	15 52 .3
Eq. Hor. Parallax of Mercury	15 .85	Semidiameter	6 .0

The difference of declination of Mercury and the sun at conjunction is 14′ 0″.8 which is less than the semi-diameter, and it is evident that there will be a transit of the planet across the sun's disk. It should also be remarked that the planet approaches the sun from the east and passes downward and westward across the disk.

By an application of the usual method for projecting eclipses of the moon it is possible, with the above data, to get the times of the contacts within two or three minutes. But we shall make use of this graphical process only for the purpose of illustration. Draw a horizontal line *IJ* (see Fig. 1) and a vertical line *GK* intersecting at right angles at *C*. Lay off *IC* to represent the semi-diameter of the sun, and with radius *IC* and center *C* draw the circle *GIK* to represent the sun's disk. Let *GK* be a portion of a great circle of the celestial sphere passing through the sun's center from the pole to the equator. Then *IJ* will be a portion of a small circle parallel to the equator and passing through the sun's center at declination + 17° 32′ 1″.3. The hourly motion in declination of the sun is 39″.53 north, and that of Mercury is 1′ 6″.68 south. They therefore approach each other in declination with an hourly motion of 1′ 46″.21 on a great circle. Lay off *mC** to represent 1′ 46″.21. The hourly motion in right ascension of the sun is 2′ 26″.22 east and that of Mercury is 1′ 18″.51 west.

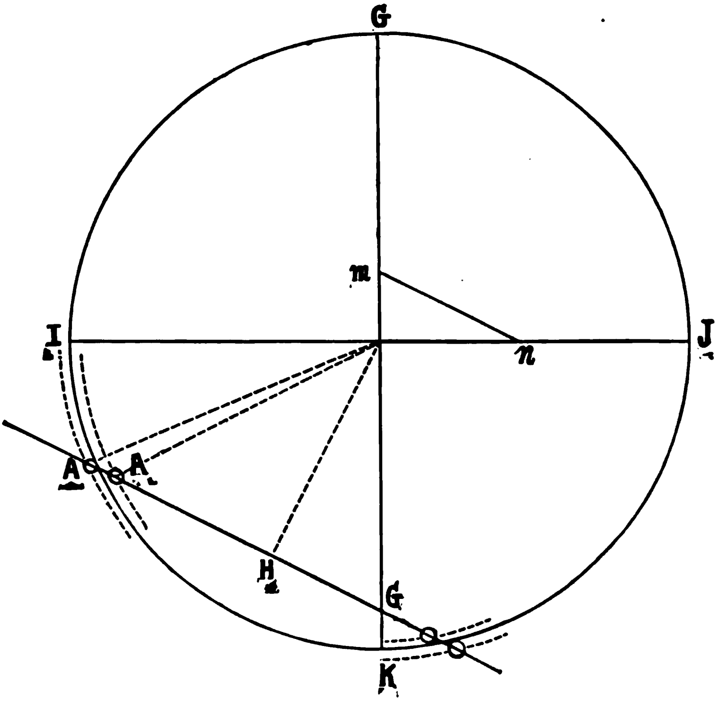

FIG. 1.

But these motions are on a small circle and being given in time, are larger than than they would be if given in angular space measured on a great circle, on the same principle that a star near the pole moves slower in its diurnal motion than a star near the equator. These motions vary as the secant of the declination, and we therefore divide the hourly

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* C should be at the middle point of the cut. Omission was engraver's fault.

motions of the sun and Mercury in right ascension by the secants of their declinations, or what is the same thing, multiply them by the cosines.

(2′ 26″.22)cos 17° 32′ + (0′ 18″.51)cos 17° 18′ = 3′ 34″.39. Lay off *Cn* equal to 3′ 34″.39 on the same scale as *mC*. Then *mn* will be parallel to the path of the planet. At conjunction the planet will be at some point on *CK* and at a distance from *C* equal to the difference between its declination and that of the sun. This difference is 14′ 0″.8, Mercury being south. Lay off *CG* equal to 14′ 0″.8 on the same scale to which the semi-diameter of the sun is drawn. *G* is a point in the path of the planet and the line *AG* drawn parallel to *mn* is the path of the planet across the sun's disc as seen from the center of the earth. From *C* with radius 15′ 58″.3, the sum of the semi-diameters of the sun and Mercury, draw an arc of a circle cutting *AG* at the point *A*. Also from the same center describe a circle with radius 15′ 46″.3, the difference of the diameters, and cutting *AG* at A′. (This cannot be done to scale since Mercury is a mere speck on the sun). *A* and *A′* are the positions of the center of the planet at 1st and 2d contact, and describing from these points small circles tangent to the sun's limb we have a true representation of the 1st and 2d contacts as seen from the earth's center, except that Mercury is drawn on a much larger scale than the sun.

Draw the lines *CA*, *CA′* and *CH*. All the straight lines in the figure really represent arcs of great circles, but their curvature is so slight that the error due to its being neglected is far from being appreciable. The triangles formed by them may therefore be solved as plane triangles.

We now proceed to calculate the times of the 1st and 2d contacts as seen from the center of the earth. From the triangle *nCm* we get *nm* = 3′ 59″.257, angle *m* = 63° 38′ 45″.5 and angle *n* = 26° 21′ 14″.5. In the triangle *ACG* we have angle *AGC* equal to *nmC* since *AG* and *nm* are parallel. AC = 15′ 58″.3 = the sum of the diameters of the sun and Mercury, and *CG* = 14′ 0″.08 = the difference of their declinations at conjunction. Having three sides and an angle we compute *AG* = 16′ 5″.46, *CAG* = 51° 49, 54″.0 and *ACG* = 64° 31′ 20″.5. We also find *CH* = 12′ 33″.4 which is the nearest approach of Mercury to the center of the sun. When at 1st contact the planet is at the distance *AG* from conjunction in right ascension, and dividing this distance, $16' 5''.46$, by $239''.257$, the hourly motion in the line *AG*, we have $4^h.03525 = 4^h\ 2^m\ 6^s.9$, the time it will take the planet to pass from 1st contact to conjunction in right ascension. The time of conjunction being $15^h\ 57^m\ 22^s.5$, and subtracting $4^h\ 2^m\ 6^s.9$ we get $11^h\ 55^m\ 15^s.6$, which is the Greenwich time of 1st contact as seen from the center of the earth. In the same way, by solving the triangle *A′CG* we find the time of 2d contact to be $12^h\ 0^m\ 11^s.0$. Subtracting 6 hours from the Greenwich time of 1st and 2d contacts gives the central time of their occurrence as about 6 o'clock P. M. On May 9th the sun sets at ten minutes past seven o'clock at this latitude and since the 3d and 4th contacts occur more than four hours later than the 1st and 2d, the last two contacts will be invisible here and are not computed for this reason.

This computation is rigorous excepting that no account is taken of the small variations in the rapidity of motion of the sun and Mercury which take place between the times of the contacts and conjunction. But the chief uncertainty lies in the computation of the time of conjunction, which is due to the fact that the places of the sun and the planet are not known with perfect accuracy. There is some uncertainty also in the adopted semi-diameter of the sun, and according to the *Berliner Jahrbuch* a variation of one second of arc in the sun's semi-diameter affects the times of the contacts by 24 seconds of time.

In order to give an idea of the accuracy that may be expected of a prediction of a transit of Mercury, we give below the times of the 1st and 2d contact as given in the American Ephemeris and the *Berliner Jahrbuch*. Different tables of Mercury are used at Washington and Berlin, but both are based on the researches of the celebrated French astronomer, *Le Verrier*.

	Geocentric 1st. Contact	Geocentric 2d Contact.
Am. Ephemeris..................	$11^h\ 55^m\ 29^s.3$	$12^h\ 0^m\ 25^s.0$
Berliner Jahrbuch..............	11 54 13	11 59 9

For any place on the surface of the earth at which the sun and Mercury are in the zenith at the time of a contact that contact will be seen at the same time as from the center of the earth. But for all other places on the earth the contact will take place sooner or later on account of the effect of parallax. We now proceed to compute the corrections for parallax at the 1st and 2d contacts as seen from Columbia, Missouri.

Interpolating the declination of Mercury for the Greenwich time of 1st contact as seen from the earth's center, and subtracting our longitude, $6^h\ 9^m\ 18^s$, from the same time we have $+ 17° 22'$ for the declination of the planet and $5^h\ 45^m\ 58^s$ for the local mean time of geocentric 1st contact. Adding to the latter the equation of time, $3^m\ 41^s$ (see p. 75 Am. Eph.), we have $5^h\ 49^m\ 39^s$ as the west hour angle of the sun at geocentric 1st contact, which diminished by 1^m, the semidiameter of the sun in time, gives very nearly, as the hour angle of the planet $5^h\ 48^m\ 39^s$. From the declination and hour angle the difference of parallax of the sun and Mercury in both right ascension and declinatian are comput ed by the usual formulæ for the purpose, which may be found in *Chauvenet's Sphr. and Pract. Ast., Vol. 1, p. 125.* This might be worked out independently by a simple application of the principles of spherical trigonometry but it would be rather tedious and it will be best to compute these small corrections by means of the formulæ above referred to, and the results only are given here. The difference of parallax in right ascension is $5''.80$ and in declination $4''.20$.

Since Columbia is north of the plane of the equator an observer here will see both the sun and Mercury projected lower down towards the celestial equator on the celestial sphere than he would if situated at the center of the earth. Mercury being nearer the earth will be more depressed than the sun, and since he is below the sun's center the effect of difference of parallax in declination at Columbia will be to depress Mercury still farther below the center of the sun. Again, conceive a plane passing through the earth's axis and the center of the sun. Since Columbia is above this plane Mercury and the sun will be depressed toward it, Mercury more than the sun, as before. But since the planet is now above the sun's center, the effect of difference of parallax in right ascension will be to throw it nearer to the sun's center. In Fig. 2, let *BF* be a portion of the sun's limb (on an enlarged scale) at the point of 1st contact, and let *a* be the place of the planet at 1st contact as seen from the earth's center (*A* in Fig. 1). Draw a vertical line *ax* to represent the effect of difference of parallax in declination (4″.20) and a horizontal line *xc* for the effect of difference of parallax in right ascension (5″.80). When the planet is seen at *a* by an observer at the earth's center it is seen on the sun's disk at *c* by an observer at Columbia, and 1st contact occurs sooner at Columbia than at the center of the earth.

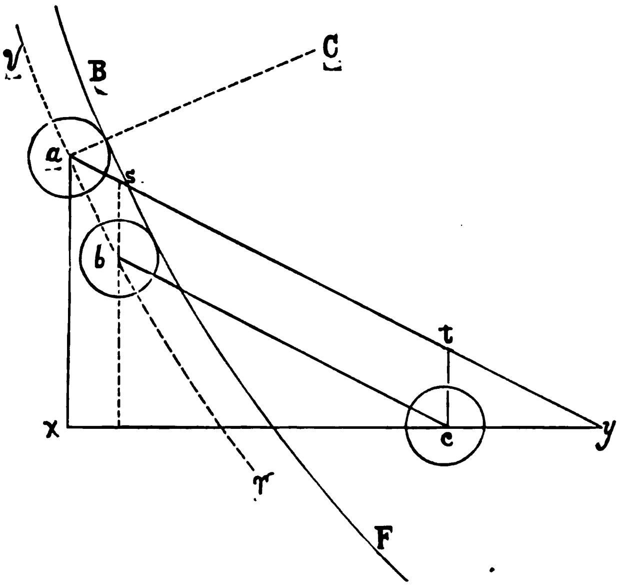

Fig. 2.

Parallax in declination depresses the planet from *a* to *x*, and parallax in right ascension shifts it from *x* to *c*. From *a* draw *aC* in the direction of the sun's center, and also *ay*, making the angle *Cay* equal to *CAG*=51° 49′ 54″.0 in Fig. 1. From the sun's center, with radius equal to the sum of the diameters of the sun, and the planet, describe the arc *qr*. Of course it will pass through *a* and all other portions of the center of the planet at exterior contact. *ay* is a portion of the path of the planet as seen from the earth's center, and *bc* drawn through *c* parallel to *ay* and cutting *qr* in *b* is a part of the path of the planet as seen from Columbia. *b* is the position of the planet as seen from Columbia. Produce *xc* to y and draw ct and sb parallel to ax. First contact takes place at Columbia earlier than it does at the center of the earth by the time it takes the planet to move from b to c. If the distance bc is known, this time may be found by dividing bc by the hourly motion of the planet. Triangle axy is similar to mCn in Fig. 1 since the sides are parallel each to each. Angle $xay = 63^\circ\ 38'\ 45''$ and the side $ax = 4''.20$ and we find $xy = 8''.46$ and $ay = 9''.44$. $ax - xc = 8''.46 - 5''.80 = 2''.66 = cy$, and from the triangle tcy we have $tc = 1''.32$ and $ty = 2.97$. In the small triangle asb, $sb = tc = 1''.32$, angle $s = 180^\circ - yax$ and angle $sab = 90^\circ - Cay = 90^\circ - 51^\circ\ 49'\ 54''$, and solving it we get $bs = 0''.91$. From ay subtracting as and ty we have $9''.44 - 0.''91 - 2''.97 = 5''.56 = st = bc$ $5''.56 \div 239''.26$ (the hourly motion) $= 0.02324$ hours $= 1^m\ 23^s.7$. An observer at Columbia sees 1st contact $1^m\ 23^s.7$ sooner than an observer at the center of the earth, and subtracting this correction for parallax from $11^h\ 55^m\ 15^s.6$ we get $11^h\ 53^m\ 51^s.9$, which is the Greenwich mean time of 1st contact as seen at Columbia. In the same way the correction due to parallax for 2d contact is computed and found to be $1^h\ 22^s.8$, and, when subtracted $12^h\ 0^m\ 11^s.0$, the time of 2d contact for the earth's center, gives $11^h\ 58^m\ 48^s.2$ as the Greenwich mean time of 2d contact for Columbia. Subtracting 6 hours from the Greenwich time gives as the central times of 1st and 2d contacts at Columbia, Missouri, according to this computation,

1st Contact, $5^h\ 53^m\ 51^s.9$, 2d Contact, $5^h\ 58^m\ 48^s.2$.

In Fig. 1, the angle $ACK = 64^\circ\ 31'$, is the angular distance from the south point of the sun at which 1st contact takes place. Or, the supplement of ACK, $GCA = 115^\circ\ 29'$, is the angular distance of 1st contact from the north point reckoned to the left.

OBSERVATORY OF THE STATE UNIVERSITY OF MISSOURI.

April 6, 1891.

METEOR RADIANTS.

W. F. DENNING, ENGLAND.

FOR THE MESSENGER.

Mr. Monck, in his letter to THE SIDEREAL MESSENGER of February, p. 109, assumes an air of injured innocence. But he is still inaccurate in certain statements, and I am sorry there is a further necessity for me to reply to your irrepressible correspondent.

He says my argument is that because he is not himself an observer he has no right to form any theory about meteors. I need hardly say this is quite inconsistent with fact. Your correspondent may theorise to his heart's content and without fear of hostile criticism from me. But he is not content to frame theories on the basis of observation; he first endeavors to subvert the observations and puts an entirely wrong construction upon them. It is this I object to.

Mr. Monck quotes his friend Mr. Gore, who, however, gives no support to his case. Mr. Gore follows a perfectly just and legitimate method in accepting observations and making computations from them, without thinking it desirable to overturn the data gathered by able and reliable men like Burnham. Suppose for a moment that Mr. Gore attempted to alter their facts and opposed the direct issues of their observations, I think it is very likely they would strongly resent such treatment. But Mr. Gore, far from assuming to dictate in such a way has a very keen appreciation of the observations, accepting them as they stand, and reducing them with honor to himself and those who made them.

If Mr. Monck will endeavor to theorise from my observations without going beyond his depth in futile efforts to overturn them, I shall be really much obliged to him, and I will give him any explanations that may be likely to help him. But when he attempts to group the radiants in an erroneous way, and derives false conclusions, it at once becomes necessary I should tell him he is not justified by experience to meddle with them in such a manner.

In his letter he remarks, "No decided case of shifting in a radiant has been established." A definite statement of this kind, emanating from a man who has never yet observed the radiant point of a single meteor shower, and which is in direct contradiction to the evidences of modern observation, is simply worthless. I must confess to a feeling of surprise at the temerity (I had almost said assumption) which prompted it to be uttered. .

Let Mr. Monck watch the sky in July and August next, and if he has any ability and patience as an observer he will see the shifting radiant of the Perseids for himself and cease this useless cavilling.

BRISTOL, Feb. 17, 1891.

[The above article was received too late for the March MESSENGER. It should have appeared in the April issue. By mistake it was omitted.—ED.]

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

The most noteworthy astronomical event to be predicted for this month is the *Transit of Mercury* across the suns's disk which will occur on May 9. Mercury passing between us and the sun will appear as a small, round, black spot, invisible without the aid of the telescope, moving very slowly across the solar disk. The transit will begin at about 5^h 54^m P. M. and will end at 10^h 53^m P. M., central time. Only the beginning will be visible in the United States, and in the eastern states the sun will then be so near the horizon that satisfactory observations will be impossible.

In our last number we gave a cut showing the paths of Mercury across the sun's disk during each transit of the present century, and also the exact times of the beginning of this transit at several of the observatories. The times of beginning of transit we will repeat for the sake of those who may not have received the last number of the MESSENGER, and call attention to the article by Professor Updegraff (See page 225).

Observatory.	External Ingress.	Standard of Time.
Harvard College,	6^h 54^m 32.55^s	Eastern.
New York City,	6 54 25.81	"
Washington,	6 54 18.64	"
Chicago,	5 54 19.73	Central.
Carleton College,	5 54 26.68	"
Lick,	3 54 17.99	Pacific.

The best way for those who have small telescopes to observe the transit will probably be to arrange the telescope so as to project the image of the sun upon a screen of white paper a foot or two back of the eye-piece. A large shade should be placed on the tube of the telescope near the object end, to cut off from the screen the direct rays of the sun. By properly adjusting the focus a sharp image from four to eight or more inches in diameter can be obtained with a telescope of only an inch and a half aperture. The image of Mercury on the sun should be perfectly round and black, having a diameter about one one-hundred-and-fiftieth of that of the sun. It will enter upon the disk of the sun about 25° south of the east point.

The observations which an amateur may make will be to note the exact times when Mercury seems to touch the edge of the sun from the outside, then on the inside of the disk. These times will, however, be of no value, unless the error of the time-piece used, and the longitude and latitude of the place of observation are accurately determined. It will be well also to watch closely to see if a bright ring can be seen around that part of Mercury's disk which is off the solar disk, between first and second contacts. Also notice carefully whether there is any trace of a dusky fringe around the planet when wholly within the disk of the sun.

Venus may be seen in the east an hour before sunrise but is not in a favorable position for observation except during the day. Venus will be in conjunction with the moon, 2° 54′ north, on the morning of May 5, and again on June 4, 0° 12′ north. On the latter occasion Venus will be occulted as seen by observers in latitudes betwen 30° north and 45° south.

Mars may still be seen in the west each evening until nine o'clock, but is not in position to be well observed.

Jupiter may be observed after three o'clock in the morning. He is among the faint stars in Aquarius, seen towards the east in the morning.

Saturn will be at quadrature with the Sun, May 31. It is past the best time for observation this year, yet the phenomena attendant upon the changes in position of the rings should be watched very closely as long as it is possible to follow the planet. Good observations may sometimes be made before sunset.

Uranus may be best observed from 8 P. M. to 2 A. M. For its position among the stars see diagram February number of THE MESSENGER (page 142). It will be in conjunction with the moon, south 2° 54′, May 20 at 6 P. M.

Neptune will be at conjunction with the sun May 27, and so it is out of our view for the month.

MERCURY.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 25........	2 52.2	+ 12 46	3 45 A. M.	10 40.2 A. M.	5 35 P. M.
June 5........	3 17.8	+ 14 32	3 20 "	10 22.6 "	5 25 "
15........	4 06.2	+ 18 31	3 11 "	10 31.4 "	5 52 "
25........	5 18.5	+ 22 41	3 24 "	11 04.4 "	6 45 "
			VENUS.		
May 25........	2 08.0	+ 11 03	3 09 A. M.	9 56.7 A. M.	4 44 P. M.
June 5........	2 59.3	+ 15 21	2 58 "	10 04.2 "	5 10 "
15........	3 47.8	+ 18 38	2 52 "	10 13.2 "	5 34 "
25........	4 38.2	+ 21 09	2 51 "	10 24.1 "	5 57 "

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MARS.		
May 25	5 34.1	+24 11	5 33 A. M.	1 21.8 P. M.	9 11 P. M.
June 5	6 06.0	+24 23	5 21 "	1 10.4 "	9 00 "
15	6 34.9	+24 12	5 11 "	12 59.9 "	8 49 "
25	7 03.4	+23 41	5 03 "	12 49.0 "	8 35 "
			JUPITER.		
May 25	23 07.0	− 6 48	1 19 A. M.	6 55.8 A. M.	0 32 P. M.
June 5	23 11.6	− 6 23	0 39 "	6 17.0 "	11 55 A. M.
15	23 14.8	− 6 06	0 02 "	5 40.9 "	11 20 "
25	23 16.9	− 5 56	11 24 P. M.	5 03.6 "	10 44 "
			SATURN.		
May 25	10 51.1	+ 9 32	11 56 A. M.	6 37.9 P. M.	1 19 A. M.
June 5	10 52.3	+ 9 23	11 15 "	5 55.9 "	0 37 "
15	10 54.1	+ 9 10	10 38 "	5 18.3 "	11 58 P. M.
25	10 56.4	+ 8 54	10 02 "	4 41.3 "	11 20 "
			URANUS.		
May 25	13 44.7	−10 14	4 08 P. M.	9 31.0 P. M.	2 54 A. M.
June 5	13 43.5	−10 08	3 24 "	8 46.6 "	2 10 "
15	13 42.7	−10 04	2 43 "	8 06.5 "	1 30 "
25	13 42.3	−10 02	2 03 "	7 26.6 "	0 50 "
			NEPTUNE.		
May 25	4 19.3	+19 52	4 40 A. M.	12 07.2 P. M.	7 34 P. M.
June 5	4 21.0	+19 56	3 58 "	11 25.7 A. M.	6 53 "
15	4 22.5	+20 00	3 20 "	10 47.9 "	6 15 "
25	4 24.0	+20 03	2 42 "	10 10.0 "	5 38 "
			VESTA.		
Apr. 24	18 30.2	−17 58	11 30 P. M.	4 19 A. M.	9 08 A. M
May 18	18 34.6	−18 28	10 00 "	2 48 "	7 36 "
June 11	18 20.3	−19 48	8 18 "	12 59 "	5 40 "
			PALLAS.		
May 30	20 19.6	+18 02	8 28 P. M.	3 46 A. M.	11 04 A. M
June 23	20 10.4	+19 33	6 37 "	2 02 "	9 27 "
			THE SUN.		
May 25	4 08.9	+21 00	4 23 A. M.	11 56.7 A. M.	7 30 P. M.
June 5	4 53.8	+22 35	4 17 "	11 58.3 "	7 40 "
15	5 35.2	+23 20	4 15 "	12 00.2 P. M.	7 45 "
25	6 16.7	+23 24	4 17 "	12 02.4 "	7 48 "
			THE MOON.		
May 20	13 53.4	− 8 19	4 18 P. M.	9 59.4 P. M.	3 32 A. M.
21	14 41.7	−13 33	5 24 "	10 43.6 "	3 55 "
22	15 33.2	−18 14	6 32 "	11 31.0 "	4 23 "
23	16 28.7	−22 08	7 43 "	12 22.4 A. M.	4 51 "
24	17 28.1	−24 50	8 54 "	1 17.7 "	5 40 "
25	18 30.9	−26 02	10 00 "	2 16.1 "	6 34 "
26	19 34.3	−25 31	10 58 "	3 15.7 "	7 38 "
27	20 37.3	−23 18	11 46 "	4 14.6 "	8 49 "
29	21 38.0	−19 32	12 25 "	5 11.2 "	10 07 "
30	22 35.7	−14 33	12 57 "	6 04.8 "	11 24 "
31	23 30.8	− 8 43	1 24 "	6 55.8 "	12 40 P. M.
June 1	0 24.2	− 2 24	1 48 "	7 45.1 "	1 50 "
2	1 16.9	+ 4 01	2 11 "	8 33.8 "	3 11 "
3	2 10.3	+10 13	2 35 "	0 23.0 "	4 27 "
4	3 05.3	+15 48	3 00 "	10 12.0 "	5 42 "
5	4 02.4	+20 26	3 30 "	11 07.0 "	6 57 "

THE MOON.

Date. 1891.		R. A. h m	Decl. ° ′	Rises. h m		Transits. h m		Sets. h m	
June	6	5 01.5	+ 23 48	4 05	P. M.	12 02.0	P. M.	8 09	P. M.
	7	6 01.7	+ 25 41	4 49	"	12 58.2	"	9 13	"
	8	7 01.6	+ 26 00	5 40	"	1 53.9	"	10 07	"
	9	7 59.5	+ 24 50	6 39	"	2 47.7	"	10 51	"
	10	8 54.3	+ 22 23	7 42	"	3 38.5	"	11 26	"
	11	9 45.8	+ 18 55	8 47	"	4 25.9	"	11 54	"
	12	10 34.1	+ 14 41	9 51	"	5 10.1	"	12 18	A. M.
	13	11 20.1	+ 9 54	10 55	"	5 52.0	"	12 39	"
	14	12 04.6	+ 4 44	11 57	"	6 32.5	"	12 57	"
	15	12 48.8	− 0 38	12 59	"	7 12.6	"	1 16	"
	16	13 33.6	− 6 03	2 02	"	7 53.5	"	1 35	"
	17	14 20.5	− 11 20	3 07	"	8 36.2	"	1 56	"
	18	15 10.3	− 16 17	4 14	"	9 22.0	"	2 22	"
	19	16 04.1	− 20 34	5 24	"	10 11.8	"	2 53	"
	20	17 02.4	− 23 51	6 35	"	11 05.9	"	3 32	"
	21	18 04.8	− 25 44	7 45	"	12 04.2	A. M.	4 22	"
	22	19 09.7	− 25 54	8 48	"	1 05.0	"	5 24	"
	23	20 14.8	− 24 15	9 42	"	2 06.0	"	6 37	"
	24	21 17.9	− 20 54	10 25	"	3 05.0	"	7 54	"
	25	22 17.8	− 16 10	11 00	"	4 00.8	"	9 13	"
	26	23 14.3	− 10 29	11 29	"	4 53.2	"	10 30	"
	27	0 08.2	− 4 15	11 53	"	5 43.0	"	11 46	"
	29	1 01.8	+ 2 09	12 16	A. M.	6 31.5	"	1 00	P. M.
	30	1 53.1	+ 8 22	12 39	"	7 19.8	"	2 15	"

Jupiter's Satellites.

		Central Time. h m		
May	16	2 00	A. M.	II Ec. Dis.
	18	12 40	"	IV Oc. Dis.
	18	1 41	"	II Tr. Eg.
	18	4 57	"	IV Oc. Re.
	19	1 26	"	III Sh. Eg.
	19	2 27	"	I Ec. Dis.
	19	3 14	"	III Tr. In.
	20	1 05	"	I Tr. In.
	20	2 05	"	I Sh. Eg.
	20	3 24	"	I Tr. Eg.
	25	1 27	"	II Tr. In.
	25	1 40	"	II Sh. Eg.
	26	1 49	"	III Sh. In.
	26	3 21	"	IV Sh. Eg.
	27	1 39	"	I Sh. In.
	27	3 01	"	I Tr. In.
	27	3 59	"	I Sh. Eg.
	27	5 20	"	I Tr. Eg.
	30	12 48	"	III Oc. Re.
June	1	1 21	"	II Sh. In.
	1	4 06	"	II Tr. In.
	1	4 16	"	II Sh. Eg.
	3	2 04	"	II Oc. Re.
	4	12 44	"	I Ec. Dis.
	4	4 23	"	I Oc. Re.
	5	12 20	"	I Sh. Eg.
	5	1 43	"	I Tr. Eg.
	6	1 25	"	III Oc. Dis.
	6	4 51	"	III Oc. Re.

		Central Time. h m		
June	8	3 58	"	II Sh. In.
	11	2 38	"	I Ec. Dis.
	11	11 55	P. M.	I Sh. In.
	12	1 18	A. M.	I Tr. In.
	12	2 14	"	I Sh. Eg.
	12	3 36	"	I Tr. Eg.
	12	11 49	P. M.	III Ec. Dis.
	13	12 46	A. M.	I Oc. Re.
	13	3 14	"	III Ec. Re.
	17	1 38	"	II Ec. Dis.
	19	1 28	"	II Tr. Eg.
	19	1 49	"	I Sh. In.
	19	3 11	"	I Tr. In.
	20	12 39	"	IV Ec. Dis.
	20	2 39	"	I Oc. Re.
	20	3 50	"	III Ec. Dis.
	20	11 57	P. M.	I Tr. Eg.
	24	2 44	A. M.	III Tr. Eg.
	26	1 09	"	II Tr. In.
	26	1 24	"	II Sh. Eg.
	27	12 54	"	I Ec. Dis.
	27	4 30	"	I Oc. Re.
	28	12 30	"	I Sh. Eg.
	28	1 49	"	I Tr. Eg.
	28	11 42	P. M.	IV Tr. In.
	29	3 26	A. M.	IV Tr. Eg.
July	1	1 25	"	III Sh. Eg.
	1	3 11	"	III Tr. Eg.

Configuration of Jupiter's Satellites at 3 a. m.

May 17	4 1 ○ 2 3	June 1	4 ○ 2 1 3	June 16	4 2 1 ○ 3
18	● 2 ○ 1 3	2	4 2 1 ○ 3	17	4 2 3 ○ 1
19	2 1 ○ 3 4	3	4 3 ○ 1 ●	18	4 3 1 ○ 2
20	3 ○ 2 4 ♃	4	● 3 ○ 4 2	19	♃ 4 3 ○ 1
21	3 ○ 1 2 4	5	3 2 1 ○ 4	20	2 4 3 ○ ●
22	2 3 1 ○ 4	6	2 3 ○ 1 4	21	1 ○ 4 2 3
23	2 ○ 3 1 4	7	1 ○ 2 3 4	22	○ 1 2 4 3
24	1 ○ 2 3 4	8	○ 2 1 3 4	23	2 1 ○ 3 4
25	♃ ○ 1 3 4	9	2 1 ○ 3 4	24	♃ 2 ○ 1 4
26	2 1 ○ 3 4	10	3 2 ○ 1 4	25	3 1 ○ 2 4
27	3 4 ○ 1 2	11	3 1 ○ 2 4	26	3 ○ 2 1 4
28	3 4 ○ 2 ●	12	3 2 ○ 1 4	27	2 3 1 ○ 4
29	4 3 2 1 ○	13	2 4 3 ○ 1	28	♃ ○ 2 3 4
30	4 2 ○ 3 1	14	4 1 ○ 2 3	29	♃ ○ 1 2 3
31	4 1 ○ 2 3	15	4 ○ 1 2 3	30	4 2 1 ○ 3
				July 1	4 2 ○ 3 1

The arrangement of the figures 1 2 3 4 indicates the positions of the four satellites relative to the planet ○. The sign ♃ signifies that the satellite whose number is missing is upon the face of the planet; ● signifies that the satellite is behind or in the shadow of the planet.

Minima of Variable Stars of the Algol Type.

[The times are given, to the nearest hour of Central Time, of only those minima which can be observed in the United States.]

U CEPHEI.

R. A..............0^h 52^m 32^s
Decl................+81° 17′
Period.........2*d* 11^h 50^m

May 26	5 A. M.
31	5 "
June 5	4 "
10	4 "
15	4 "
20	3 "
25	3 "
30	3 "

S CANCRI.

R. A..............8^h 37^m 39^s
Decl.............+ 19° 26′
Period.........9*d* 11^h 38^m

May 17	5 A. M.
June 5	5 "
23	4 "

δ LIBRÆ.

R.A.............14^h 55^m 06^s
Decl................— 8° 05′
Period.........2*d* 07^h 51^m

May 16	8 P. M.
19	4 A. M.
23	8 P. M.
26	4 A. M.
June 2	3 "
9	3 "
16	2 "
23	2 "
30	2 "

U CORONÆ.

R. A............15^h 13^m 43^s
Decl............... +32° 03′
Period.........3*d* 10^h 51^m

May 17	5 A. M.
24	3 "
31	1 "
June 6	11 P. M.
13	8 "
24	5 A. M.

U OPHIUCHI.

R. A............17^h 10^m 56^s
Decl.............. + 1° 20′
Period.........0*d* 20^h 08^m

May 18	1 A. M.
18	9 P. M.
23	2 A. M.
23	10 P. M.
28	3 A. M.
28	11 P. M.
June 2	4 A. M.
2	midn.
3	8 P. M.
8	1 A. M.
8	9 P. M.
13	1 A. M.
13	9 P. M.
18	2 A. M.
18	10 P. M.
23	3 A. M.
23	11 P. M.
28	4 A. M.
28	midn.

Y CYGNI.

R.A.............20^h 47^m 40^s
Decl...........+ 34° 15′
Period........ 1*d* 11^h 57^m

May 17	5 A. M.
20	4 "
23	4 "
26	4 "
29	4 "
June 1	4 "
4	4 "
7	4 "
10	4 "
13	4 "
16	4 "
19	4 "
22	4 "
25	3 "
28	3 "

Occultations Visible at Washington.

			IMMERSION.		EMERSION.		
Date.	Star's Name.	Magnitude.	Wash. Mean T. h m	Angle f'm N. P't. °	Wash. Mean T. h m	Angle f'm N.P't. °	Duration- h m.
May 15	...η Leonis	3.3	3 58	143	5 14.9	265	1 17
15	...42 Leonis*	6.0	13 42	114	14 33.9	291	0 52
17	...ν Virginis	4.0	10 34	57	11 10.1	4	0 36
22	...41 Libræ	5.9	12 00	92	13 18.1	319	1 18
22	...$\varkappa$ Libræ	5.1	14 09	104	15 25.9	291	1 17
June 1	...33 Ceti	6.1	14 37	353	14 51.3	318	0 15
1	...35 Ceti	6.3	15 05	52	16 03.1	252	0 58

* Whole occultation below the horizon of Washington.

Phases and Aspects of the Moon.

			Central Time. d	h	m	
First Quarter..............................	1891	May	15	1	04	P. M.
Apogee.......................................	"	"	16	10	54	"
Full Moon..................................	"	"	23	12	26	"
Last Quarter..............................	"	"	30	12	54	"
Perigee......................................	"	"	31	3	06	"
New Moon..................................	"	June	6	10	26	A. M.
Apogee......................................	"	"	13	6	00	P. M.
First Quarter..............................	"	"	14	6	34	A. M.

New Minor Planets.

A planet was discovered by Borelly of Marseilles, March 31.4436 Gr. M. T. $\alpha = 12^h\ 24^m\ 49^s.3$; $\delta = -1°\ 55'\ 32''$. Daily motion -40^s in α, and 5′ northward. Magnitude not given. This is apparently No. 309.

Another planet was discovered by Palisa at Vienna April 6.399 Gr. M. T., in right ascension $12^h\ 41^m$, and in declination $-6°\ 15'$. Daily motion is 14′ westward and 4′ northward. Magnitude 13th. The telegram was in error, so that a more complete statement of position or date of discovery of the planet can not be given. Probably No. 310.

Names have been given to asteroids as follows: 283, Emma; 284, Amelia; 285, Regina; 289, Nenetta; 290, Bruna; 291, Alice; 292, Ludovica; 293, Brasilia; 294, Felicia; 295, Theresia; 296, Phaëtusa; 297, Cecilia; 298, Baptisina; 300, Geraldina; 302, Clarissa.

New Planetary Nebula. (*DM.—12° 1172 magn. 9.2*). [Communicated by Edward C. Pickering, Director of Harvard College Observatory.] The photographic spectrum of DM−12° 1172 magnitude 9.2, whose approximate position for 1900 is in R. A. $5^h\ 22.9^m$, Dec. — 12° 46′, was obtained at this Observatory with the 8-inch Draper telescope on March 26, 1891, and proves to be that of a planetary nebula. Confirmation of this was obtained photographically on March 30, and also visually with the 15-inch equatorial telescope. As the hydrogen line F in this object is unusually strong as compared with the line whose wave-length is 500, the visual spectrum differs in a marked manner from that of the planetary nebulæ already known. M. FLEMING.

Harvard College Observatory, Cambridge, Mass., April 14, 1891.

COMET NOTES.

Comet a 1891 (Barnard, March 29). The first comet of this year was discovered by E. E. Barnard at Lick Observatory, March 29.695 Gr. M. T. in R. A. $1^h\ 00^m\ 08^s$; Decl. north 44° 18′. Daily motion in declination 1° south. The head of the comet was about 1′ in diameter, the nucleus of the tenth magnitude, tolerably well defined, and the tail less than 30′ long. In a private letter dated April 12, Mr. Barnard says: "My comet of March 29 has been hidden by the clouds since the third of April and it will now be too near the sun to observe, even if it should clear again this spring. I only succeeded in getting six nights observations of it. It is scarcely probable that it will be visible after perihelion."

We have as yet (April 21) received no ephemeris of this comet. Mr. Wendell wrote April 16 that he had an orbit of the new comet partly finished, but learned that there was an error in one of the observations which he was using, so that it was necessary to do the work over again.

Winnecke's Periodic Comet. From a private letter we learn that Mr. Barnard has looked for Winnecke's comet with the great Lick telescope, but failed to find it. He says that it is either excessively faint or is not within 50^s in R. A., or 6′ in Decl. of Dr. Von Haerdtl's ephemeris position.

Discovery of a new Comet. On Monday evening, March 30 at 9 P. M., while comet-seeking with my 10-inch reflector, power 40, I alighted upon a nebulous object in Andromeda which I failed to identify. Being acquainted with the conspicuous nebulæ in this region I immediately suspected it to be a comet, and a few minutes sufficed to reveal motion. I then sent a telegraphic notification of the discovery to the Astronomer Royal at Greenwich, and the following morning, March 31, he wired to Professor Krueger at Kiel. I observed the new comet on March 30 at $16^h\ 30^m$, and on March 31 and April 4 at $8^h\ 30^m$. The motion of the comet is carrying it rapidly to the S.S.E., and it will disappear with the sun's rays in a short time. Towards the end of April the comet will be close to the sun in Aries.

On April 4 the sky was very clear, and the comet was seen to have a delicate, tapering tail. The nucleus and coma were decidedly brighter than on the occasion of my first observation on March 30. W. F. DENNING.

Comet Wolf 1884. Mr. Berberich of the Berlin Observatory, has communicated to Mr. Barnard the elements and an ephemeris for Comet Wolf 1884, the return of which is expected during the coming summer or fall. Mr. Barnard has through the medium of the Astronomical Journal put these data in the possession of American observers, and I see that the ephemeris has been printed in the April MESSENGER.

The changes in the elements due to the action of the planets have been very small. The longitude of the node has been lessened only 17″, the longitude of the perihelion increased slightly over 6′, the inclination decreased 1′, the angle of excentricity made small by about 16′, the mean daily motion shortened 3″.5, and the period of the comet augmented 6 days.

Professor Thraen has, from all the observations of the comet in 1884-5, made a careful determination of the orbit, the probable errors derived being quite small. I was apprehensive that an early ephemeris of the comet would not appear, and had from Thraen's elements computed an ephemeris for May and June next. I had just about completed my work when Mr. Barnard published Mr. Berberich's computation.

On comparison the places determined by the two sets of elements differ so slightly that mine would have served as a sweeping ephemeris.

It will be remembered that this comet was discovered by Dr. Wolf at Heidelburg, on September 17, 1884, when it was about ninety-four million miles from the earth, and last seen by Professor Young at Princeton, when it had increased its distance to 240 million miles. The comet is predicted to appear in the morning sky, rising on May 3d four hours before the sun, which is increased on July 6th to six hours.

The chances are exceedingly favorable for finding the comet at this return, and it is hoped that it will not elude the eyes of comet seekers as did Denning's of 1881, Barnard's of 1884 and Brorsen's. GEO. A. HILL.

Naval Observatory, Washington, D. C., April 7, 1891.

A Total Eclipse of the Moon will take place on May 23d, beginning at $3^h 36^m$, and ending at $9^h 23^m$ Greenwich mean time. It will be invisible in the United States, but may be seen generally throughout the western part of the Pacific Ocean, Australia, Asia, Africa and Europe.

An Annular Eclipse of the Sun will occur on June 6. The moon will be so far from the earth at that time that its shadow will fail to reach the earth. An observer standing upon the earth directly under the apex of the shadow, would at the middle of the eclipse, see the moon upon the face of the sun surrounded by a very narrow ring of bright light. The difference between the diameters of moon and sun at that time will be only 11″.

Unfortunately for us the central line of the eclipse will pass very near the north pole, crossing the Arctic Ocean and touching land only in the northern part of Siberia. The portions of the earth where the eclipse will be partial are shown upon the chart on page 243. The line of the southern limit of the eclipse passes across the United States from the western part of Texas to the west of Lake Erie, through Canada, between Newfoundland and Labrador, across the Atlantic and the northern part of Spain, touching the northernmost part of Africa. The looped curves on the chart show the places where the beginning, middle and end of eclipse occur at sunrise and sunset. Between these loops and the southern limit of eclipse the reader will notice some dotted curves which show where the eclipse begins or ends at certain hours of Greenwich mean time. In the Eastern part of the United States the eclipse will be wholly invisible. At Chicago it will last only 25 minutes, beginning at $9^h 12^m$, and ending at $9^h 37^m$ central time. At Carleton College Observatory the eclipse will be a little larger, beginning $8^h 45^m$, and ending at $10^h 8^m$ central time. The magnitude of the eclipse, *i. e.*, the portion of the solar disk which will be covered by the moon is shown in the accompanying cut, Fig. 2. The moon will be seen to touch

ANNULAR ECLIPSE OF THE SUN, JUNE 6, 1891.

NOTE:—The hours of beginning and ending are expressed in Greenwich mean time.

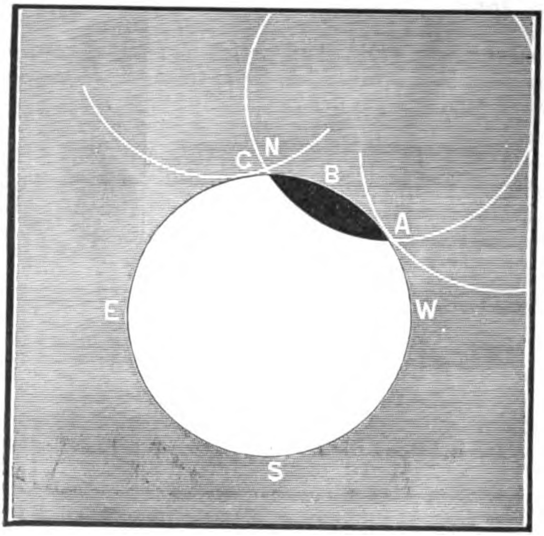

FIG. 2.

the sun's disk first at A, about 55° west from the north point, and to leave it at C, 10° east from the north point. In the western part of the United States, and especially in Alaska, the obscuration of the sun will be much greater.

AMATEUR STUDY AND OBSERVATION.

This issue contains a large amount of matter which is presumed to be useful to the amateur. Attention is called to Mr. Updegraff's paper which students may easily master, and should thoroughly study. G. P. Serviss' article below opens a field of study in astronomy that ought to give useful and pleasurable employment to hundreds of young people who have access to a good opera-glass. It is not saying too much to claim that every teacher of elmentary astronomy ought to have an opera-glass, and to practice its use in the study of the stars.

Among the Stars with an Opera-Glass.

GARRETT P. SERVISS.

FOR THE MESSENGER.

I have frequently taken pleasure in witnessing the mingled surprise and delight of persons who have accepted my invitation to look at the stars with an opera-glass, a thing they had never thought of doing, although the opera-glass had been their familiar companion at the theatre or the race track. It hardly needed the many letters I have received from readers of

"Astronomy with an Opera Glass," acknowledging that a new source of intellectual entertainment had been opened to them, to convince me that the powers of this simple instrument in celestial observation are as little suspected by most persons as they are surprising to those who try them for the first time. Take the simple fact that the number of stars visible to the naked eye on a clear night averages only about 3,000 at the most, while at the same time a powerful opera-glass, or field-glass, will reveal about 60,000 and nothing more needs to be said to demonstrate the value of such an aid in star-gazing. It is therefore with a full conviction that the result to be attained is worth the labor it costs that I have undertaken, at the request of the editor of THE SIDEREAL MESSENGER, to point out some of the things that the observer with an opera-glass may expect to see, and some of the things he should look for.

Many persons, it must be admitted, are satisfied after their first wondering glance at the starry riches that lie hidden in certain places in the heavens, and care no more about the matter. What I am about to write is not intended for them. Enthusiasm is as necessary to the observer with a mere opera-glass as to him who uses a powerful telescope. He must find his reward in his work. In that spirit one can go out under the dome of night with his glass, and study the wonderfully varied colors and tints of the stars, the striking contrasts of near neighbors in the celestial ranks, and their curious groupings, with undying delight. To him Sirius and Aldebaran and the Pleiades become more than mere names. His mind gradually opens to the sublime truth contained in that line of Aratus:

> "From all quarters Heaven speaks to man."

It is important, in the first place, to choose a good opera glass. Not only should it be achromatic, but it should be large enough not to be ranked as a mere toy. If the observer does not mind the expense he should purchase a glass for the express purpose of star observations, and he will find that it answers all the other purposes of an opera-glass far better than the ordinary instruments sold under that name. The object lenses should not be less than an inch and a half in diameter. Two inches is a much better size. The magnifying power for a two-inch glass should be four or five diameters. With such a glass splendid views can be obtained of the richer parts of the Milky Way, and of such stellar assemblages as the Pleiades, the Hyades, and the star swarms around the Belt of Orion and α Persei. If possible a strong field-glass should also be at hand for the observation of some of the wider double-stars, and clusters too dense to be well seen with the weaker instrument.

During the month of May the constellations best placed for observation are Boötes, Virgo, Coma Berenices, Hydra, Corvus, Crater and Leo. To these may be added early in the month Cancer and Gemini, and perhaps Auriga and Canis Minor, and late in the month Libra, Corona Borealis, the head of Serpens and Hercules. Of the circumpolar constellations Ursa Major is too near the zenith, and Cassiopeia and Cepheus too near the horizon to be conveniently studied with the opera-glass; but Ursa Minor and Draco are very well situated. The amateur who is not familiar with the face of the sky should furnish himself with a series of maps of the constellations, or with a planisphere which may be purchased for a few shillings.

Suppose the observer begins with Leo, which lies on the meridian about eight o'clock at the beginning of the month. One of the most interesting things to be seen here is the decided difference in color between Regulus and Gamma Leonis, which comes out well with an opera-glass. Three minute stars near Zeta Leonis make a very pleasing little group with their larger neighbor. The eighth magnitude star about five minutes of arc south of Denebola is well worth searching for with a strong glass. No mere toy opera-glass will show it.

The star cluster in Cancer, called the Manger, is one of the best objects for the opera-glass. Galileo was able to count thirty-six stars in this cluster.

In Gemini there is a mine of starry wonders, particularly where the foot of the constellation meets the Milky Way. I have turned again and again with ever-renewed pleasure to the cluster 35M and the delicate star-streams around it.

Auriga is also a very rich constellation, containing several condensed assemblages of small stars that affect the naked eye like patches of faint light, but become very beautiful groups of stars when viewed with a glass. There are two or three catalogued star clusters in this constellation that can be recognized with a good field-glass.

Beginning with the striking group of stars under Cancer that marks the head of Hydra the observer can profitably follow out the long crooked course of this imaginary serpent, crossing the whole breadth of the southern sky and ending in the east under Virgo. The deep color of its chief and only conspicuous star, Alphard, commands admiration. Corvus and Crater, particularly the former, have some interesting star groupings, which I have pointed out elsewhere, and which the reader can easily find for himself.

The most interesting thing in Virgo at present is the planet Uranus, which can be easily seen with a strong opera-glass and readily identified after a few evenings of watching when its motion among the small stars near it becomes apparent. The observer can find out where to look for the planet by consulting the little chart of its path given in THE MESSENGER for March, p. 142. Having located the planet as near as may be in this manner, let him make a little chart of the stars visible with his glass, including the one which he suspects to be the planet. Repeat this charting on several successive evenings, or at intervals of two or three nights, and in a very short time, the identity of Uranus will become apparent. Moreover in this way the amateur observer will obtain a valuable object lesson in star charting which will be of great value to him in all subsequent observations. There is a charm, too, in the recognition, in this manner of the motion of a slow-moving planet like Uranus, that is as indescribable as it is delightful. One thus enjoys a touch of the same sort of pleasure that comes to the discoverer of a new planet.

Spica, the chief star of Virgo, is an admirable object when viewed with any kind of a glass. The purity and beauty of its white rays are almost unrivalled in the heavens.

Turning from Spica to Arcturus, the great yellow star in Boötes, is like passing from one range of the universe to another. There could hardly be a more striking contrast. I call Arcturus yellow, and yet in certain circumstances of atmosphere and position its color is decidedly reddish. It is very beautiful in the glass and the tiny stars that twinkle here and there through the glare of its powerful rays add much to the beauty of the spectacle.

Berenices' Hair, or Coma Berenices, is a most beautiful little constellation for the opera glass observer. It would be an excellent exercise for him to make a chart of the stars that he is able to recognize in this remarkable assemblage, showing their comparative brightness as nearly as possible.

In Libra the star Alpha is one of the neatest doubles for opera-glass observation to be found in the sky. The peculiarity of color in Beta should be carefully studied.

In Hercules look particularly for the celebrated globular cluster between the stars Eta and Zeta. A good opera-glass readily shows it as a curious speck of light lying nearly on a line joining two little stars.

Directions for Copying and Using the Perpetual Calendar.

R. W. McFARLAND.

FOR THE MESSENGER.

Take a half sheet of foolscap, rule it lengthwise, as on p. 131, March number of THE MESSENGER. Let the spaces be half an inch wide, and extend to about two inches from the top. Set off seven inches for the lower set of figures, three-fourths of an inch each for old style and new style, and one inch and a half for the days of the month. Write out all the figures as they stand on p. 131, putting the heavy-faced type and 1800 new style in *red ink.* Cut a strip one inch and a half wide lengthwise from another half sheet; and rule three sets of spaces each half an inch wide, the short way of the slip. In the middle set write out the days of the week and the months as they stand on the upper part of p. 131. Then write the days of the week in the regular order in the upper and lower thirds of the slip, but omit the months. This gives the week three times and the months once. In the large sheet, at the place corresponding to the upper line of the blocks containing "Sun." and "Jan., Oct.," p. 131, cut a slit a little more than an inch and a half long: cut an equal parallel slit half an inch above the first. In like manner cut two slits below, the inner one corresponding to the line below "Sat." and "April, July" on p. 131. Draw the slip through these four slits, and place the middle third so that the sheet will in every respect be as the printed page above referred to. The calendar is then complete and ready for use, at an expense of half a cent or less.

Write the words "*Old style*" and "*New style*" in the proper places. The three sets of the days of the week are for the convenience of the one using the calendar.

To Set the Calendar for January, 1891.

Pull the slip down till Jan. stands opposite 91, in the lower block of figures. Then you see that the 1, 8, 15, 22, and 29 fall on Thursday.

To Set the Calendar for July, 1891.

Draw the slip upwards till July is opposite 91, then the 1, 8, etc., fall on Wednesday; the 2, 9, etc., on Thursday, etc.

The calendar is based primarily on the present century, and the only thing to do is to put the month opposite the required year. That operation sets the calendar not only for the present century, but for all others which fall into the same column with 1800 new style, viz., 2200, 2600, etc., also 200, 900, 1600, etc., old style.

Examples.

What day of the week will June 3, 1895, be?

Solution: Put June opposite 95; Monday is the 3d. So Monday will be the 3d for 2295, 2695, etc., new style, and for June 3d in the years 295, 995, 1695, etc., old style.

Remark: For January and February in any *leap year* in both styles set Jan. or Feb., as the case may be, against the figures in *red ink. Use the red ink numbers in no other months whatever.*

Required the day of the week for Feb. 22, 1840.

Solution: Put February opposite the *red ink* 40; the 22d was Saturday.

Required the day of the week for July 4th, 1840.

Solution: Put July opposite the other 40, and the 4th was also Saturday.

For Other Centuries.

First set the calendar as above directed; notice what day of the week is opposite 1800 new style; then draw the slip so as to put that day of the week opposite the required centesimal year.

Example: What day of the week was the 4th of July, 1776?

Solution: Put July opposite 76, Tuesday is opposite 1800; draw the slip up or down till *some* Tu. is opposite 1700 new style. In this case draw it down, otherwise the slip will be drawn out of its place. The 4th is Thursday.

Required the day of the week for Feb. 22, 1732, new style.

Put Feb. opposite the *red ink* 32; then Sat. is opposite 1800; draw the slip so as to put Sat. opposite 1700 new style. The 22d was Friday. Two or three more examples may suffice.

The reformation of the calendar by Gregory was in 1582; the last day of the old style was Oct. 4, 1582. Required the day of the week. Set Oct. opposite 82; Wed. is opposite 1800; draw the slip so as to put Wed. opposite 1500, old style. The 4th was Thursday. The next day was the first day of new style, but it was called Oct. 15th. Of course it was Friday, but find it by the calendar. Thus, set Oct. as before opposite 82, Wed. is opposite 1800; set Wed. opposite 1500 *new style;* the 15th was Friday.

By their own account the Pilgrims landed on the 11th of December, 1620. But the count was by old style. What day of the week was it? Put Dec. opposite 20, then Mon. stands by 1800. But 1600 old style is in the same column with 1800, and the slip must not be moved. The 11th was Monday. Change that date to new style. Set the calendar as before, and draw the Mon. opposite 1800 down to 1600 new style. The Mondays of that month were 7, 14, 21, and 28.

As a last example, required the day of the week for July 4, one thousand years in the future. Put July opposite 91, Sat. stands opposite 1800; draw the Sat. down to 2800 new style, and the 4th is on Wednesday.

A practice of half an hour ought to render any intelligent person master of this calendar so that any date in either style can be found in a minute. An experienced operator can find any date in either style in 5 seconds.

In order to use this calendar it is not necessary that the operator know anything about the history of chronology, any further than it is given in this paper. And I have thought it unnecessary to write any of that history.

How to Observe Variable Stars. We have asked one or two of the best observers of variable stars that we know of in this country to give suggestions for amateur work in this direction. Some useful work will be mapped out next time.

NEWS AND NOTES.

Scientific Control of the Naval Observatory. It is noticeable recently that the opposition to the transfer of the management of the Naval Observatory to scientific control comes from persons who say that astronomers want this change because of recent complications in the standard time question. While it is true that astronomers generally are of the opinion that the positition of the Naval Observatory in regard to the standard time has been, and is, wrong and unjust, that is not the point at issue with them. They claim that the national Observatory is a scientific institution,—that and nothing less, and because its character is such, it ought to be under scientific control. Astronomers everywhere should be on their guard and not let the discussion be turned from the main issue.

Triangulating in Coma Berenices. Dr. W. L. Elkin, of Yale University, is now carrying on the triangulation of the principal stars in Coma Berenices by the aid of the heliometer. By his request observations of the *relative positions* of some of these stars are being made by the Meridian Circle at Carleton College Observatory to aid Dr. Elkin in this another important piece of his heliometer work.

School of Practical Astronomy aud Mathematics. By reference to announcement elsewhere given, it will appear that the advantages for study in post-graduate lines will be considerably extended during the coming year. Students or teachers having completed the ordinary college course, and desiring better knowledge of the branches of mathematics and astronomy, are respectfully asked to consider the facilities now offered by Carleton College Observatory in these special lines. The new astronomical instruments that will be in place next month, and the various kinds of original practical work already begun will suggest the rare opportunities for study offered at this institution. For particulars correspond with the Director of the Observatory.

New Rooms for the Astronomical Society of the Pacific. On the evening of March 28 the Astronomical Society of the Pacific held its second annual meeting in the new rooms allotted to it, in the new building of the California Academy of Sciences, located on Market street, San Francisco. In one of the local papers of March 29 we notice the following statement: "Mr. Charles Burckhalter, secretary, read the proceedings of the Board of Directors, among which were acts relating to the distribution of the Donohoe Comet medal, by which the laws governing its award were considerably modified. It appeared that although the medal had been earned six times since its foundation, it was only accepted by five of the discoverers since Professor Barnard of Mount Hamilton, who had all along contended that the reward should not attach to the re-discovery of periodic comets, chose the occasion of his finding d'Arrest's comet last year to refuse the medal, and to request that the conditions be changed. It will now be given only for the first discovery of a periodic comet, and not for its earliest detection at a subsequent return. The dates of the Mount Hamilton meetings are also changed, making these come but twice during the year.

Solar Disturbances and Terrestrial Magnetism. Last month a private letter of unusual interest was received from T. S. H. Shearmen of Brantford, Canada, in which he speaks of the fact that Professor Young has recently called attention to the re-discovery in the United States, that there is a connection between the visibility *from the earth* of solar disturbances and terrestrial magnetism. Mr. Shearmen claims that he detected the relation in question nine years ago, and that he secured the right to the discovery by publishing an account of his conclusions in a newspaper under a *nom de plume.* The reasons for so publishing the account seemed to him good at the time, and we do not wonder at his course as explained.

The announcement was published in the London (Canada) *Free Press,* Nov. 27, 1882, a copy of which is believed to be still on file in the office of publication. We have asked Mr. Shearmen to give our readers an account of his discovery.

Washington Magnetic Observations for 1888-89 is a volume of 100 pages accompanied by fourteen large maps giving automatic records of instruments. This volume contains a brief description of buildings, instruments, observations, manner of reducing them, personnel, explanation of tables and plates. Then follows the tabulated observations which occupy about nine-tenths of the book.

Carleton College Observatory Library has been favored by copies of publications from the Royal Observatory of Greenwich, as follows:

Greenwich Magnetical and Meteorological Observations for 1888.

Greenwich Astronomical Results for 1888.

Greenwich Spectroscopical and Photographic Results for 1888, and also for 1889.

These are valuable records.

Errata. In April number of MESSENGER, line 13, page 171, 0".8 should read 0".08. In January issue, page 6, line 10, from bottom η should read ζ.

Emersion of Rhea from an Eclipse. On the evening of Wednesday, April 8th, while looking at Saturn with a friend, we noticed that Rhea was missing, and on examining the ephemeris found that the satellite must be either behind the planet, or else immersed in its shadow.

At $8^h\ 56^m.0$ [Eastern Standard Time], she reappeared rather suddenly, about 3″ from the planet's eastern limb, and opposite the parallel of 60° or 70° of south latitude. At first the satellite was very faint, but it rapidly brightened, and in about three and a half or four minutes had recovered its normal brilliance; this would indicate for it a diameter of from twelve to fifteen hundred miles. The eye-piece was an achromatic giving a power of about 500.

At this time Tethys was approaching its northern conjunction with the western extremity of the ring, and Enceladus was skirting the southern edge of the eastern ansa; both of them apparently very closely on time. Mimas was not seen, and according to the ephemeris was then on the planet's disc.

The seeing was only fairly good, so that the Cassinian division was visible only at the ends of the ring, and was not very easy to make out even there. The gauze ring was well seen in the ansæ, but where it crossed the ball was lost in the shadow of the other rings. The planet's belts were conspicuous, but no spots were visible upon the disc. At times the so-called "square-shouldered" form of the ball was rather striking; but on hiding either end of the ring behind an occulting bar, the appearance vanished on that side of the planet, showing the peculiarity to be a mere illusion, due to the cutting down of the irradiation of the equatorial diameter of the planet by the brightness of the adjacent part of the ring.

Princeton, N. J., April 10, 1891. C. A. YOUNG.

New Annalen der K. Sternwarte in Bogenhausen bei Munchen. This publication is issued under the direction of Hugo Seeliger and is the first volume of the new series. It is a volume of 717 pages of large quarto form, and contains a catalogue of 33082 stars, ranging in magnitude usually from 7 to 10. Each page has ten columns with heads, as follows: star number, magnitude, right ascension for 1880, No. Obs., precession for 1880, declination for 1880, No. Obs., precession, epoch, and reference catalogues. This volume has a full introduction giving a description of instruments and methods of reduction.

Standard for Wave-Length in the Spectrum Analysis. In April *Observatory* (English) is a brief, incisive letter by Dr. J. Scheiner, on the standard of wave-lengths to be used by practical workers in spectrum analysis. It was written chiefly to answer one point of criticism by Miss Clerke in these words: "Unfortunately, however, the wave-lengths are given in a Potsdam scale, the introduction of which is equally unnecessary and undesirable. Angström's scale can not, of course, be permanently retained, but Rowland's is its destined successor, and the multiplication of standards should be strenuously resisted." On this point Dr. Scheiner says: "I should like to hear upon what grounds Miss Clerke bases the inference that Rowland's tables are to be the successors of Angström's? Upon ground, I fear, artistic rather than scientific. There can be no doubt that Rowland's tables are finer than the Potsdam ones, nor that they are the best which exist, unfortunately Professor Rowland has not given a *Catalogue of all his lines from exact measurement of the negatives*. The wave-lengths from the Rowland tables can be employed for many purposes but not for all—for example, for the reduction of photographic stellar spectra, they are not sufficiently complete. The Potsdam wave-lengths can be employed for *all* purposes. I know no other catalogue of such completeness. Moreover, the Rowland standards have been changed from time to time, and there is no publication which makes directly evident the method by which the Rowland standards were calculated. They all depend on the wave-length of one single line."

In comparing the Rowland Chart and the Potsdam Catalogue, Dr. Scheiner thinks they are like a fine chart of the heavens and a meridian catalogue of stars. The chart is indispensible for orientation, and useful in some cases for positions, but generally the catalogue must be consulted for positions. He says he has advised, in his new book, the use of the one for orientation, the other for calculation, and that the constant differences between Rowland and Potsdam are small and that there is no difficulty in finding Rowland's lines from Potsdam's wave-lengths. Dr. Scheiner holds the common view, that "the multiplication of standards should be strenuously resisted."

Accurate Measures by Mr. Keeler. Some very astonishing facts appear in the study of Mr. Keeler's work with the spectroscope at Lick Observatory. His own general statement will indicate something of what we mean. He says that he would "with some confidence undertake to determine the month of the year, by measuring the distance of the principal line (in the spectrum of the nebula of Orion) from the lead-line used in the comparison spectrum.

Professor John Haywood, Otterbein University, Westerville, Ohio, on the evening of April 10, observed an unusual display of faculæ near the eastern limb of the sun, and on the southern spot zone.

Peculiar Star Occultation. On the evening of April 11, I observed the immersion of a star in Taurus, 6.5 or 7 magnitude, 60° from the north point, 10° from the vertex. The star disappeared at $8^h\ 10^m\ 1^s$, Central standard time; re-appeared and disappeared again about one second after the first disappearance. The moon's altitude was 20°, the definition in the vicinity of the moon was unsteady; the details of the moon would be very distinct for an instant, then blurred. It would thus seem that the action of the earth's atmosphere would account for the above double disappearance.

J. A. PARKHURST.

U. W. Lawton, Jackson, Mich., in a recent private letter gives an interesting account of the new small Observatory that he is erecting at the above named place.

Observatory at Dakota Agricultural College. We admire the earnest purpose of President Lewis McLouth, Agricultural College, Brookings, Dakota, in bringing that institution promptly to the front rank in general scientific work. He has already ordered an astronomical outfit from Mr. G. H. Sægmuller of Washington, D. C., consisting of a five-inch equatorial telescope with driving-clock, micrometer, etc., 2-inch transit instrument, clock and chronograph. He purposes to build a small Observatory and to determine his longitude early this summer.

Photographic Notes. The Report of the Washington University eclipse party contains much of interest on the photographic work done at the time of the eclipse on Jan. 1, 1889. The method of exposure and careful manipulation in development are described with interesting detail. Professor Charropin states that the protuberances are found to contain more actinic rays than the corona. Professor Pritchett calls attention to the fact that negatives of short exposure are characterized by sharp definition of the polar filaments, while those of longer exposures show the streamers of the outer corona. He closes his report with the following statement: "The testimony of the negatives of the corona of January 1889, is to confirm the opinion already held that there is a characteristic form of the corona corresponding to periods of sun-spot maxima and minima." Artotypes of five of these negatives are published with the report.

The Scientific American of April 11 devotes three columns to an article by Nicolas Pike on "Photography as it was and is." Mr. Pike traces in an interesting and concise way the history of photography from the time of Baptista Porta, who discovered the camera obscura in the sixteenth century. Of especial interest are his statements in regard to the photography of color, past and present. Sir John Herschel is named as being undoubtedly the first discoverer of a method for color photography; at about the same time Sir Robert Hunt secured many colored pictures of the spectral rays, dark upon a bright ground; ten years later M. Edmund Becquerel produced on metallic plates the colors of the spectrum. In 1856 Mr. Pike visited Dr. Diamond, of Surrey, England, of whose pictures he says: He showed me the only good picture I have ever seen made with a camera and lens in colors. It was a view of an old fashioned, two-story, frame clapboarded house, with moss and lichens in many places over the doors and windows. The picture was partly colored, the lichens showing their yellow and gray markings, and the house of a dark brown color. It was very pretty but the doctor said it was taken while he was experimenting, and he could not account for it."

Mr. F. Bligh Bond of Bristol has on exhibition a colored photograph of Land's End said to have been taken directly from a set of three negatives; it is printed in blue, carmine and yellow.

Professor Lippmann's claims to the production of color films are seriously doubted by the British Journal of Photography.

Mr. Ranyard made the following statements before the Royal Astronomical Society: "We cannot rely upon the star images being condensed in the same way by different object-glasses, or even with the same object-glass on different parts of the plate. The rapidity of the photographic action is intimately associated with the way in which the light from a luminous point is collected into a point or a patch on the sensitive plates. There is also a great difference in the transparency of the air for the photographic rays from hour to hour; so that we shall not be able to rely on star magnitudes derived from the duration of the exposure."

At the Greenwich Observatory the following plates have been tried in astro-photographic work: Wratten and Wainright, Seed Company, and Star; a slight preference is expressed for the Star plates.

Speaking of change in the transparency of the air Mr. Roberts says: "The companion of Polaris is about the 9th magnitude. I have been able to photograph it on some nights in a single second, and at other times it takes a minute.

Meeting of the Astronomical Society of the Pacific, March 28, 1891.

The Society met for the first time in the lecture hall of the new building of the California Academy of Sciences, President Holden in the chair.

The thanks of the Society were returned to the California Academy of Sciences for their invitation to hold its San Francisco meetings in the lecture hall of the Academy building, and the invitation was accepted.

At the meeting of the Directors, held in the society's rooms, twenty-one members were elected as follows:

Miss Elizabeth H. Pearson, No. 219 Savin Hill avenue, Boston, Mass.; Lewis A. Pagin, No. 122 South Market street, Chicago, Ill.; A. L. Smith, No. 23 Washington street, Chicago, Ill.; Francis G. Du Pont, Wilmington, Del; Mrs. Sarah B. Gamble, No. 1222 Pine street, San Francisco; Joseph B. Walker, Geological Survey, Austin, Tex.; Miss Estella Guppy, San José, California; Oliver E. Pagin, Room 40, United States Custom House, Chicago, Ill.; F. S. Archenhold, 57 Invaliden strasse, Berlin, Germany; S. Wilson Fisher, 1502 Pine street, Philadelphia, Pa.; Camilo Martin, 411½ California street, San Francisco; Charles T. Blake, Berkeley, Cal.; L. J. Holton, 1207 Seventeenth street, Alameda, Cal.; Harry W. Syz, 410 California street, San Francisco; C. B. Kendall, 137 Montgomery street, San Francisco; California Camera Club, 819 Market street, San Francisco; Professor Meller W. Haskell, University of California, Berkeley; Archer B. Pierce, University of California, Berkeley; William Sturtevant Harlow, Oakland, Cal.; A. R. Blake, Berkeley, Cal.; T. C. Johnson, 27 Market street, San Francisco.

Mr. H. F. Newall, Observatory, Cambridge, England; J. C. Cebrian and Dr. J. Callandreau, of San Francisco, were elected life members.

At the regular meeting, the committee on nominations reported the following names for Directors and Committee on Publication:

For Board of Directors—Wm. Alvord, Charles Burckhalter, Chas. B. Hill, S. G. Hillborn, E. S. Holden, James E. Keeler, E. J. Molera, Wm. M. Pierson, J. M. Schaeberle, Frank Soulé, F. R. Ziel.

For Publication Committee—E. S. Holden, James E. Keeler, Chas. G. Yale. The ticket was unanimously elected, Messrs. McConnell and Veede acting as tellers.

The Treasurer made the following report:

Receipts for the year, - - - - - - -	$1,980.63
Expenditures for the year, - - - -	2,347.89
Cash in bank, - - . . - - -	744.65

Over $1,000 is still due from members for dues for the present year.

The above expenditures do not include the amount expended for the Library.

The Alexander Montgomery Library Fund of the Society shows $1.590 and the Donohue Comet Medal Fund $527, both the above funds being in savings bank bearing interest.

The Library Committee reported that the library has 491 volumes, 431 of which were purchased from the Montgomery Library Fund. The cost of the library to date has been $1,017.50, and non-resident members may draw books by mail—the member withdrawing the books paying the postage.

The Committee on Comet Medal reported that five medals had been awarded as follows: To Messrs. BROOKS, COGGIA, DENNING, SPITALER and ZONA, for comets *a*, *b*, *c*, *e* and *f*, 1890. The medal is awarded only for unexpected comets.

Article IX. of the by-laws was changed so that hereafter there will be two meetings at the Lick Observatory each year, viz., the second Saturday in June and the first Saturday in September.

A committee consisting of Professor G. W. Hough, G. E. Hale, G. A. Douglas and R. W. Pike, of Chicago, Wm. M. Pierson and C. B. Hill, of San Francisco, and A. J. Burnham, of Lick Observatory, was appointed to make arrangements for an astronomical exhibit at the Columbian Exposition in Chicago.

The following papers were announced:

a. The Fireball in Raphael's Madonna di Foligno, by Professor H. A. Newton, Yale University.

b. On the Similarity of Certain Orbits in the Zone of Asteroids (second paper) by Professor Kirkwood, Riverside.

c. Astronomical Observations in 1890, by Torvald Kohl, Denmark.

d. Address of the Retiring President of the Society, by Professor Holden, Mt. Hamilton.

e. A few Hints to Beginners in Solar Observations, by Miss E. Brown, of England.

f. Lunar Work for Amateurs, by Thomas Gwyn Elger, F. R. A. S., of England

g. The Total Solar Eclipse of January, 1889, by Professor H. S. Pritchett, Washington University, St. Louis.

The chairman announced the presence of Lord Rosse. The Earl was introduced and said that he did not propose to read all the papers that he had before him, but would make a few remarks about reflecting telescopes. He said that he had worked with reflectors and was naturally a special pleader in their favor. He had just seen the great refractor at Mt. Hamilton and was much pleased with it. A three-feet reflector can be built for less money than a three-feet refractor. The one built by his father has a diameter of six feet. Before claiming any advantage each should be tested and given a fair trial. His telescope was made by native workmen. It is naturally inferior to what could be made to-day. His father's idea was to follow Sir William Herschel and sweep the heavens and resurvey the 2000 nebulæ in his catalogue. One of the great advantages of a large object glass is to furnish so much light to the eye as to enable us to see objects which could not be seen otherwise. When it comes to work with a spectroscope, or when you want to photograph a nebula, an instrument made fifty years ago requires some changes. There is some trouble in keeping the speculum in place, but the trouble is purely mechanical. It is difficult to compare reflectors with refractors. In the case of photography, with the refracting telescope you cannot get the rays to blend together· This trouble does not exist with the reflector. We should give the reflector a fair trial. In Paris two years ago it was decided that reflectors were best for photography. In measuring the heat from the moon the reflector will do the best work. He was astonished to see the number of people visiting the Observatory at Mount Hamilton. In England no such interest is manifested.

The thanks of the society were given to the Earl of Rosse for his explanation of reflectors. Professor Holden said that when the great telescope was finished at Washington it was his work to go over the observations of Sir William Herschel and he had compared his with those of Lord Rosse and had found his work absolutely correct. The reflector has a priceless advantage for photography. The question of supporting the speculum is purely mechanical. In spectroscopy and photography the reflector is the best, but there is a place for both side by side.

The President's report was read, showing that the society started two years ago with 40 members, and now had 380.

The society has members in twenty-six states of the Union, and nineteen foreign countries. There are 42 life, and 338 active members.

After the regular meeting the newly elected directors held a meeting at which the following officers were elected to serve for the ensuing year:

Wm. M. Pierson, president; Frank Soulé, J. M. Schæberle, E. J. Molera, vice-presidents; J. E. Keeler, Charles Burckhalter, secretaries; F. R. Ziel, treasurer.

The next meeting will be held in the library of Lick Observatory, June 13th.

CHAS. BURCKHALTER,
Secretary.

BOOK NOTICE.

Elements of Plane and Spherical Trigonometry. By Edward S. Crawley, Assistant Professor of Mathematics in the University of Pennsylvania. Publishers, Messrs. J. B. Lippincott Company, Philadelphia, 1890. pp. 159.

The aim of the author in this book has been to present that portion of the subject of Trigonometry which is generally given in a college course, in as clear and concise form as possible. The first part of the branch is worked out in detail carefully; later the student is thrown upon his own resources, the object being to develop him in the power of making intelligent use of the materials found in the earlier part of his course. In the chapter on the solution of oblique spherical triangles two methods are given for each of the ordinary cases, one by Napier's Analogies, the other by means of a perpendicular. This is a useful feature. The grouping of most important formulæ at the end of the book is also very desirable. The book is well planned for the use of the class-room, and it appears in an orderly, neat and easy typographical dress which its publishers know how so well to furnish.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 10, No. 6. JUNE, 1891. WHOLE No. 96

PHOTOGRAPHY AND THE INVISIBLE SOLAR PROMINENCES.

BY GEORGE E. HALE.*

FOR THE MESSENGER.

In 1868 a new field of investigation was opened to astronomers by the discovery of a method of observing the solar prominences in full sunshine. Hidden by the overpowering glare of the atmosphere the prominences had remained invisible except when a total eclipse allowed them to be seen rising above the limb of the moon. But in the hands of Janssen and Lockyer the great dispersion of powerful spectroscopes weakened the atmospheric spectrum until the bright prominence lines could be seen upon it, and it was then only necessary to open the slit of the spectroscope, thus bringing to view the prominences themselves. Many astronomers took up the new method of research, and countless phenomena of the greatest interest and value, became the objects of systematic investigation. In the course of time it naturally occurred to some that the prominences might be photographed, and several methods were devised for accomplishing this result. One of these is described by Dr. Braun in the "Berichten von dem Haynald-Observatorium in Kalocsa," but it required apparatus of a special nature, and has never been tried in practice. Dr. Lohse of Potsdam devoted considerable attention to the problem, and invented a "rotating spectroscope" of such ponderous proportions that mechanical difficulties alone would easily account for its failure. In 1870 Professor Young obtained photographs of two prominences through the $H\gamma$ line and a wide slit, but the evident defects of the method were visible in the pictures thus made, and nothing more was done in this direction. Thus for many years nothing was learned about the prominences by the aid of photography.

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* Kenwood Physical Observatory, Chicago, Ill.

This was the situation in the summer of 1889. The important advances accomplished by the use of photographic processes in other fields of astronomical research led me to the conclusion that another attempt should be made to photograph the prominences, and I accordingly devised two new methods for this purpose. In the first of these the image of the sun was to drift across the radial slit of a powerful spectroscope, the driving-clock of the telescope being slowed to produce the drift. It is evident that if the prominence were on the limb the length of any bright line at the focus of the spectroscope would define the height of the prominence, and as the sun drifted across the slit this line would continually change in length. If now the line in use were made to pass through a slit just within the focus of the observing telescope of the spectroscope (called hereafter the "second slit") so as to be in focus on a plate beyond the slit, it is easily seen that all that is required to photograph the prominence is to move the plate slowly at right angles to the second slit. Fresh portions of the plate are thus exposed to corresponding portions of the prominence, and the prominence image is built up from a succession of bright line images of the slit.

The second method proposed accomplishing a similar result in a different manner. The clock of the equatorial is so adjusted that the image of the sun is kept in a fixed position. The plate on the end of the collimator which carries the slit, is then slowly moved across the sun's limb at the point where the prominence is present, and a second slit, moving at the same speed before a stationary plate, excludes the light from the spectrum on either side of the line in use, and reduces fogging to a minimum.

The investigations carried on at the Harvard Observatory in 1889 and 1890, with the apparatus as originally designed, has been already described,* and need not be referred to at length here. The 18-inch silvered mirror of the horizontal telescope employed was so greatly distorted by the sun's heat that as a rule no trace of the chromosphere or prominences could be seen, and of course photography under such conditions was out of the question. It soon be-

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* Technology Quarterly, Vol. III, No. 4, 1890. Astronomische Nachrichten, 3006.

came evident that an equatorial refractor of sufficient size to carry my large diffraction spectroscope was needed for the work, and instruments of the highest class became available through the kindness of Professor Holden and Professor Young, who offered the use of the 36-inch Lick telescope, and the 23-inch Princeton refractor. It was decided at this time, however, to complete the equipment of the Kenwood Physical Observatory by the addition of a 12-inch equatorial refractor built especially for spectroscopic work, and this instrument was completed and ready for use early in April of the present year. An excellent object-glass of 12.2 inches aperture was furnished by Brashear in an incredibly short time, and the very satisfactory dome and mounting were made by Warner & Swasey. The telescope and spectroscope are practically united into a single instrument, and for rigidity and convenience nothing better could be desired. The prominences are shown with the greatest perfection of detail, and the principal difficulty encountered with the horizontal telescope is thus entirely eliminated.

Meanwhile the apparatus originally designed for moving the plate at the focus of the spectroscope has undergone important modifications, and great improvements have been effected. All experiments so far made have been with the first method described above. This requires a moving plate at the focus of the spectroscope, and in the first apparatus a small plate-holder was held by a spring clip in a light frame of brass tubing sliding between V-shaped guides. After many experiments the steadiest motion that could be obtained was derived by a fine wire from the clock of the horizontal telescope, but this was very unsatisfactory, and the friction of the guides of the sliding-plate-holder made it impossible to obtain a perfectly smooth and uniform motion. In August, 1890, I planned a new form of sliding-plate-holder, in which the friction was relieved by wheels running on knife edges, a simple change giving a stationary slit and moving plate, or a moving slit and a stationary plate. But this apparatus was never constructed, for a new idea occurred to me which was carried out in an apparatus made by Mr. Brashear. In the place of a sliding-plate-holder a rotating cylinder was substituted, and around this a strip of thin celluloid photographic film is wrapped, and held by a spring clips. The cylinder is held in a small brass box attached to the end of the observing telescope of the spectroscope, the axis of the cylinder passing through the top of the box, and carrying the pulley by which the cylinder is rotated. The bottom of the box is hinged, so that the cylinder can be removed in order to allow the second slit to be observed with a positive eye-piece passing through the back of the box. This slit can be opened or closed by turning a head at the side of the box; and by means of a slide passing before the slit the box can be closed and removed from the spectroscope without danger of exposing the film to the light.

A means of producing a slow and uniform motion is the other requisite of the method, and a modified form of clepsydra is attached to the observing telescope for this purpose. A well packed piston slides in a smoothly bored and polished brass cylinder, the piston-rod passing through stuffing boxes in each head. The cylinder is filled with a mixture of equal parts of glycerine and water, and by the motion of the piston this fluid is forced through a small brass tube connecting the two ends of the cylinder. A valve in the center of the tube regulates the rate of flow, and this is controlled by a pointer moving over a divided arc. A ten pound weight is attached to one end of the piston-rod by a flexible cord of braided wires, and the other end of the rod is connected with the pulley on the axis of the rotating film-carrier by means of a silk cord. A small "snap rubber" passes around the pulley in the opposite direction, and supplies the necessary tension. It has been found that below a certain speed the motion of the small clepsydra used cannot be relied upon as being entirely uniform, so that it is advantageous in the case of a very slow drift of the sun across the slit, to attach an arm about ten inches long in place of the pulley on the axis of the film-cylinder. The thread from the end of the piston-rod is looped over a pin on the circumference of an arc at the extremity of the arm, and as the radius of the film cylinder is only an inch, the linear velocity of a point on its surface will be only one-tenth that of the end of the arm. By means of this reduction of speed the clepsydra can run ten times as fast as when a small pulley is used, and a smooth and uniform motion is easily secured. There are some disadvantages, however, in the present form of the valve, and some changes and further improvements will be embodied in the more convenient and practical type of apparatus now being worked out.

In my previous publications on the subject of prominence photography I have advocated the use of the C line on account of the sharp and bright images seen through it. Its position at the red end of the spectrum precludes the employment of ordinary silver bromide dry plates, and I have consequently tested a number of sensitizers for red light, but none of them have given a sufficient degree of sensitiveness. Cyanin, alizarin blue, and fresh alcoholic solutions of grass chlorophyll increase by greater or less amounts the sensitiveness of ordinary plates to red light, and are consequently very useful in some branches of spectroscopic work, but all fall short of the requirements of prominence photography. For the yellow region of the spectrum erythosin is a most valuable dye, and it is probable that prominence photographs through D_3 may be obtained by its use as a sensitizer. F has noc yet been employed in this work with much success, but it is expected to prove useful. $H\gamma$ and h, though in the region where ordinary plates are most sensitive, are rarely very bright, and the nebulous character of the lines is much against them. It was through $H\gamma$, however, that my first prominence photograph was made.

But let us consider for a moment the two lines which to my mind form the most interesting group in the solar spectrum. Situated in the extreme violet the H and K lines are at about the limit of the ordinary vision. Each lies almost hidden at the center of a dark nebulous shade, within which are also included a number of other lines. Both H and K are due to calcium, and though they are probably produced at all temperatures from the Bunsen flame to the hottest star, (as I soon hope to show in a paper on this subject) they undergo great variations in intensity. Everything tends to show that calcium plays a most important part in all solar phemomena. It was found by Professor Young at Mt. Sherman in 1872 that both H and K were always bright in the chromosphere and prominences, and the same thing is shown in a large number of photographs of the chromosphere and prominence spectrum recently made here. Professor Young also observed the reversal of both lines in spots, and in all photographs which I have made of spot spectra in this region both lines have been strongly reversed, in many cases when none of the hydrogen lines were seen bright over the spots. It is thus evident that either H or K is well suited for photographing the prominences by my method, especially as the dark shade allows the use of a wider second slit with less fogging of the plate than with any other line in the spectrum.

But most important of all is the means thus afforded of photographing prominences which cannot be seen by the spectroscopic method, and are consequently only known through photographs taken at a total eclipse. In his report of the eclipse of August 29, 1886, observed at the island of Grenada, Prof. W. H. Pickering writes as follows: "Turning now to the spectrum of the prominences, most of them showed the usual hydrogen lines, accompanied by H and K. In all cases the latter were the prominent lines, the hydrogen lines F, G, and h being decidedly weaker and less conspicuous, as is the case in the spectrum of the sun. But in the largest prominence of all—one that rose apparently in a somewhat spiral form to the altitude of 150,000 miles—the only lines visible were the H and K, and a faint trace of an ultra-violet line, about half-way between K and L. These, in addition to a brilliant continuous spectrum in the visible region, comprised the whole of its light. It was therefore quite invisible, before and after totality, by the usual spectroscopic method, as was in fact noted at the time by Professor Tacchini. It is highly probable that a great number of prominences pass by entirely unnoticed, because we rely solely upon visual instead of photographic methods of observation."*

Other observations bearing on the same point might be quoted, but the above is sufficient to show that the invisible prominences play no unimportant part among solar phenomena. Daily records are kept of the number and general forms of the spots and prominences visible on the sun, and in discussing the relation between the two, the invisible prominences are necessarily left out of account, simply because up to the present time there has been no method by

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* Annals of Harvard College Observatory, Vol. XVIII, No. V, p. 99.

which they could be observed or photographed. It is evident, however, that my method takes no account of the visibility or invisibility of a prominence, but will photograph one as well as the other if either H or K is used. In fact, as H and K are so bright in the invisible prominences, they will be the easier photographed. The following record of results will show that we are now in possession of a method perfectly capable of recording the forms of any invisible prominences which may appear upon the sun.

Work on the prominences was commenced with the 12.2-inch equatorial on April 7, 1891, and the lines F and Hγ were employed, the dispersion being that of the second or third order of a 14,438 Rowland grating. Some time was occupied in adjustment of the apparatus and tests of the clepsydra, and the first photograph showing a prominence was made through the Hγ line of the second order on May 7, the sun being allowed to drift across a narrow tangential slit without employing the driving clock of the equatorial. Several more photographs were taken through the same line, but although they all showed the rough outline of the prominence, a lack of contrast made them appear very faint. It was then decided to try H and K, but a difficulty arose as to a means of bringing these faint lines on to the second slit. Induction sparks and other methods did not prove very successful and it was finally decided to use the K line in the fourth order, find its position in the green of the third order by taking $\frac{4}{3}$ its wave-length, and then bring this point in the green on to the second slit. This method proved entirely successful, and on May 14 the first attempt to photograph a prominence with the apparatus adjusted for the K gave the best result obtained up to that time. On May 18, a number of photographs of a prominence were made through the same line, the driving clock of the telescope being slowed, so that the sun drifted about $\frac{1}{8}$ inch in five minutes across a narrow tangential slit. The prominence images in some of these photographs, though of course small, show strong contrast and considerable detail, yet when compared with drawings of the same prominence made just after the exposure through the C line, the finer details of structure are missing in the photographs. If an invisible prominence had been present at this point it would certainly have been shown, but in this case the forms through C and K were very similar. A search for invisible prominences will shortly be made and it is even hoped that they may be photographed over sun-spots or on the disk itself, though the difficulty of such work does not justify much confidence in its success.

Kenwood Physical Observatory,
Chicago, May 20, 1891.

ON THE CHIEF LINE IN THE SPECTRUM OF THE NEBULÆ

JAMES E. KEELER.*

As my paper on the Motions of the Planetary Nebulæ in the Line of Sight† did not give a final determination of the exact position of the chief nebular line, and might therefore possibly be regarded as leaving in abeyance the question as to whether that line could be regarded as a remnant of the magnesium fluting, I beg to be allowed to state briefly the results of some more recent observations, which have enabled me to fix with great accuracy the true position of the chief nebular line.

At the time when my paper on the motions of the nebulæ was printed, I had not been able to obtain any satisfactory comparisons of the third nebular line with terrestrial hydrogen, all the nebulæ in my list having proved to be too faint for the purpose. I was, therefore, compelled to adopt the mean position of the principal line for the ten nebulæ observed as the normal position from which to measure displacements, and it was for the reason that the ten nebulæ did not have the uniform distribution in the sky which was desirable that the numerical results for their motions were stated as "not to be regarded as final."

In October, 1890, when the Orion nebula came within reach of the telescope, comparisons of the third line with the Hβ line of hydrogen were made without difficulty, and on

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* Astronomer at the Lick Observatory.

† 'Publications of the Astronomical Society of the Pacific,' No. 11, p. 265.

the same nights the position of the principal line was determined. One such double observation, if perfect, completely solves the problem, since the displacement of the third line gives the necessary correction to the position of the first. The only question is in regard to the accuracy of the observations.

It is evident from what has already been written on this subject by Dr. and Mrs. Huggins, Professor Lockyer, and myself, that the answer to the question whether the chief nebular line is coincident with the edge of the magnesium fluting at λ 5006.4 depends upon very small differences of position, differences which would, in fact, be considered small even in solar spectroscopy. But their minuteness, although it increases the practical difficulty of observation, does not detract from their importance, since absolute coincidence of spectral lines is necessary (although not always sufficient) to establish a claim to identity of origin. It is therefore necessary to determine from a careful consideration of the Lick Observatory measures whether they are of a sufficiently high order of accuracy to prove that the small observed interval between the nebular line and the magnesium fluting is real, and not due to errors of observation.

A detailed account of all the tests to which the apparatus was ,subjected cannot be given here. Nothing that suggested itself was omitted. The best tests, however, both for constant and for accidental errors, are afforded by observations of the motion in the line of sight of bodies whose motion is already known. As an example of such·observations, I may refer to the measures of the motion of Venus in the line of sight given in the table on p. 270, 'Publications of the Astronomical Society of the Pacific,' No. 11, in which the greatest error is one English mile per second. Similar measures of the displacement of lines in the lunar spectrum were seldom in error by more than two miles, and measures of the motion of α- Tauri and α-Orionis, usually made on the same nights that the nebula was observed, were of the same order of accuracy, as determined by their agreement with each other, and with the photographic results of Professor Vogel.

In work of this character the periodic shifting of lines in the spectra of the stars and nebulæ due to the earth's annual motion is of a magnitude not to be neglected, and it should appear in the comparison of observations made at different seasons. So faithfully is the orbital motion of the earth reflected in my observations on the nebula of Orion, that I would with some confidence undertake to determine the month of the year, by measuring the distance of the principal line from the lead line used in the comparison spectrum.

With these remarks on the degree of accuracy which characterizes the observations, I give below the results which have been obtained, up to the present time, for the nebula of Orion.

From sixteen complete measures, made on eleven different nights (two of which were in the winter of 1889-90), the wave-length of the principal line, corrected for orbital motion of the earth, is λ 5006.22 ± 0.014, the probable error corresponding to an uncertainty of 0.5 mile per second in the line of sight. When two measures were made on the same night, they were always in different spectra of the grating.

Ten comparisons of the third nebular line with terrestrial hydrogen were made on seven nights in 1890-91, showing, when corrected for the orbital motion of the earth, a displacement of the nebular line toward the red of 0.28 ± 0.0026 tenth-metres. This corresponds to a motion of recession of the nebula from the sun of 10.7 ± 1.0 miles per second.

In recent comparisons of hydrogen with the third nebular line, I have not been able to attain the small probable error of 1½ miles per second for a single evening's comparison, given in my letter to the 'Observatory,' as the first comparisons were made under exceptionally favourable conditions. Some small improvements in the apparatus make it probable, however, that it can be reached in the future.

Examination of the individual results for each night's work shows that the errors are purely accidental; hence, the mean of the results for the third line will be used to determine a correction to the mean of the results for the first line.

A displacement of the third line toward the red of 0.28 tenth-metre corresponds to a displacement of the principal line, in the same direction, of 0.29 tenth-metre, which is the amount by which the principal line is seen to be too near the red end of the spectrum, on account of the recession of the nebula from the sun.

Hence the wave-length of the principal line, if determined by an observer at rest relatively to the nebula, would be λ 5005.93, and this, therefore, is the *normal position* of the chief nebular line, according to all the observations of the nebula of Orion which have been made, up to the present time, at the Lick Observatory. The probable error of this result is, by the theory of least squares, 0.03 tenth-metre. The position of the MgO fluting, on the same scale, is λ 5006.36 or 0.43 tenth-metre below the normal position of the nebular line. An interval of this magnitude is not only measurable with my apparatus, but noticeable at a glance in the telescope.

An incident which occurred during the course of the work may be mentioned here, as showing how much greater the above stated interval is than any error which could be made under good conditions of observation. The measures of January 26, 1891, on being reduced the next morning, made the interval between the nebular and lead lines 0.15 tenth-metre greater than it should have been according to previous measures. This difference led me at once to infer that something was wrong with the apparatus, and on examining the instrument I found that the observing telescope was set to a reading 5° different from the usual one, in such a direction that a higher dispersion than usual had been employed. On determining the value of the micrometer for this position of the grating, and re-reducing the observations, the discrepancy was then but a few hundredths of a tenth-metre.

In the 'Journal of the British Astronomical Association,' Mr. Maunder says, in reference to the possibility of my having over-measured the interval between the chief nebular line and the edge of the magnesium fluting, "Further, some allowance must be made for the difficulty of comparing a line with a fluting; we ought certainly not to measure from the center of the nebular line to the extreme edge of the fluting. This will apply a small, but a further, correction in the same direction." Mr. Maunder's criticism does not, however, apply to my own observations, which were made with this difficulty in view. If the distance between the line and the edge of the fluting could be measured with a slit-width vanishingly small, the true interval would be obtained. With a practicable slit-width, the position of the center of the line is unchanged, but the edge of the fluting is shifted toward the red by half the width of the line. In my observations of nebulæ, the slit-width used was such as to make the bright, sharp lead line (and hence, also, the nebular line) just the width of the coarse micrometer wire (about 0.4 tenth-metre). The bright lines were observed by occulting them with the wire, the observations thus referring to their centres, but the magnesium fluting was observed by bringing its extreme edge and the *lower* edge of the micrometer wire into coincidence, the center of the wire falling therefore upon the edge of the fluting with infinitely narrow slit. Measures of the interval between the lead line and the edge of the magnesium fluting, made with the fine micrometer wire and as narrow a slit as could be used, gave the same value as measures made in the manner just described.* The correction mentioned by Mr. Maunder is therefore unnecessary.

It appears to me, from what has been shown above, that the non-coincidence of the chief nebular line and the magnesium fluting must be regarded as proved.

In regard to the character of the line, recent observations at Mount Hamilton have shown nothing which does not confirm the opinion I have already expressed,† that under no circumstances of observation does the line tend to assume the aspect of the remnant of a fluting.

The observations which have been made at Mount Hamilton demonstrate the incorrectness of the view that the chief

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* I may call attention to the fact that my own value of this interval (1.86 tenth-metres) is 0.04 tenth-metre *smaller* than the most reliable measures which have yet been published.

† "A single prism of 60° was first employed, then a compound prism of about three and one-half times the dispersion of the latter, and finally a Rowland grating of 14,438 lines to the inch. With these different degrees of dispersion, and also with other spectroscopes, employed the nebular lines appeared to be perfect monochromatic images of the slit, widening when the slit was widened and narrowing to excessively fine, sharp lines when it was closed up. The brightest line showed no tendency to assume the aspect of a 'remnant of a fluting' under any circumstances of observation."—'Publications of the Astronomical Society of the Pacific,' No. 11, p. 266 and 280.

nebular line is in any way connected with the magnesium fluting at λ 5006.36, for reasons which may be briefly summarized as follows:—

(1). The nebular line is 0.43 tenth-metre more refrangible than the lower edge of the magnesium fluting.

(2). The nebular line has no resemblance to a fluting.

(3). Flutings and lines of magnesium, which could not fail to appear at the same time with the fluting at λ 5006.36, are entirely absent in nebular spectra.

Additional reasons have been given by Professors Liveing and Dewar, and by others who have investigated the subject, but I wish to consider here only such observations as have been made at the Lick Observatory.

NEW ORIGIN FOR TERRESTRIAL LONGITUDES.

The Paris Geographical Society has recently had under consideration the fixing of a new meridian from which to reckon longitudes and set the clocks all over the earth. The matter was previously discussed by the Royal Academy of Sciences of the Bologna Institute, which admitted its inability to recommend the location of a primary meridian, but tacitly admitted that the new one now in use, passing through the Observatory at Greenwich, England, is by no means acceptable. Since then several French societies have united to recommend that the new line pass through Jerusalem and Lake Nyanza, nearly in east longitude 35 degrees according to the present method of reckoning. One reason for the selection is a long land line in the direction of the poles.

If it be admitted that a change is advisable there should be no difficulty in obtaining assent to the proposition that the most prominent geographical facts ought to govern in making the choice. The following facts may help the reader to see that the line proposed is not the best, and that another selection may be made that would be far preferable, having really overwhelming arguments in its favor.

A comparison of the numerous measures of arcs of the meridian and along parallels to the equator that have been surveyed within the last century, proves the earth to be doubly ellipsoidal. Not only is the polar axis some twenty-six miles shorter than an equatorial diameter, but the equatorial curve itself is an ellipse, the difference between its greatest and least diameters being not far from two miles. Now, just as the equatorial line is the most natural origin for measures of latitude, so the greater and lesser meridians are the only natural lines from which to measure longitude on the earth's surface. Every other origin is open to the charge of being entirely artificial, as was the Island of Ferro with the early navigators, and as is the Greenwich Observatory now. But there are other reasons why we should select these natural meridians as the origin for measures of longitude and time reckoning, and some of them are almost entitled to be called startingly interesting.

The most complete reduction of the arc measures yet given to the world is that made by Capt. Clarke of the British Navy, who, being an Englishman, was not likely to furnish arguments in favor of unseating the Greenwich Observatory as the standard of longitude unless in obedience to the stern logic of facts. But he locates the major meridian in fifteen and a half (15°.34) degrees of east longitude. There is an uncertainty of a few minutes in the determination, so that it is not well to aim at too great precision of statement now, though it is highly desirable that the problem be again studied with the object of locating the position exactly. But as nearly as we are warranted in writing about it at present that major meridian passes one hour of longitude west of the Great Pyramid of Egypt, about which so much has been written as the earliest exponent of ancient mathematical knowledge and architectural skill that has been preserved to our day. It enters the African continent several degrees further south than does the proposed Jerusalem-Nyanza meridian, affording a magnificant land stretch from the topic of Capricorn to the Arctic circle, the only important water break in which is the Mediterranean Sea. Its extension through the poles and round the other side of the globe runs approximately through Behring Strait, and, thus divides off the American continent from the Asiatic, while it furnishes a far more natural dividing line on which the navigator of the Pacific Ocean shall change his day of reckoning than is the one now used. Then the minor meridian, ninety degrees from the major, not only passes through the City of New York, thus distinguishing the commercial capital of this continent, but it actually runs through the Island of San Salvador, which was the first land made by Columbus when he discovered the New World four centuries ago.

With such a mass of evidence in favor of establishing the new origin of longitude on the plan above noted can there be any hesitation in pronouncing for it as against any and all others that may be advocated by scientific men who appear to have utterly ignored the greatest reasons which should govern in the selection? And if the people of the Old World cannot be brought to agree on the propriety of the plan here briefly described ought not those of the United States and of other countries on this continent to be unanimous in demanding it? Not only are the major and minor meridians of the earth the sole origins from which measures of time and longitude can legitimately be reckoned, but they offer to us the important feature of passing over the first discovered land in this hemisphere and the biggest city in it, while limiting us to the westward. It may also be mentioned that the major meridian lies almost exactly midway between the Greenwich Observatory and the earliest one we know of, as the great pyramid was undoubtedly used for purposes of astronomical observation. The matter thus briefly introduced should meet with the attention it deserves, and in that case there is no fear it will be dropped as a topic of passing interest or mere scientific curiosity.—*Chicago Tribune* April 5th, 1891.

THE SMITHSONIAN ASTRO-PHYSICAL OBSERVATORY.

The Smithsonian Institution has established as one of its departments a Physical Observatory which, with the instruments, has been supplied from the Smithsonian fund. It occupies at present a temporary structure, though funds have been subscribed for a permanent building when Congress shall provide a suitable site. For the maintenance of the Observatory an appropriation has been made by Congress which will become available on the 1st of July, 1891. The actual instrumental work of the new Observatory will necessarily devolve largely upon a senior and a junior assistant, who have not yet been appointed, who can devote their entire time to research, and it is hoped that with the improved apparatus it will be possible to prosecute advantageously investigations in Telluric and Astro-physics and particularly those with the bolometer in radiant energy.

In accepting the position of Assistant Secretary of the Smithsonian Institution in 1887, Mr. Langley retained the Directorship of the Observatory at Allegheny for the purpose of completing the researches begun there, and after his appointment as Secretary of the Institution, he still continued the titular Directorship, though but a limited amount of time could be spared from his official duties at the capital. With the completion of the equipment of the little Observatory at Washington, he, however, formally resigned on April 30th, 1891, the Directorship at Allegheny which he had held since 1887, and he will, so far as his administrative occupations permit, give a personal attention to the general directions of the investigations.

The class of work which is referred to does not ordinarily involve the use of the telescope, and that which is contemplated is quite distinct from what is carried on at present at any other Observatory in the United States. The work for which the older Government Observatories at Greenwich, Paris, Berlin and Washington were founded, and in which they are now chiefly engaged, is the determination of relative positions of heavenly bodies and our own place with reference to them. Within the past twenty years all these Governments except that of the United States have established astro-physical Observatories, as they are called, which are, as is well known, engaged in the study of the heavenly bodies as distinct from their positions, in determining, for instance, not where, but what the Sun is, how it effects terrestrial climate and life, and how it may best be studied for the purposes of the meteorologist, and for other uses of an immediately practical nature.

The new Observatory is established for similar purposes. Its outfit includes a very large Siderostat (recently completed by Grubb, which is mounted in such a way as to throw a beam of light horizontally in the meridian. It is intended to carry a mirror of 20 inches diameter, and is perhaps the most massive and powerful instrument of its kind ever constructed. Within the dark room is mounted another large instrument, the spectrobolometer, which is in effect a large spectroscope with 20 inch circle reading to 5 seconds of arc, specially designed for use with the bolometer. It was made by William Grunow & Son of New York, as the outcome of Mr. Langley's experience with smaller apparatus during his earlier investigations. The most important part of the instrumental equipment is completed by specially designed galvanometers, scales and a peculiar resistence box; and these three instruments used in conjunction with the bolometer, and perhaps with the aid of photography, will be employed in the investigations upon light, heat and radiant energy in general, for which the Observatory is primarily intended, though some departments of terrestrial physics may also receive attention.

THE ORBIT OF OΣ 285.

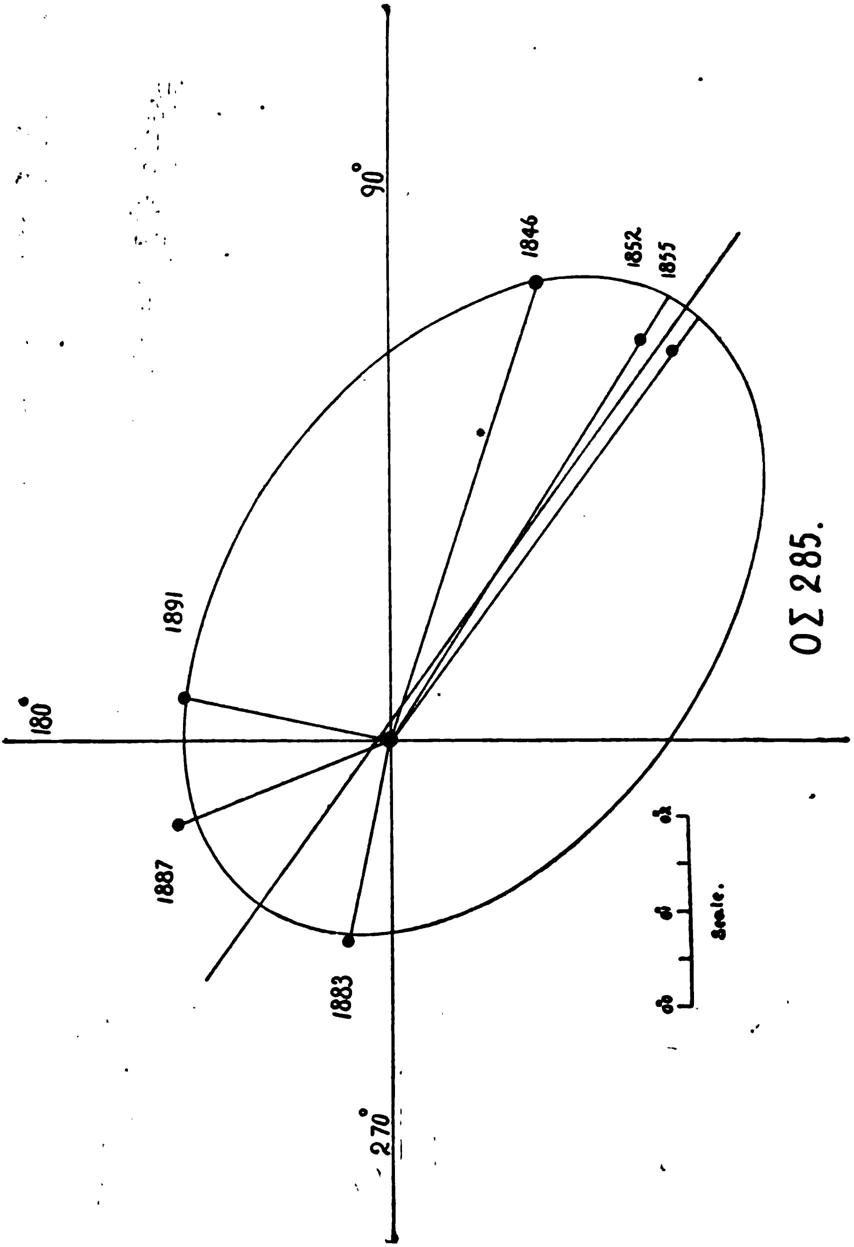
S. W. BURNHAM.

FOR THE MESSENGER.

This has always been a moderately close pair since its discovery by OΣ more than half a century ago, and therefore but few measures have been made of it. No orbit has been computed, and indeed until recently the data has been insufficient to obtain any reliable approximate period. I have measured this pair lately with the large refractor, and with the new position there should be no difficulty in getting a provisional period, and a fairly accurate representation of the apparent orbit.

The following is a complete list of the measures to the present time.

1845.80	72.2°	0.61″	OΣ	3n
1847.96	72.2	0.42	Ma	3n
1852.69	60.6	0.45	Ma	1n
1852.74	57.8	0.50	OΣ	4n
1855.84	53.9	0.51	OΣ	3n
1857.50	65.5	0.4	Se	1n
1881.50	round or doubtful		β	
1883.84	78.3	0.22	En	5n
1887.60	202.2	0.24	Sp	4n
1891.30	168.7	0.24	β	3n


OΣ 285.

In laying down these observations, as shown on the accompanying diagram, for a graphical determination of the period, I have used a mean of the first two measures, and have rejected the single measure by Secchi in 1857, the angle of which is obviously much too large.

From this ellipse we have the following:

Period	72.7 years.
Maximum distance (1853)	0.55″
Minimum distance (1881)	0.20
Major axis (55°)	0.78
Minor axis	0.50

The distance is now increasing, and in a few years it will be comparatively easy.

This pair is never really single, and should be measurable in all parts of its orbit with a large refractor. It will be noticed that at the time I found it doubtful in 1881 the distance was minimum, and unless the occasion was very favorable, a distance of 0″.2 might be easily overlooked even with the Chicago refractor of 18½ inches. In April, 1876, I examined this with my 6-inch telescope, and noted "certainly a slight elongation in about 350°, but very close and difficult." At this time the distance must have been 0″.3, and therefore well within the reach of that instrument under suitable conditions. For some years this pair should be regularly measured. A more accurate period can then be determined, together with the other elements of the orbit.

The star is B. A. C. 4885 (= P xiv, 182), and its place (1880):

R. A. = $14^h\ 40^m\ 59^s$
Decl. = + 42° 53′

Lick Observatory, May 15.

DR. EDWARD SCHŒNFELD.*

A. KRUEGER.

On the 1st of May of the present year, after long suffering, Privy Counsellor Professor Edward Schönfeld, Director of the Bonn Observatory, died in his sixty-third year. Born at Hildburg, Dec. 22, 1828, he attended the Gymnasium of his native city and afterward the Polytechnic School at Cassel

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* Translated from the German (Astronomische Nachrichten 3033) by Miss F. E. Harpham, Post-Graduate student at Carleton College.

for the study of architecture. After a year here he went to the Polytechnic school at Hanover to attend the lectures of Karmarsch, Rühlmann and Schwarz.

Here he first determined to follow his desire to study the natural sciences, and in the autumn of 1849 he went to Marburg University where, after thorough studies in chemistry, he was introduced by Gerling to the study of astronomy. In the the spring of 1852 he came to Bonn to pursue the special branch of astronomy still further. Argelander recognized at once the extraordinary talent and glowing enthusiasm of the prospective astronomer, and at Easter, 1853, when the removal of Schmidt to Olmutz left the assistant's place vacant, he bestowed it upon Schönfeld without delay, even before his promotion which took place in 1854.

Argelander was already busy in his work of mapping the northern heavens; upon Schönfeld's entry the work was hastened forward with zeal and was soon finished. During Argelander's long absence at Pulkowa, he began his first zone observations with the small comet seeker, and upon the Director's return, laid his work before him. The opportunity was given to the author of these lines to assist in this great undertaking, at first only as a volunteer but later as a constant fellow worker. The work was pushed forward steadily and successfully under the mutual emulation of the Director and his assistant.

In 1859 Schönfield was called to Mannheim as Director of the Observatory, to which place his wife, who was a true helpmate to him to the end of his life, soon followed him. In Mannheim he wished to take up work corresponding to the moderate means of the Observatory and this he accomplished successfully. The study of the variable stars, begun at Bonn was continued here and the result published in the two Mannheimer catalogues. Then with the refractor, he observed the visible nebulae of which he published an excellent catalogue. During this time the "Astronimische Gesellschaft" was founded, in the promotion of which he was of great service, especially as secretary until the year 1875.

When in 1875 the Bonn Observatory was deprived by death of the memorable Argelander, there was no question as to what astronomer should succeed him. Schönfield took the new work and, wishing to follow the traditions of the

Observatory, undertook the great work of mapping the southern sky, for which he himself made the observations and performed the greater part of the reductions. The over-exertions of these ten years laid the foundation of his later illness.

It would be an injustice to pass over in silence the service rendered by the deceased as a teacher in the university. As Privat-docent before his residence at Mannheim, he gave lectures which were distinguished by clearness of thought and profound erudition. Later, as professor of astronomy, he gave the greatest attention to this province of his work.

The wide range of Dr. Schönfeld's knowledge was surprising. He was very willing to give information and gladly conversed on topics which were beyond his own knowledge, in order to inform himself. Having a fine memory, he was extraordinarily well read and aroused the wonder of all who came into contact with him.

What his death is to his friends, the author of these lines who has been his friend more than thirty-eight years, can well estimate. He was kind and sympathetic to every one, nor did he permit any to feel his superiority. His unassuming modesty was perhaps at times too great, but for that cause no one could feel either enmity or jealousy.

Kiel, May 2, 1891.

MR. BURNHAM ON DOUBLE STARS.

GEORGE C. COMSTOCK.

FOR THE MESSENGER.

In comparing my own double-star observations with those of other observers about a year ago, I found a very persistent systematic difference between my observed position angles and Mr. Burnham's measures of the same stars. In order to obtain, if possible, an explanation of the difference between our results I asked Mr. Burnham to give me an account of his methods of observing, which he very kindly did in a letter the greater part of which is reproduced below, and which cannot fail to be of interest to every one concerned with observations of this class. It is needless to say that the letter was not written for publication. Mr. Burnham has, however, consented that those parts of it which are of general interest may appear in THE MESSENGER.

It is not at all surprising that there should be difference between two observers in measuring close pairs, but there certainly should be no systematic difference in angles of either close or wide pairs, provided, of course, the proper plan is pursued in making the measures. It is absolutely necessary that the line joining the eyes should be either perpendicular or parallel to the wires. (This is true of both distances and angles.) Just how you will place the wires with reference to the stars in making angles will, of course, depend on the kind of pair you are observing, and what would be the best in one case would not be in another. A little experience will enable you to know exactly what to do in each case. In a wide pair you would ordinarily bisect the stars; with a close pair you cannot do this. In a general way, so far as I can state it, my plan is this: With one hand on the pinion and the other on the coarse screw which moves both wires, I rapidly throw the double from one side of one wire to the other, changing the angle until the wire appears to be parallel to the stars in the three positions, |: :|: :|. In some cases I try it also between the wires at some distance apart, that distance varying with the distance between the stars. Good measures of either distances or angles must be done quickly—that is, the motion of the wire must be rapid, and of course anything like a tangent screw and clamp is wholly unsuitable and unreliable. I don't know that now-a-days anybody uses so absurd a plan. It is far better to move the wires in position-angle by hand. In fact that is a good way, though not as convenient nor as quick. I was obliged to do this in all the measures with the Chicago micrometer. But the important thing is to have the eyes right *with reference to the object.* This is so obvious a precaution that it seems strange that any one should ever think of doing the thing in any other way, because it is in the experience of every one that it is involuntarily done under all circumstances in every day life. Let any one try to use the eyes in estimating distances, or the position of things, or to read with the head inclined 90° or wrong side up, and he will see it is the next thing to not seeing at all.

Of course in distances I always place the wires over the star. Any other plan would be but little, if any, better than an estimate, and certainly would not be measuring. I have but little faith in much that has been written about systematic errors and especially in position-angles. It is easy enough to see how one would record a transit sooner or later than another, but that has no more to do with this question than the result of throwing dice. We all go wrong, and I suppose we are never right unless by accident, but the errors in the long run should compensate each other just as much as though the angles were estimated or set down at random.

As to getting the zero of the wires, of course I let a star run along with the lowest power on. This gives it to a tenth or two, which is far nearer than anybody can measure anything with certainty and any further refinement to find the parallel would be a waste of time which would be much better spent in observing. Here, with the frequent changes in the use of the instruments I have to get the parallel almost every night.

All other sources of error in measuring double stars are insignificant when compared with that which comes from improper illumination. My measures here in 1879 with the 6-inch of the micrometer you have are of very little value from that defect. Very trifling things make the difference. Be sure you have your instrument just right, when it is right you can measure everything you can see, and with a feeling that it is fairly well done, and your results will agree with each other.

THE DIRECT ACTION OF SOLAR DISTURBANCES ON TERRESTRIAL MAGNETISM.

T. S. H. SHEARMEN.

FOR THE MESSENGER.

During the year 1882 I became convinced that there is a connection between the visibility of the sun spots *as seen from the earth* and terrestrial magnetism. At the time I was making almost daily observations of the sun, and havincidentally observed an aurora frequently follow the appearance of large spots at the sun's east limb, I connected the two events and concluded I had brought a new fact to light. Having secured my right to the discovery by publishing a note on the subject (unfortunately in a newspaper), I tried to interest astronomers in the matter by private correspondence. In this I failed, and I therfore determined to wait until after another spot maximum for fresh evidence before again bringing the matter up; but Professor C. A. Young having recently published an article in which he refers to this connection as having been recently discovered (or rather re-discovered) in the United States, I am compelled to again refer to my work in this connection without further delay.

This being merely a preliminary note I will give my results for three years only. They are quite sufficient though to show that there is a distinct connection between the visibility of solar disturbances from the earth and terrestrial magnetism. They show, in other words, that an active spot, or other result of a solar disturbance, when on the visible hemisphere, apparently has a greater effect on the earth's magnetism than when on the hemisphere turned away from our view. This discovery was originally made by finding on many occasions an aurora following the appearance of large spots at the sun's east limb; but I soon found that solar disturbances of every size, when first seen at that limb, apparently caused a disturbance of the earth's magnetism. To illustrate this I will give the results for the period 1885, July—1888, July. I have compared my observations of solar disturbances and auroræ during this period with the magnitude and auroral results published in the *Monthly Weather Review* of the Canadian meteorological service kindly furnished for this purpose by C. Carpmael, Esq., M. A., F. R. A. S. The accompanying table shows the result of this comparison:

Period of Observation.	No. of Disturbances at E. limb.	Coincidences with Auroræ.	Magnets more or less disturbed.	No Record. (See note.)
1885, July—1886, July....	49	29	17	3
1886, July—1887, July....	34	23	10	1
1887, July—1888, July....	26	13	11	2

NOTE.—"No record" means that the disturbance (if any) of the magnets at Toronto Observatory was not sufficient to be noticed by Mr. Carpmael in the short magnetic reviews which I consulted.

An inspection of the above table shows, I think, the connection very distinctly. It will be seen that on 65 of the 109 occasions when disturbances were at the sun's E. limb an aurora is recorded on the same date. Of the remaining occasions the magnets at the Toronto Observatory were more or less disturbed on 38 dates. This leaves only six dates to be accounted for. A closer agreement could hardly be desired—especially when we remember that many of the solar disturbances in the list were quite small.

After deducting from the list of auroræ and magnetic disturbances those caused by a solar disturbance becoming visable at the sun's E. limb, I find many remain for explanation. I will deal with these at length in a future paper, and will only say here that many disturbances of the earth's magnetism can be traced to the breaking out of spots on the sun's visible hemisphere; and to sudden changes in the activity of a disturbance already visible. I would also say here that I find faculæ can even, when without neighboring maculæ, affect the earth's magnetism. This being the case

I generally use the term *disturbance* in place of "spot." Faculæ, spots, prominences, etc., are, of course, merely the results of a solar *disturbance*. This subject will also be referred to on a future occasion.

Brantford, Canada, May 4, 1891.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at superior conjunction with the sun July 6 and will not be easily seen during the month of July. August 16 he will be at greatest elongation east from the sun, 27° 25′. For about a week he will be visible to the naked eye during the first hour and a half after sunset.

The transit of Mercury, on May 9, was unfortunately obscured by clouds over a large part of the United States. The only places, so far as we have heard, where good observations were obtained, were at Lick Observatory and Washington University Observatory, St. Louis, Mo. Mr. Barnard writes that he succeeded in getting both contacts at the beginning of transit. His results as to the atmospheric fringe about Mercury, both on and off the solar disk, are entirely negative. He saw no white spot upon Mercury's disk. Mr. Very, at Allegheny Observatory, observed second contact, but under very unfavorable atmospheric conditions. Mr. Comstock, at Washburn Observatory, saw the planet through clouds but lost both contacts. Mr. C. W. Pritchett, at Morrison Observatory, reports the same. At Carleton College Observatory dense clouds covered the sun until about ten minutes before sunset. We saw the planet but the images were so distorted that no fine details could be made out on the sun's surface.

Venus will be "morning star" until September, but is getting closer to the sun so it will not be observable except during the day. Venus and Neptune will be in conjunction, only 29′ apart, June 22.

Mars will be out of view for the rest of the year. *L'Astronomie* for May contains an interesting paper by C. Flammarión on observations of Mars during the past opposition. The paper reviews the observations of three Italian astronomers, Guillaume, at Peronna, Giovannozzi, at Florence, and Schiaparelli, at Milan, and is illustrated by reproductions of several drawings of the planet by these persons. They all, to a large extent, confirm the observations by Schiaparelli of the so-called "canals."

The Journal of the British Astronomical Association also contains an article by A. Stanley Williams on the same subject, reviewing observations by different observers.

Jupiter will be at quadrature with the sun June 7, rising then a little after midnight. In the morning hours before twilight good views of this planet may be obtained. His motion among the stars will be very slow during the summer, being eastward until July 7 and westward after that time. The planet is in the constellation of Aquarius, about half way between, and a little to the east of α Pegasi (*Markab*) and α Piscis Austrinus (*Fomalhaut*). In *Monthly Notices*, April, 1891, Mr. A. Stanley Williams gives an article on the Reduction of Measures of Photographs of Jupiter taken at Lick Observatory in 1890. These photographs were enlarged directly in the telescope 8.3 times, so that the image of the planet as photographed at the time of opposition was nearly an inch in diameter. The measures of the belts and spots agree closely with visual observations made about the same time and show that photography may be made of great use in this line of work.

Saturn, although coming into unfavorable position, with reference to the sun, should be watched very closely during the summer months and all changes in the appearance of the rings, as the sunlight lowers upon them, carefully noted. During August it will be impossible to observe the planet after sunset, but good observations are possible in daylight when the altitude of the sun is low. On June 9 the sun will be 2° 13′ below the plane of the rings, while the earth will be 5° 07′ below the same plane. June 29 the same data will be respectively 1° 55′ and 4° 30′; August 8, 1° 17′ and 2° 37′; and August 28, 0° 59′ and 1° 30′. Of course one will look for this planet toward the west in the early evening.

Uranus will be in good position for observation during all of the summer months. For its position among the stars, we refer the reader to the chart of the constellation Virgo in the March number of THE MESSENGER, page 142. It will be best observed in the early evening when it is near the meridian.

Neptune is morning star but so near the rays of the sun that it will be invisible during the summer.

MERCURY.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
July 5	6 50.4	+24 10	4 08 A. M.	11 56.8 A. M.	7 45 P. M.
15	8 21.3	+21 22	5 14 "	12 48.1 P. M.	8 22 "
25	9 35.6	+15 43	6 15 "	1 22.7 "	8 30 "
Aug. 5	10 38.5	+ 8 31	7 03 "	1 42.1 "	8 19 "
15	11 20.4	+ 2 23	7 32 "	1 44.8 "	7 58 "
25	11 45.3	− 2 07	7 35 "	1 30.3 "	7 25 "

VENUS.

July 5	5 30.2	+22 42	2 56 A. M.	10 36.5 A. M.	6 17 P. M.
15	6 23.1	+23 12	3 07 "	10 50.1 "	6 34 "
25	7 16.2	+22 34	3 23 "	11 03.7 "	6 44 "
Aug. 5	8 13.6	+20 27	3 48 "	11 17.7 "	6 47 "
15	9 04.5	+17 47	4 12 "	11 29.0 "	6 46 "
25	9 53.7	+14 08	4 38 "	11 38.8 "	6 40 "

MARS.

July 5	7 31.3	+22 51	4 56 A. M.	12 37.6 P. M.	8 19 P. M.
15	7 59.6	+21 44	4 50 "	12 25.7 "	8 02 "
25	8 25.9	+20 22	4 44 "	12 13.3 "	7 43 "
Aug. 5	8 54.8	+18 35	4 38 "	11 58.9 A. M.	7 20 "
15	9 20.1	+16 45	4 33 "	11 45.2 "	6 58 "
25	9 45.6	+14 44	4 27 "	11 30.8 "	6 34 "

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			JUPITER.		
July 5	23 17.9	− 5 53	10 41 P. M.	4 21.4 A. M.	10 02 A. M.
15	23 17.5	− 5 59	10 02 “	3 41.7 “	9 22 “
25	23 16.0	− 6 12	9 22 “	3 00.8 “	8 40 “
Aug. 5	23 13.0	− 6 34	8 37 “	2 14.7 “	7 52 “
15	23 09.3	− 6 59	7 56 “	1 31.6 “	7 07 “
25	23 04.9	− 7 29	7 14 “	12 47.9 “	6 22 “
			SATURN.		
July 5	10 59.2	+ 8 36	9 27 A. M.	4 04.9 P. M.	10 42 P. M.
15	11 02.6	+ 8 14	8 53 “	3 28.8 “	10 05 “
25	11 06.1	+ 7 51	8 19 “	2 53.1 “	9 28 “
Aug. 5	11 10.6	+ 7 22	7 42 “	2 14.2 “	8 47 “
15	11 14.8	+ 6 55	7 08 “	1 39.2 “	8 10 “
25	11 19.3	+ 6 27	6 35 “	1 04.2 “	7 33 “
			URANUS.		
July 5	13 42.1	− 10 01	1 24 P. M.	6 47.2 P. M.	12 11 A. M.
15	13 42.3	− 10 02	12 44 “	6 08.0 “	11 32 P. M.
25	13 42.7	− 10 05	12 06 “	5 29.3 “	10 53 “
Aug. 5	13 43.6	− 10 11	11 24 A. M.	4 47.0 “	10 10 “
15	13 44.8	− 10 18	10 46 “	4 08.8 “	9 31 “
25	13 46.2	− 10 26	10 09 “	3 30.9 “	8 53 “
			NEPTUNE.		
July 5	4 25.4	+ 20 06	2 03 A. M.	9 32.1 A. M.	5 01 P. M
15	4 26.7	+ 20 08	1 26 “	8 54.1 “	4 22 “
25	4 27.8	+ 20 11	12 47 “	8 15.8 “	3 44 “
Aug. 5	4 28.9	+ 20 13	12 05 “	7 33.6 “	3 02 “
15	4 29.6	+ 20 14	11 26 P. M.	6 55.1 “	2 24 “
25	4 30.2	+ 20 14	10 48 “	6 16.2 “	1 45 “
			THE SUN.		
July 5	6 58.0	+ 22 47	4 22 A. M.	12 04.3 P. M.	7 47 P. M.
15	7 38.7	+ 21 30	4 30 “	12 05.7 “	7 42 “
25	8 18.9	+ 19 37	4 40 “	12 06.3 “	7 33 “
Aug. 5	9 01.8	+ 16 56	4 51 “	12 05.8 “	7 20 “
15	9 39.8	+ 14 00	5 03 “	12 04.3 “	7 06 “
25	10 16.8	+ 10 42	5 15 “	12 01.9 “	6 49 “
			CERES.		
June 23	22 35.7	− 20 40	11 50 P. M.	4 27 A. M.	9 04 A. M.
July 17	22 34.4	− 22 50	10 25 “	2 51 “	7 17 “
Aug. 10	22 20.4	− 25 39	8 50 “	1 02 “	5 14 “
			PALLAS.		
June 23	20 10.4	+ 19 33	6 36 P. M.	2 01 A. M.	9 26 A. M.
July 7	19 52.9	+ 18 58	4 46 “	12 09 “	7 32 “
Aug. 10	19 34.8	+ 15 58	3 08 “	10 17 “	5 26 “
			JUNO.		
June 23	21 59.7	− 0 39	9 49 P. M.	3 50 A. M.	9 51 A. M.
July 17	21 57.7	− 0 48	8 14 “	2 14 “	8 14 “
Aug. 10	21 43.4	− 3 00	6 33 “	12 25 “	6 17 “
			VESTA.		
July 5	17 56.5	− 21 39	6 28 P. M.	11 00 P. M.	3 32 A. M.
29	17 41.6	− 23 21	4 47 “	9 11 “	1 35 “
Aug. 22	17 45.5	− 24 43	3 24 “	7 41 “	11 58 P. M.

Jupiter's Satellites.

		Central Time.				
		h	m			
July	3	1	06	A. M.	II	Sh. In.
		3	39	"	II	Tr. In.
		4	01	"	II	Sh. Eg.
	4	2	48	"	I	Ec. Dis.
	5	12	04	"	I	Sh. In.
		1	20	"	I	Tr. In.
		1	23	"	II	Oc. Re.
		2	23	"	I	Sh. Eg.
		3	38	"	I	Tr. Eg.
		9	17	P. M.	I	Ec. Dis.
	6	12	49	A. M.	I	Oc. Re.
		10	06	P. M.	I	Tr. Eg.
		11	04	"	IV	Ec. Re.
	8	1	51	A. M.	III	Sh. In.
	11	10	39	P. M.	II	Ec. Dis.
		11	58	"	III	Oc. Re.
	12	1	58	A. M.	I	Sh. In.
		3	09	"	I	Tr. In.
		3	48	"	II	Oc. Re.
		11	11	P. M.	I	Ec Dis.
	13	2	38	A. M.	I	Oc. Re.
		9	36	P. M.	I	Tr. In.
		10	11	"	II	Tr. Eg.
		10	45	"	I	Sh. Eg.
		11	54	"	I	Tr. Eg.
	14	9	05	"	I	Oc. Re..
	18	11	14	"	III	Ec. Re.
	19	12	17	A. M.	III	Oc. Dis.
		1	13	"	II	Ec. Dis.
		3	35	"	III	Oc. Re.
	20	1	06	"	I	Ec. Dis.
		9	46	P. M.	II	Tr. In.
		10	20	"	I	Sh. In.
		10	34	"	II	Sh. In.
		11	24	"	I	Tr. In.
	21	12	37	A. M.	II	Tr. Eg.
		12	39	"	I	Sh. Eg.
		1	42	"	I	Tr. Eg.
		10	53	P. M.	I	Oc. Re.
	23	10	49	"	IV	Oc. Dis.
	24	2	18	A. M.	IV	Oc. Re.
	25	11	53	P. M.	III	Ec. Dis.
	26	3	14	A. M.	III	Ec. Re.
		3	48	"	II	Ec. Dis.
		3	50	"	III	Oc. Dis.
	27	3	00	"	I	Ec. Dis.
		10	17	P. M.	II	Sh. In.
	28	12	09	A. M.	II	Tr. In.
		12	14	"	I	Sh. In.
		1	09	"	I	Tr. In.
		1	11	"	II	Sh. Eg.
		2	33	"	I	Sh. Eg.
		3	00	"	II	Tr. Eg.
		3	27	"	I	Tr. Eg.
		9	29	"	I	Ec. Dis.
	29	12	40	A. M.	I	Oc. Re.
		9	01	P. M.	I	Sh. Eg.

		Central Time.				
		h	m			
July	29	9	40	P. M.	II	Oc. Re.
		9	54	"	I	Tr. Eg.
	31	11	39	"	IV	Sh. In.
Aug.	1	3	59	A. M.	IV	Sh. Eg.
	2	3	54	"	III	Ec. Dis.
	4	12	55	"	II	Sh. In.
		2	08	"	I	Sh. In.
		2	30	"	II	Tr. In.
		2	57	"	I	Tr. In.
		3	49	"	II	Sh. Eg.
		11	23	P. M.	I	Ec. Dis.
	5	2	26	A. M.	I	Oc. Re.
		7	40	P. M.	II	Ec. Dis.
		8	36	"	I	Sh. In.
		9	02	"	III	Tr. In.
		9	23	"	I	Tr. In.
		9	25	"	III	Sh. Eg.
		10	55	"	I	Sh. Eg.
		11	41	"	I	Tr. Eg.
		11	58	"	II	Oc. Re.
	6	12	21	A. M.	III	Tr. Eg.
		8	53	P. M.	I	Oc. Re.
	11	3	33	A. M.	II	Sh. In.
		4	02	"	I	Sh. In.
	12	1	18	"	I	Ec. Dis.
		9	55	P. M.	III	Sh. In.
		10	15	"	II	Ec. Dis.
		10	30	"	I	Sh. In.
		11	07	"	I	Tr. In.
	13	12	26	A. M.	III	Tr. In.
		12	49	"	I	Sh. Eg.
		1	24	"	III	Sh. Eg.
		1	25	"	I	Tr. Eg.
		2	14	"	II	Oc. Re.
		3	43	"	III	Tr. Eg.
		7	47	"	I	Ec. Dis.
		10	38	P. M.	I	Oc. Re.
	14	7	18	"	I	Sh. Eg.
		7	46	"	II	Sh. Eg.
		7	51	"	I	Tr. Eg.
		8	50	"	II	Tr. Eg.
	17	10	09	"	IV	Sh. Eg.
		10	43	"	IV	Tr. In.
	18	2	14	A. M.	IV	Tr. Eg.
	19	3	13	"	I	Ec. Dis.
	20	12	24	"	I	Sh. In.
		12	49	"	II	Ec. Dis.
		12	51	"	I	Tr. In.
		1	56	"	III	Sh. In.
		2	43	"	I	Sh. Eg.
		3	09	"	I	Tr. Eg.
		3	45	"	III	Tr. In.
		9	41	P. M.	I	Ec. Dis.
	21	12	22	A. M.	I	Oc. Re.
		6	53	P. M.	I	Sh. In.
		7	17	"	I	Tr. In.
		7	29	"	II	Sh. In.

	Central Time. h m				Central Time. h m	
Aug. 21	8 17 P. M.	II Tr. In.		Aug. 28	8 47 P. M.	I Sh. In.
	9 12 "	I Sh. Eg.			9 00 "	I Tr. In.
	9 35 "	I Tr. Eg.			10 07 "	II Sh. In.
	10 22 "	II Sh. Eg.			10 33 "	II Tr. In.
	11 08 "	II Tr. Eg.			11 06 "	I Sh. Eg.
22	6 48 "	I Oc. Re.			11 18 "	I Tr. Eg.
23	8 37 "	III Oc. Re.		29	1 00 A. M.	II Sh. Eg.
26	1 34 A. M.	IV Ec. Dis.			1 24 "	II Tr. Eg.
27	2 18 "	I Sh. In.			8 32 P. M.	I Oc. Re.
	2 34 "	I Tr. In.		30	7 49 "	II Oc. Re.
	3 24 "	II Ec. Dis.			7 59 "	III Ec. Dis.
	11 36 P. M.	I Ec. Dis.			11 53 "	III Oc. Re.
28	2 06 A. M.	I Oc. Re.				

Configuration of Jupiter's Satelites at Midnight.

July 1	4 3 1 ○ 2	July 21	4 2 ○ 1 3	Aug. 11	2 1 ○ 3 4
2	4 3 ○ 2 1	22	4 3 1 ○ 2	12	♃ ○ 3 4 ●
3	4 2 3 1 ○	23	● 3 ○ 1 2	13	3 ○ 1 2 4
4	● 4 ○ 1 3	24	3 2 1 ○ 4	14	3 1 2 ○ 4
5	● 4 ○ 2 3	25	2 3 ○ 1 4	15	3 2 ○ 1 4
6	2 1 4 ○ 3	26	1 ○ 2 3 4	16	1 ○ 3 2 4
7	2 ○ 3 1 4	27	4 ○ 1 3 4	17	♃ ○ 1 2 3
8	3 1 ○ 2 4	28	● 2 ○ 3 4	18	4 2 1 ○ 3
9	3 ○ 2 1 4	29	1 3 ○ 2 4	19	4 2 ○ 1 3
10	3 2 1 ○ 4	30	3 ○ 1 2 4	20	4 3 ○ 2 ●
11	2 ○ 3 1 4	31	3 2 1 ○ 4	21	4 3 1 2 ○
12	● ○ 2 3 4	Aug. 1	4 2 3 ○ 1	22	4 3 2 ○ 1
13	2 1 ○ 3 4	2	4 1 ○ 3 2	23	4 1 ○ 3 2
14	2 ○ 1 3 4	3	4 ○ 2 1 3	24	4 ○ 1 2 3
15	3 1 4 ○ 2	4	4 2 1 ○ 3	25	2 1 4 ○ 3
16	3 4 ○ 2 1	5	♃ 4 3 ○ ●	26	2 ○ 1 3 4
17	4 3 2 1 ○	6	4 3 ○ 1 2	27	3 1 ○ 2 4
18	4 2 ○ 1 ●	7	4 3 1 2 ○	28	3 1 ○ 4 ♃
19	4 1 ○ 2 3	8	2 4 3 ○ 1	29	3 2 ○ 1 4
20	4 2 ○ 3 4	9	1 ○ 4 3 2	30	● 1 ○ 2 4
		10	○ 2143	31	○ 1234

Phases and Aspects of the Moon.

			Central Time. d	h	m	
New Moon....................................	1891	July	5	9	58	P. M.
Apogee....................................	"	"	11	12	24	"
First Quarter....................................	"	"	13	11	29	"
Full Moon....................................	"	"	21	7	54	A. M.
Perigee....................................	"	"	23	11	00	"
Last Quarter....................................	"	"	27	10	33	P. M.
New Moon....................................	"	Aug.	4	11	12	A. M.
Apogee....................................	"	"	8	4	12	"
First Quarter....................................	"	"	12	3	12	P. M.
Full Moon....................................	"	"	19	3	28	"
Perigee....................................	"	"	20	2	54	"
Last Quarter....................................	"	"	26	6	09	A. M.

Wolsingham Observatory. A new variable star was found March 2nd, at $4^h\ 26^m\ 4^s$, + 65° 53′ ('55). Var. confirmed at Harvard. T. E. Espin.
Circular, No. 31.

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.............$0^h\ 52^m\ 32^s$
Decl.............+ 81° 17′
Period..........$2d\,11^h 50^m$

July 5	2 A. M.
10	2 "
15	2 "
20	1 "
25	1 "
30	1 "
Aug. 3	midn.
8	"
13	"
18	11 P. M.
23	11 "
28	11 "

ALGOL.

R. A.............$3^h\ 01^m\ 01^s$
Decl.............+ 40° 32′
Period..........$2d\,20^h 49^m$

July 11	3 A. M.
13	10 P. M.
31	3 A. M.
Aug. 2	midn.
5	8 P. M.
23	1 A. M.
25	9 P. M.

δ LIBRÆ.

R. A............$14^h\ 55^m\ 06^s$
Decl............. — 8° 05′
Period.........$2d\ 07^h\ 51^m$

July 13	midn.
20	"
27	"
Aug. 3	11 P. M.
10	11 "
17	11 "
24	10 "
31	10 "

U CORONÆ.

R. A...........$15^h\ 13^m\ 43^s$
Decl...............+ 32° 03′
Period $3d\,10^h 51^m$

July 7	midn.
14	10 P. M.
21	7 "
Aug. 8	2 A. M.
14	11 P. M.
21	9 "
28	7 "

U. OPHIUCHI.

R. A..........$17^h\ 10^m\ 56^s$
Decl...............+ 1° 20′
Period........$0d\ 20^h\ 08^m$

July 3	4 A. M.
3	midn.
4	8 P. M.
9	2 A. M.
9	10 P. M.
14	2 A. M.
15	11 P. M.
19	3 A. M.
19	11 P. M.
24	midn.
25	8 P. M.
30	3 A. M.
30	11 P. M.
31	7 "
Aug. 4	2 A. M.
4	10 P. M.
9	2 A. M.
9	10 P. M.
14	3 A. M.
14	11 P. M.
19	midn.
20	8 P. M.
25	1 A. M.
25	9 P. M.
30	2 A. M.
30	10 P. M.

Y CYGNI.

R. A............$20^h\ 47^m\ 40^s$
Decl............+ 34° 15′
Period.........$1d\ 11^h\ 57^m$

July 4	3 A. M.
7	3 "
10	3 "
13	3 "
16	3 "
19	3 "
22	3 "
25	3 "
28	2 "
31	2 "
Aug. 3	2 "
6	2 "
9	2 "
12	2 "
15	2 "
18	2 "
21	2 "
24	2 "
27	2 "
30	1 "

Occultations Visible at Washington.

			IMMERSION.		EMERSION.		
Date.	Star's Name.	Magnitude.	Wash. Mean T. h m	Angle f'm N. P't. °	Wash. Mean T. h m	Angle f'm N.P't. °	Duration. h m.
July	16...κ Libræ	5.1	6 42	120	8 01.4	296	1 19
	19...φ Sagittarii	3.7	11 46	126	12 46.9	226	1 01
	23...τ^1 Aquarii*	5.8	9 12	57	10 11.7	263	1 00
	29...ω^2 Tauri	5.7	14 46	123	15 20.7	187	0 35
Aug.	18...35 Capricorni	6.2	11 36	121	12 17.6	186	0 42
	18...37 Capricorni	6.0	15 42	78	16 37.8	230	0 56
	22...*f* Piscium	5.1	13 24	100	14 14.4	185	0 51
	25...B. A. C. 1242	6.3	13 49	36	14 51.2	269	1 02

* Multiple Star.

COMET NOTES.

Ephemeris of the Tempel-Swift Periodic Comet. In *Bulletin Astronomique*, May, 1891, M. Bossert has published an ephemeris of this comet for the apparition of 1891. He has computed the perturbations by Jupiter and Saturn and derives the following elements for this year:

$$T = 1891, \text{Nov. } 14.95835 \text{ Paris M. T.}$$

$$\left.\begin{array}{l} \pi = 43^\circ\ 14'\ 15.7'' \\ \Omega = 206\ \ 31\ \ 14.8 \\ i = 5\ \ 23\ \ 13.8 \end{array}\right\} 1891.0$$

$$\varphi = 40\ \ 43\ \ 44.4$$

$$\log a = 0.495370 \qquad a = 3.1288$$

$$\log q = 0.036071 \qquad q = 1.0866$$

The position of the comet in November will be very favorable for observation, as it will be almost opposite the sun at the time of its nearest approach to the earth, which will be in the latter days of November. The factor $\frac{1}{r^2\Delta^2}$ by which we judge of the brightness of the cometwas 13.17 and 6.04 in 1869 at the first and last dates of observation. In 1880 the factor was 18.46 on the first and 1.70 on the last date. This year the factor will become 1.70 on Aug. 23 and will increase to a maximum of 19.7 Nov. 26.

1891		App. R. A.	App. Decl.	log Δ (from earth)	Aberration (time)	$\frac{1}{r^2\Delta^2}$
July	2	$22^h\ 04^m\ 24^s$	$-10^\circ\ 07.5'$	0.0492	$9^m\ 18^s$	0.21
	6	06 08	− 9 38.6			
	10	07 28	− 9 09.8	9.9993	8 17	0.28
	14	08 23	− 8 41.2			
	18	08 50	− 8 12.6	9.9473	7 21	0.39
	22	08 49	− 7 44.1			
	26	08 15	− 7 15.7	9.8936	6 30	0.54
	30	07 09	− 6 47.3			
Aug.	3	05 27	− 6 18.9	9.8390	5 44	0.74
	7	03 10	− 5 50.4			
	11	22 00 18	− 5 21.8	9.7845	5 03	1.04
	15	21 56 52	− 4 52.9			
	19	52 52	− 4 23.5	9.7314	4 28	1.44
	23	48 25	− 3 53.4			
	27	43 31	− 3 22.6	9.6812	3 59	1.97
	31	38 20	− 2 50.9			
Sept.	4	21 33 02	− 2 18.2	9.6353	3 35	2.66
Oct.	2	21 06 24	+ 2 30.1	9.5114	2 42	6.30
Nov.	3	21 44 11	+ 13 01.6	9.3851	2 01	14.09
	27	23 43 49	+ 26 24.2	9.3119	1 42	19.68
Dec.	29	3 34 45	+ 29 36.3	9.4883	2 33	6.94

The complete ephemeris for September and later months will be given in our later numbers.

The Re-Discovery of Wolf's Periodic Comet. A year ago Dr. Berberich very kindly sent me an ephemeris of Wolf's periodic comet of 1884, which he had computed in hope that I might be able to find it during 1890. I made repeated and careful searches for the comet with a 12-inch then without any success, and have also searched carefully as soon as its position was favorable this year. Though the position was carefully examined the comet remained too faint to be detected until the morning of May 4th when I finally discovered it with the 12-inch close to the predicted place. Accurate filar micrometer observations gave its position.

$$\begin{aligned} &\text{1891 May } 3d\ 15^h\ 23^m\ 33^s \text{ Mt. Hamilton, M. T.}\\ &\alpha \text{ appt.} = 22^h\ 33^m\ 16^s.71\\ &\delta \text{ appt.} = +13^\circ\ 11'\ 27''.3 \end{aligned}$$

The comet was extremely faint and small. The estimated magnitude would be between 13.5 and 14. It was about 5″ or 10″ in diameter—a small indefinite speck of light, bright in the middle to perhaps an indefinite nucleus.

The observations that morning showed motion, so that no hesitation remained as to the identity of the object. A cipher telegram to Harvard College Observatory announcing the discovery was sent that morning at $5^h\ 45^m$. The comet has since been observed on three mornings.

In the May MESSENGER Mr. George A. Hill has given an interesting account of this comet which covers all that is known of it, except perhaps the fact that it was independently discovered on Sept. 22, 1884, by Dr. Ralph Copeland at Dun Echt, *with the spectroscope*, while searching for objects with peculiar spectra. Dr. Copeland's discovery was made before Wolf's announcement reached Dun Echt (see Dun Echt Circular, No. 89). This part of its history is important, as it is the only comet ever discovered with the spectroscope. E. E. BARNARD.

Mt. Hamilton, May 11, 1891.

Orbit and Ephemeris of Comet a 1891 (Barnard, March 29). From Barnard's observations of March 29 and April 3, and my own of April 8, I have computed the following elements and ephemeris:

$$\begin{aligned} T &= 1891,\ \text{April } 27.2156 \text{ G. M. T.}\\ \pi - \Omega &= 175^\circ\ 8'\ 19''\\ \Omega &= 193\ \ 43\ \ 57\\ i &= 120\ \ 32\ \ 41\\ \log q &= 9.61900 \qquad q = 0.41601 \end{aligned}$$

Gr. M. T.	App. R. A.	App. Dec.	Log r	Log Δ	Light.
June 1.5	$4^h\ 7^m\ 36^s$	− 32° 13′	9.9743	0.0137	1.05
2.5	4 14 42	− 33 28			
3.5	4 22 5	− 34 42			
4.5	4 29 42	− 35 53			
5.5	4 37 34	− 37 3	0.0073	0.0110	0.91
6.5	4 45 41	− 38 11			
7.5	4 54 0	− 39 17			
8.5	5 2 33	− 40 20			
9.5	5 11 18	− 41 20	0.0377	0.0143	0.78
10.5	5 20 16	− 42 19			
11.5	5 29 24	− 43 14			
12.5	5 38 44	− 44 5			
13.5	5 48 13	− 44 53	0.0658	0.0238	0.66
14.5	5 57 50	− 45 38			
15.5	6 7 32	− 46 20			
16.5	6 17 19	− 46 58			

Gr. M. T.	App. R. A.	App. Dec.	Log r	Log Δ	Light.
June 17.5	6 27 7	− 47 33	0.0918	0.0386	0.54
18.5	6 37 1	− 48 4			
19.5	6 46 52	− 48 32			
20.5	5 56 37	− 48 57			
21.5	7 6 18	− 49 19	0.1160	0.0579	0.44
22.5	7 15 56	− 49 36			
23.5	7 25 26	− 49 52			
24.5	7 34 49	− 50 5			
25.5	7 44 2	− 50 15	0.1386	0.0805	0.36
26.5	7 53 6	− 50 21			
27.5	8 1 56	− 50 26			
28.5	8 10 34	− 50 29			
29.5	8 18 58	− 50 32	0.1598	0.1053	0.29
June 30.5	8 27 8	− 50 33			
July 31.5	11 6 26	− 45 25	0.2930	0.3085	0.06

An examination of the ephemeris shows that the theoretical light of the comet will be three magnitudes fainter on July 31st than at discovery. This would make the comet about 11.5 magnitude, not allowing for any intrinsic light which may have been developed. O. C. WENDELL.

Harvard College Observatory, May 13, 1891.

Observations of the Transit of Mercury.

Washington Observatory, St. Louis. These observations were made at the Observatory of Washington University, St. Louis, with the 6½ Clark Refractor, using the full aperture. A magnifying power of 140 was employed, and a shade glass was used which gave a dirty white color to the sun's disk. Although the sun had an hour angle of nearly 6 hours when the transit began the images were very steady and sharp.

Phase A, $11^{h}\ 53^{m}\ 14^{s}.6$, Gr. M. T.—Using a micrometer with the wire set to cut off a small segment at the exact point where the planet was expected, this was the instant when the first disturbance at the sun's edge could be detected.

Phase B, $11^{h}\ 55^{m}\ 17^{s}.4$, Gr. M. T.—At this instant the planet's disk was estimated to be exactly bisected by the sun's limb. This phase can be noted with great sharpness and the time given cannot be, I think, more than 4 or 5 seconds in error.

Phase C, $11^{h}\ 57^{m}\ 29^{s}.6$, Gr. M. T.—The planet appeared to be at this moment in geometrical contact with the sun's limb.

Phase D, $11^{h}\ 57^{m}\ 49^{s}.0$, Gr. M. T.—The light first flashed round the disk of the planet. Between observations (C) and (D) there was no distortion of the planet's disk but it seemed to cling to the edge of the sun. This time no doubt corresponds to the moment of true internal contact.

Observations (A) and (C) are, I think, corresponding observations of external and internal contact as affected by the irradiation. Their mean corresponds closely with (B.) H. S. PRICHETT.

May 9, 1891.

U. S. Naval Observatory. I have the honor to acknowledge the receipt of your letter of the 13th inst., respecting the late transit of Mercury, and beg you to accept my thanks for it.

Doubtless you will be interested to know that although the sun here was only about ten minutes high at the beginning of the transit, and the seeing was poor, Professor Frisby succeeded in getting very fair observations of the first and second contacts with the 9.6 in. equatorial. The resulting Greenwich mean times were:

1st contact at 11^h 53^m 49^s
2d contact at 11 57 41

May 18, 1891. F. V. McNair, Captain U. S. N., Supt.

The observations were made at the U. S. Naval Observatory with the 9.6 inch equatorial. The sun's image was very unsteady, but the observation of the first contact was made on the chronograph at the very first instant that anything could be seen, the second contact was the first glimpse of light that could be seen around the planet; this was also recorded on the chronograph. The times of contact are believed to be as good as the very unfavorable conditions would admit of. The magnifying power used was 132. E. Frisby.

Washburn Observatory, Madison, Wis.—Director George C. Comstock reports that "we had almost uninterrupted fair weather with beautiful 'seeing' for a fortnight, but the afternoon of the 5th, about two hours before the predicted time of the first contact for the transit of Mercury with the sun, the sky was completely overcast." No observations received.

Glasgow, Missouri.—Professor C. W. Pritchett writes: "I made very careful preparation to observe the contacts, but clouds entirely baffled me. Had the critical moments been 10^m *earlier*, or 3^m *later* I could have succeeded well. I felt much disappointed."

St. Paul, Minn.—Dr. T. D. Simonton was on the look-out for the transit. He says: "The sun was wholly invisible here at the time of contacts. At near 7 o'clock, P. M., I had a satisfactory view of Mercury crossing the sun's disc. Singularly enough at the right of Mercury was a *conspicuous round sun-spot* that might have been taken for a second (intra-Mercurial?) planet, but of double his diameter. If the atmosphere disturbances at the low altitude of the sun had not prevented my seeing the penumbra of the spot I might not have thought of such a thing."

Warner Observatory Rochester, N. Y.—Dr. Swift writes: "My observations of the transit of Mercury were rendered useless, by atmospheric tremors caused mostly by the sun being just above the roof of a building near by. The planet more nearly resembled a carrot than a disk. Two or three minutes after second contact the sun disappeared behind a large tower of the house mentioned above."

Observatory of the University of Missouri, Columbia.—Director Updegraff says: "The transit of Mercury was partially visible here through clouds. For a week preceding the transit the sky had been almost cloudless, and the limb of the sun was plainly visible in the telescope until ten minutes before first contact. After that time clouds obscured the sun until about two minutes after the first contact. At second contact the clouds had cleared away somewhat so that I was able to observe it; but both the planet and the sun's limb were so ill-defined that the observation is not very accurate:

Second contact took place, 11^h 57^m 58^s G. M. T., with uncertainty of about 7^s. Physical observations were impossible on account of clouds. Instrument used was a 7½-inch equatorial.

Mr. H. C. Williams, a student, observed with a two-inch alt-azimuth telescope making second contact time, 11^h 57^m 48^s G. M. T.

Lyons, N. Y.—Dr. M. A. Veeder, of Lyons, N. Y., made "a satisfactory observation of the transit of Mercury with a 6-inch telescope." "The planet was seen indenting the sun's edge at 6^h 55^m and 19^s or 20^s Eastern time. The first flash of light between the planet and the sun's limb was seen at 6^h 58^m 39^s or 40^s. I think that the time of the second contact was very nearly correct."

Observations of the Transit of Mercury May 9, 1891, made with the 12-inch Equatorial of the Lick Observatory.—The transit of Mercury was successfully observed here on May 9 with the 12-inch equatorial.

The day proved clear throughout, though the preceding few days promised anything but a clear day for the 9th.

The first and second contacts were observed, the planet being sharply caught at the position angle predicted by Mr. Schaeberle:

1st contact 1891, May 9th, 3^h 46^m 32.7^s, Mt. Hamilton, M. T.
2d contact 1891, May 9th, 3^h 51^m 19.9^s, Mt. Hamilton, M. T.

I also made forty-six filar micrometer measures for the polar and equatorial diameters of Mercury, and eleven measures of the position of the planet on the sun's disk.

No trace of Mercury could be seen before first contact though it was carefully looked for, nor was that portion off the sun visible between first and second contacts. No bright spot was seen on the planet, nor any atmospheric ring—such as was seen about Venus at the transit of December 6, 1882. A careful examination of the sun's disk showed nothing that could be taken for a satellite.

Some excellent photographs of the transit were made by Mr. Burnham with the twelve inch between the micrometer measures.

As a matter of popular interest I would say that a preliminary reduction of the measures for the planet's diameter give 2960 miles for that value, which must be taken as altogether provisional, until the measures are thoroughly reduced. The measures do not indicate any polar compression.

E. E. BARNARD.

Mt. Hamilton, May 11, 1891.

NOTE. The times of contact expressed in Standard Pacific Time (8^h slow of Greenwich) would be

1st contact, 3^h 53^m 7.0^s.
2d contact, 3^h 57^m 54.2^s.

The first contact occurred 1^m 11.5^s earlier than the prediction of Professor Schaebrle, which was based on the data of the American Ephemeris and Nautical Almanac; and 1^m 11^s earlier than the prediction of Professor Coakley. E. B. B.

Central High School, Philadelphia, Pa.—Under date of May 4, Professor M. B. Snyder, of the Central High School, Philadelphia, sent us the following important statement in regard to observing the transit of Mercury. We are sorry that it was not on hand earlier for the use of observers who read the MESSENGER. He says: "Calling your attention to an account of peculiar observations made on Mercury in Transit of May, '78 (see Washington Observatory, 1876, Part 2, Report of Transit of Mercury, page 100 and 101), I would ask you to see whether Mercury can not be seen as a complete disc when midway on the solar limb, using rested eyes and quick glance into the telescope. In '78 I at that phase caught a glimpse of the entire disc and very delicately illumined. Since this phenomenon has seemed to me evidence of an atmosphere of Mercury, and so far as I know the only telescopic evidence revealed by transits, I am anxious to have a careful trial made to see it again. It being possible that the phenomenon mentioned can be seen only at a certain phase of the transit it seems desirable to make repeated trials in the manner mentioned at about midway between first and second contacts.

First contact can be caught *most certainly* by the *contrast method* used by me successfully both on Mercury and Venus. Sweep telescope at the point and signal chronographically the *first peculiar change in the light tone* along the limb. Then watch and verify the appulse."

Annular Eclipse of the Sun June 6, 1891.—In our last number we gave notice of this eclipse, with chart of the path of the moon's shadow across the earth, and cut showing maximum obscuration at Northfield. For the sake of readers who may not have seen that number we repeat the substance of that note.

The central line of eclipse crosses the Arctic Ocean, touching land only in the north of Siberia. In the United States, the eclipse will be partial in the western states. At Chicago, it will last only 25 minutes, beginning at 9^h 12^m and ending at 9^h 37^m central time. At Carleton College Observatory it will begin at 8^h 45^m and end at 10^h 08^m, the moon covering only about one-eighth of the sun's diameter at the middle of eclipse. The moon will first touch the sun's limb about 55° west from the north point and leave it at 10° east from the north point. In the western part of the United States, and especially in Alaska, the obscuration will be much greater and last longer.

Brilliant Meteor. On May 3, at 9:45 P. M., Eastern standard time, a meteor appeared (as viewed from Charlottesville, Va.) near π Draconis, passed a little to the south of β Cephei, and vanished near γ Cassiopeiae, occupying about 3 seconds of time in its flight. It was many times as bright as Venus at her maximum brilliancy, and presented the appearance of a ball from a large "Roman candle" at a distance of some 200 yds. Its light was pure white when it vanished, but during its flight there was a striking iridescence. This iridescence I cannot describe accurately, as the meteor was seen through the foliage of trees. The same cause prevented a a more accurate observation of its path. It passed behind some streaks of thin cloud, and I think the iridescence was greatest when it was shining through these. M. W. H.

University of Virginia, May 4, 1891.

A Bright Meteor. I give herewith an account of a meteor seen by myself on Sunday, May 3, at 6:13 P. M., local time; it was bright sunlight at the time. The meteor started from a point about 20° above the south-eastern horizon, pursued a northerly course, traversing an arc of about 70°, disappearing at a point about 50° above the horizon at north-east. The color was an intense white, the apparent diameter of the disc was about 10′ and there was a distinct train some six degrees in length. I could detect no report but at the point of disappearance the sky assumed a copper color for some seconds.

It was rather difficult to estimate the diameter of the meteor as it had something of the appearance of an arc light seen through ground glass. I have given what appeared to be the diameter of the nucleus.

Detroit, Mich. H. S. HULBERT.

NEWS AND NOTES.

The unusual demands on those in charge of the Observatory and THE MESSENGER during the month of May, have delayed the issue, of this number for a few days. The chief cause was the attention demanded in setting the new 16-inch telescope recently completed and now in place.

Appropriate reception exercises for the new Williams telescope, and ceremonies for naming the new Observatory building will take place June 11, 1891. This will be one of the important features of the Annual Commencement occasion at Carleton College for this year. The principal address in connection with these exercises will be delivered by Professor Charles S. Hastings, Department of Physics, Yale University. His theme will be "The History of the Telescope." A large number of invitations have been given to scientific gentlemen in the state and outside of it. The occasion promises to be one of large interest.

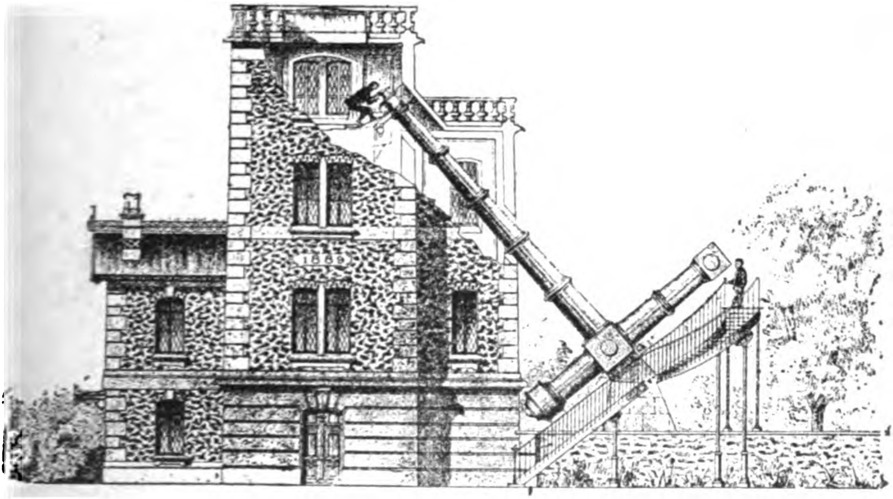
Mr. W. R. Warner, Warner & Swasey, Cleveland, Ohio, will be present in Northfield, during the Commencement occasion, and formally turn over the new telescope mounting to the College authorities on the part of the makers. Mr. J. A. Brashear, of Allegheny City, will also be present at the same time bringing with him the 16-inch objective and other optical parts belonging to the telescope which he is under contract to furnish. The mounting has several new features which will be described soon that our readers may know definitely of them. So far as known from preliminary tests the objective has come out handsomely. A full report of it will also appear in due time. The rapidity with which this 16.2-inch objective has been completed is simply marvelous. The methods used in constructing this telescope and two others recently, one for E. E. Hale, of Chicago, and the other for Professor Upton, of Brown University, Providence, R. I., seem to us to promise a speedy revolution in the art and science of telescope-making.

Last month, we made a trip to Cleveland and to Pittsburgh to examine the new telescope and to give orders for details and accessories. While in Cleveland we were delightfully entertained at the home of Mr. and Mrs. W. R. Warner, who know how so well to make even informal ways contribute to a continual round of pleasure in their gifted hospitality. It was here we met Dr. Thwing, President of the University, Professor Morley and other friends including Mr. Brashear, of Pittsburgh, and Mr. and Mrs. Swasey. While in Allegheny City, to view the progress of our optical work, we found a hearty and generous welcome at the home of Mr. and Mrs. Brashear, and the day, at his shop, witnessing the tests for centering our large crown lens, and other work upon it, as well as some tests on an imperfect lens to determine causes of trouble, furnished rare opportunity for knowledge of the practical side of the optician's art. Such lessons are invaluable, no one can forget them.

Astronomical Societies. We have noticed with interest, that there is desire in the minds of those looking for means of improvement in scientific studies and general information, to form associations for this purpose. This is to be commended, and such a movement will certainly result in large profit to those who will wisely use means at hand, or that which is within easy reach. The study of elementary astronomy is no exception. It is difficult, as many an earnest student has found, to go rapidly and wisely forward, in this, or any other study, depending wholly on self-instruction. The mind should be exercised largely, liberally and sharply, in testing and using the thoughts of others on the same topics. In view of this well-known principle, we always like to give an encouraging word to those who desire to form associations for mutual aid in this respect. For amateur study, there should be at least three or four live, current publications within reach, so that students may know the drift of practical work and investigation by those who have experience. Suitable publications for this purpose are: "Publications of the Astronomical Society of the Pacific," Secretary Burckhalter, San Francisco, California; "The Journal of the British Astronomical Association," E. W. Maunder, Editor, London, England; "The Observatory," edited by H. H. Turner and A. A. Common, Royal Observatory, Greenwich, England. For knowledge and study of the professional side of the science, "The Astronomical Journal," by Dr. B. A. Gould, Cambridge, Mass., and the "Astronomische Nachrichten," by Dr. A. Krueger, Kiel, Germany, are periodicals of great value.

Another indispensible aid to the study of elementary astronomy is a telescope, large or small, according to the means of the individual or the association. The all-important question that meets the student at this point is, How can the best instrument be procured with the least outlay of money? Upon this point more will be said under another head or later.

The New Elbow Equatorial at the Observatory of Paris.—Several years ago M. Loewy devised an equatorial telescope of the "elbow" form, which would permit the observer to sit in a comfortable room, without changing position with the diurnal motion of the star in view. Such an instrument was constructed at the Observatory of Paris and has proved so satisfactory in use, that a new instrument on the same plan, considerably larger than the first, has been made and was this spring installed in its new building at Paris. The illustration which we give is reproduced from "L'Astronomie," May, 1891. The telescope is provided with both visual and photographic objectives of 0.60^{m} (23.6 in.) aperture, and 18 metres (59 feet) focus. The polar axis is 18 metres long, the tube of the telescope itself forming this axis. The elbow which turns about the lower end of this axis is 4 meters long. This carries the two large plane mirrors which reflect the light of stars into the object glass. The eye-piece is at the upper end of the tube in a closed room of the tower at a height of 49 feet. An ingenious mechanism enables the telescope and mirrors to so move that the observor, without changing his position and without the discomfort of external temperature, may follow any star in its diurnal motion in any part of the visible heavens.



The new instrument, including the building in which it is placed, cost about 400,000 francs.

The image of the moon at the focus of the telescope will be 0.18^{m} (7.08 inches), and this will be magnified directly by the instrument so that photographs of the moon over three feet in diameter may be taken.

The Perseid Radiant. I am still unable to see any grounds for the personal quarrel which Mr. Denning seeks to fasten on me. I accept all his published observations just as Mr. Gore accepts all those of Mr. Burnham. I merely contend that these observations do not prove any shifting of the Perseid radiant, and on this point I think any reader of the SIDEREAL MESSENGER who will examine his catalogue (striking out the word "Perseids" in his description, which in my opinion is often misapplied) will agree with me that the evidence at present available is insufficient to establish the shifting to any high degree of probability—except, perhaps for a very few days before and after August 10. This contention is based not on the rejection but on the acceptance of Mr. Denning's observations. I may illustrate it thus, Mr. Burnham contends that the observations on 61 Cygni prove nothing but rectilinear motion. I think it would be quite competent for me to contend that they establish curvilinear motion, notwithstanding that I have never measured this star myself and that my inferences might be chiefly drawn from Mr. Burnham's observations. And I am quite sure that if I did so, Mr. Burnham would reply to me in a very different tone from that adopted by Mr. Denning.

I hope the coming shower will be observed carefully in America, and I should be glad to hear the opinion of American observers—Mr. Sawyer in particular, as to the supposed shifting of the radiant.

Dublin, May 14, 1891. W. H. S. MONCK.

The Paris Observatory. The Annual Report of the Director of the Observatory of Paris for the year 1890 has recently come to hand. It gives a very full statement of the work which is being done by the different observers, and impresses one with the magnitude and variety of work which is being carried on. The principal events of 1890 to which the Director calls the attention of the Council, are the completion of the building for the new equatorial coudé of 23.6 inches aperture and the creation of a department of astronomical spectroscopy. The work in this department is put under the charge of M. Deslandres, who has already got together quite a laboratory and is adapting two instruments, the great equatorial and the Foucault siderostat, to the special work.

A considerable portion of the report is given up to a plea for the establishment of a branch Observatory outside of the city. For several years the Observatory has been becoming more and more hemmed in by the spreading city and now a railroad is run within 500 feet of the building which will render nadir observations and others, requiring perfectly stable foundation for instruments, almost impossible. The subject of the branch Observatory has been under consideration for several years and has been voted by the Council of the Observatory, and by the Academy of Sciences, but the government has not been willing to grant the necessary funds. To meet the expense of buildings the Director, Admiral Mouchez, has proposed to sell part of the vacant grounds of the Observatory which now have greatly enhanced in market value but are of no value for astronomical purposes. This has been agreed to by the Council but the Academy refuses to sanction it, and so the project has been deferred. It is to be hoped that soon some way out of the difficulty will be found, for it is a pity to have the splendid equipment of the Paris Observatory employed at a disadvantage when there are plenty of good locations near the city.

Four great national Observatories have recently found themselves in similar situations. The Observatory of Brussels has just been installed in its new quarters at Uccle. those of Rio Janeiro, Copenhagen, and Washington are now in process of removal to new sites removed from the disturbances of the great cities.

Smithsonian Astro-Physical Observatory. Attention is called to an article elsewhere in this issue, setting forth the important fact that the Smithsonian Institution has established, as one of its departments a Physical Observatory, the object of which is to prosecute advantageously investigations in Telluric and Astro-Physics and particularly those with the Bolometer in radiant energy.

This news is gratifying in the extreme, because there is so little scientific work of this kind done anywhere in this country, and because presumably, Professor Langley will have the responsible direction of that which is now proposed at Washington, and which he is so well fitted to advance, if the needful appliances are forthcoming. It is to be hoped that the undertaking will receive hearty encouragement from every source.

New Director of Allegheny Observatory. Astronomer J. E. Keeler, of Lick Observatory, has been chosen Director of the Allegheny Observatory, to succeed Professor Langley who has recently tendered his resignation. Mr. Keeler has also been appointed Professor of Astro-Physics in the Western University of Pennsylvania located in Allegheny City, and he will assume the duties of the new position about July 1 of this year. The new buildings of the University are located very near the grounds of the Observatory and the shops of Mr. J. A. Brashear.

The Observatory at Nice.—The third volume of the Annals of the Observatory of Nice, issued in 1890, has recently been received. This is a fine quarto volume of 406 pages with also an atlas containing seventeen large steel plate engravings of the solar spectrum. The volume contains the results of observations of the solar spectrum by M. Thollon, from which the atlas was constructed, a memoir on the Theory of Vesta by M. Perrotin, meridian circle observations by MM. Fabry, Jabely, Simonin and Colomas, during the years 1887 and 1888, and observations of comets and planetoids by M. Charlois from 1886 to 1888. All of these works are of a most accurate and valuable character, but that which attracts most attention is the work of M. Thollon on the solar spectrum. The chart of the spectrum is the most accurate and, so far as it extends, most complete of any in existence which depends upon micrometric measures. The measures were made with a very powerful spectroscope designed by M. Thollon, with a train of compound prisms of bisulphide of carbon and crown glass. The chart was only completed from the extreme red region to the group (*b*) in the green. In this nearly half of the visible spectrum M. Thollon has designated 1100 purely *telluric* lines and 277 in which telluric lines appear to be superposed upon solar lines. It was his intention to extend the chart to the ultra-violet but illness, which resulted in his death in 1887 prevented. M. Trépied is continuing the work.

Photographic Notes.—The *Observatory* for May contains much of interest on the recent meeting in Paris of the Astrophotographic Chart Committee; below are given brief quotations from these reports of the meeting. The first resolution was that the guiding stars might be chosen at a distance up to 40′ from the centre of the field. Another point was that the plates were to be oriented for the epoch 1900 in the zones from 65° of the pole. It was arranged that the first series of plates for the chart (centres at even degrees of declination) were to be taken with a single exposure; further researches were to decide whether the committee would recommend two or three exposures instead of one for the duplicate series. Another point of importance was the selection of the reference stars in each plate, and arrangements for determining their positions; it was agreed that on each plate there should be about 6 stars the positions of which were to be well determined by meridian observations; thus it would be necessary to form a catalogue of 60,000 to 70,000 stars from meridian observations to be made within the next few years. There seemed to be a general feeling that it would be unworthy of the map if it were produced (from the negatives, by anything except photography, and that the most delicate tool—light—should replace the pantograph.

The method proposed by Captain Abney for determining stellar magnitudes photographically is worthy of careful attention. He measures the total obstruction to light offered by the image when it is placed as a screen in front of an aperture. It can in this way be compared with a scale of screens or with a graduated screen and the total action measured; the relation between the total action and the brightness of the source has been specially and successfully investigated by Captain Abney.

Mr. Roberts speaks strongly of the uncertainties which are met in determining lengths of exposure in stellar photography. He mentions extraordinary differences in results on different nights, having found in one case that an hour's exposure on a seemingly good night photographed less stars than a fifteen minute exposure on an apparently bad night.

In regard to preliminary exposures Captain Abney recently said: "I think it would be very much better to get a more sensitive plate which does not require a preliminary exposure. As a rule I believe that every quick plate that is sold has had a preliminary exposure, or what is equivalent, a preliminary decomposition of silver salts, that is to say that the manufacturer has fogged it unwittingly. A plate 15 on the sensitometer may be made to show 23 by a preliminary exposure. When you come to estimate star magnitudes you must recollect you are altering entirely the ratio of your densities and discs when you give this preliminary exposure. * * * If you want to get out a great many stars and do not care about their magnitudes particularly it would be very advisible to give a preliminary exposure, but if you wish to measure magnitudes do not do it. It is better to have a standard, and the only standard is a plate that is perfectly bright."

It is stated that the first photograph of lightning was taken by Mr. Hestler, of Chicago, in 1856, when he obtained a daguerreotype of a flash of lightning which was of excellent quality.

Boston University Observatory for Instruction.—Boston University has recently added to its facilities for instruction, by the erection of a small Astronomical Observatory. The telescope has an object glass of seven inches clear aperture, with a focal length of eight feet and one inch.

The lenses were ground by John Clacey, of Boston, and are finely corrected. The equatorial mounting, driving clock and filar micrometer were made by G. W. Saegmuller, of Washington. A Bond sidereal chronometer furnishes the time; it is being rated by comparison with a sounder placed in the Observatory, and, through the courtesy of Director E. C. Pickering, connected with the Cambridge time service.

The dome was erected by N. M. Lowe, of Boston. It is twelve feet in diameter, formed of oak ribs covered with copper, and revolves with greatest ease upon wheels in a "live ring." The shutter, two and one-half feet wide, is believed to be, in some respects, unique in its mechanical arrangement. It moves to one side by means of a crank and endless chain with rack and pinion. This movement leaves practically the entire slit free, and in every position the shutter fits closely to the dome, thus offering no objectionable surface to the wind.

The provisional position of the telescope is $\varphi = 42^\circ\ 21'\ 32.5''$, $\lambda = 4^h 44^m 15^s$. The instrument is designed primarily for purposes of instruction, though such work will be undertaken as the location of the instrument and the duties of the lecture room will permit.

Defects of Sensitive Levels.—Professor Safford's interesting article upon meridian observations, contained in the last number of the MESSENGER calls attention to a defect in the spirit levels which is too rarely taken into account by observers in this country: "In some cases impurities in the ether dissolve particles of the glass, loosen other particles, and they make the bubble sluggish by adhesion." It is interesting to note that this peculiarity of levels has been made the subject of special study by one of the scientific bureaux of the German government and the results attained are briefly summarized in a communication recently submitted to the Reichstag.* The following is a rather free translation of that part of the report which has reference to this matter:

In the course of time secretions are formed upon the inner surface of the glass and render the level unfit for use. It has been ascertained by experiment that these are due to the action of the water, traces of which are usually found in the ether with which the levels are filled. Since it is exceedingly difficult to fill a level with ether which is entirely free from water a kind of glass which is but little affected by the action of water should be chosen in the construction of the level. A method for testing this quality of the glass by means of a color re-action has been devised and may easily be applied even by an unskilled person. Let a glass tube be filled with a solution of water and ether containing also a little eosin. After the solution has stood for some time in the tube the glass will assume a ruddy tint and the greater the action of the water upon the glass the more pronounced will

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* Die Thatigkeit der Physikalisch—Technischen Reichsanstalt bis Ende 1890. Loewenherz.

this tint become. By the decomposition of the glass a certain quantity of alkali is liberated and is transformed by the eosin into a colored salt.

The conclusion of the whole matter reached by the author of the report is, that: A level tube before it is filled should always be subjected to a special treatment consisting in removing from the ground glass surface their alkaline components by means of an acid. GEO. C. COMSTOCK.

Double Star S 503.—Amateur observers can hardly find a more interesting and striking example of proper motion than S 503, a double star first observed by South in 1825. It is an easy object, the stars being about the seventh and eighth magnitudes. For the past few years the brighter star has been passing by the fainter at a rapid rate. Their nearest approach occurred in 1886. After South's measurement in 1825, it was not observed again until 1873 when Dembowski measured it and found the position so unlike that of South that he at first supposed it to be a new double. Since that time it has been followed by the leading double star observers. Its rapid motion has led me to look up the earlier measurements, and these I will give below, as the sources may not be available to all your readers. I find most of them in Mr. Burnham's Contribution to the Memoirs of the Royal Astronomical Society, 1883, and the more recent in the Astronomische Nachrichten. I subjoin my own values for '90 and '91. S 503, $5^{h}\ 49^{m} + 13^{\circ}\ 56'$.

1825 07	134.1°	39.94″	S.
1873.93	120.1	8.08	De.
75.21	118.6	7.07	De.
75.88	117.5	6.72	De.
81.18	99.3	3.58	B.
82.16	92.4	3.28	B.
83.11	82.6	2.90	B.
86.19	40.0	2.27	Ho.
87.04	30.4	2.83	Tarrant.
88.17	19.7	3.29	Tarrant.
89.11	8.6	3.36	B.
90.14	0.8	4.41	
91.21	353.2	4.60	

M. W. WHITNEY.

The Perseid Radiant. The approach of the season for observing the Perseid meteors leads me to express a hope (through the medium of your columns) that these meteors will be closely observed in America during the present year. The chief points to which observation should be directed (at least as regards the rival theories of Mr. Denning and myself) are as follow:

1. Do meteors come from the principal radiant situated at about 44° R. A. 56 N. Decl. before and after the first fortnight in August?

2. Mr. Denning's first five positions of his shifting radiant being 3° R. A., 49° N. Decl. on July 8; 11° R. A., 48° N. Decl. on July 13; 19° R. A., 51° N. Decl. on July 19; 25° R. A., 52° N. Decl. on July 22 and 23 and 29° R. A., 54° N. Decl. on July 27; two questions arise: (*a*) Do meteors come from these five points at other dates than those given above? And (*b*) do meteors come from intermediate positions at intermediate dates?

Dublin, May 9. W. H. S. MONCK.

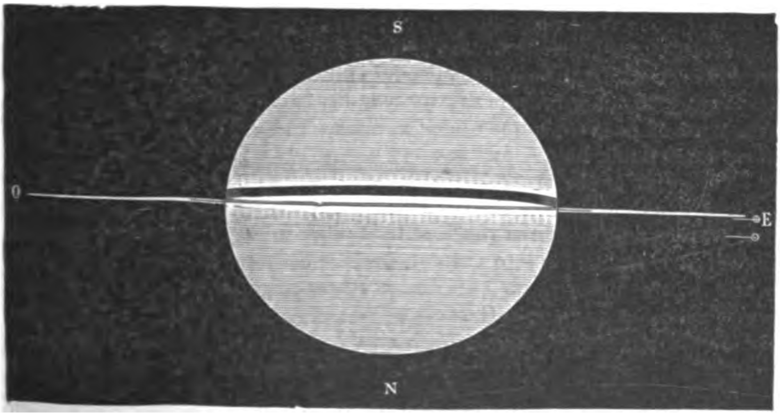
Brooklyn Institute.—At the annual meeting of the Astronomical Department of the Brooklyn Institute on May 11 officers were elected as follows: President, Garrett P. Serviss; Vice President, Arthur C. Terry; Secretary, W. F. Sebert; Treasurer and Librarian, B. G. Way.

The annual reports showed the department to be in a flourishing condition. Besides its regular meetings it has given during the past year a series of popular lectures which have been very largely attended. During the coming year an effort is to be made to extend the activity and usefulness of the department both in its scientific work and in its relations to the public at large.

Catalogue of the Crawford Library of the Royal Observatory, Edinburgh, Scotland.—This is a royal octavo volume of 497 pages. It contains the titles of the various books, pamphlets and manuscripts collected in the Library of the Dunecht Observatory it the years 1872 to 1888, the whole of which were presented to the Edinburgh Royal Observatory by James Ludovic, Earl of Crawford, in the Autumn of 1888.

The Catalogue is an alphabetical one, arranged chiefly according to the authors' names which appear in clear heavy-faced type; then follow the title of the book, and sub-titles when necessary to give a more definite idea of the book, or to distinguish it from other editions by the same author, the tomes, parts or volumes; the size, place of publication and other important characteristics that a complete catalogue might be expected to show. For more ready reference for some works, subject-headings have been introduced. In such cases if the author's name is given the book is catalogued twice. These subject-headings may be illustrated by the following examples: "Academies," "Astronomical Curiosities," "Aurora Borealis," "Bibliography," "Calendars," "Comets" and "Dictionaries." This catalogue was completed and has been distributed by Ralph Copeland the director of the Royal Observatory at Edinburgh, and is certainly a very useful one for students of astronomy and kindred sciences.

Erratum. We are very sorry to notice too late for correction that Fig. 7, page 172, was repeated in the place of Fig. 9 which is given below and is meant in explanation on page 179.



BOOK NOTICES.

THE PACIFIC STATES; THE WORKS OF HUBERT HOWE BANCROFT. In thirty-nine volumes, San Francisco: The History Company.

The annals of literature cannot furnish a parallel to the remarkable achievement of Mr. Hubert Howe Bancroft. We have here an imposing series of massive volumes, aggregating some thirty thousand pages, all published within nine years; and this enormous product is not, like poetry or fiction, evolved from the mind of the writer, but it is the product of the most laborious research through a vast mass of raw material, conducted with the most painstaking care. The whole Pacific slope has been carefully treated, from the five volumes on the Native Races down to the year 1890.

It is not strange that many devotees of literature have felt and expressed a mild contempt for a work planned on so vast a scale and so rapidly executed. The man who puts ten years of conscientious labor on a volume or two, can hardly look with complacency upon another who can put forth forty volumes in the same time, and feels that quality must have been sacrificed to quantity. In a certain sense this has been done. As Mr. Bancroft tells us in the volume on "Literary Industries," the material has been worked up, and in large part the narratives written, by a corps of assistants, and his own work has been that of editor, though he has himself worked out some more critical portions of the history. In no other way could the prodigious work have been accomplished. It is not for its literary qualities that the work is valuable. It is hardly likely that the enthusiastic hope of the author will be realized, that the work will be a household treasure in the homes of the western slope, and the boys and girls will devour these volumes as they now do their magazines. It is as a storehouse of material and an index of original sources that it is of greatest value; as such it is invaluable.

By no means do we deny to these volumes an interest to the general reader. If they will not take a place beside the works of Gibbon and Macaulay in general literature there are passages and even whole volumes full of fascination. But the very size of the work is against its general acceptance. The reader of to-day is too lazy, and he finds too much of literary sweet-meats carefully broken to his taste, to make it at all likely that he will even attempt to work his way through such a mass as this. But to the serious-minded reader of American history, and to the special student this work is of great value and interest, and it certainly ought to be in every large public library and in every college library.

The story of the growth of this great enterprise as told by Mr. Bancroft is one to stimulate the reader through the writer's own enthusiasm. The transformation of the youthful bookseller among the rough surroundings of early California into the enthusiastic collector in every part of the world where material on the Pacific states might exist, and his further transformation into the author-editor of the greatest literary enterprise of the day is certainly unique. The great collection of historical material made in preparation for the writing of these histories, is an honor to the man, and to the region that contains it. It was indeed a noble enthusiasm that took so capable a business man from his great business, and drove him to spend years of time and hundreds of thousands of dollars, to preserve and set forth the history of his adopted state, and the resulting work is of great value not only to the region treated of, but to the whole world.

While the literary execution of the history is not marked by great rhetorical excellence, it is not slovenly nor inadequate. The temper of mind is judicial, and the facts are set forth, so far as we can judge, without fear or favor. It is a history of the people and preserves for all time the picture of an unique period in the world's history, in such detail as to make it vivid and lasting.

We hope to follow this general article with others on some of the separate parts of Mr. Bancroft's work.

Telescopic Work for Starlight Evenings, by William F. Denning, F. R. A. S., Messrs. Taylor & Francis, Red Lion Court, Fleet Street, London, England. 1891, pp. 361.

This important book was written by Mr. Denning, at the suggestion of friends who became interested in the articles which he prepared on "Telescopes and Telescopic Work" for the *Journal* of the Liverpool Astronomical Society, in 1887-8; on "Large and Small Telescopes," "Planetary Observations," and kindred topics that he has furnished from time to time to the *Observatory* and other scientific serials. These articles have been rewritten and so much extended to include new matter that they are virtually new, and the book itself has the force of an entirely new production. A glance at its table of contents will interest any reader of astronomy who knows anything of the author's ability as a practical astronomer and a ready writer on general astronomical themes. The first chapter deals with the Telescope, its invention and the developement of its powers. The early history of attempts at telescope making, and a reference to the state of scientific knowledge in the seventeenth century is a fitting introduction, for a brief and concise statement of the elemental principles of the telescope, which began to be known in the study of the optical powers of glass and some other transparent substances. The different forms of the reflecting telescope are illustrated and commented upon, accompanied by good pictures of Sir Isaac Newton and the Royal Observatory at Greenwich in Flamsteed's time. This chapter closes with a statement concerning the efficiency of the refracting telescope as an instrument for astronomical work which the author is inclined to rate a little higher than American Astronomers generally do, and, we suppose, rightly, because from long use he knows exactly what that kind of telescope can do. He also speaks of the large telescopes of the world, giving items of cost, kind of work they are doing, and something of the men who handle them. We notice one slip of the pen on page 18, where it is said that the noble instrument of the Lick Observatory at Mt. Hamilton, California, "is due to the munificence of one individual, the late James Lick, of Chicago," etc. Mr. Lick was a resident of California and not of Chicago.

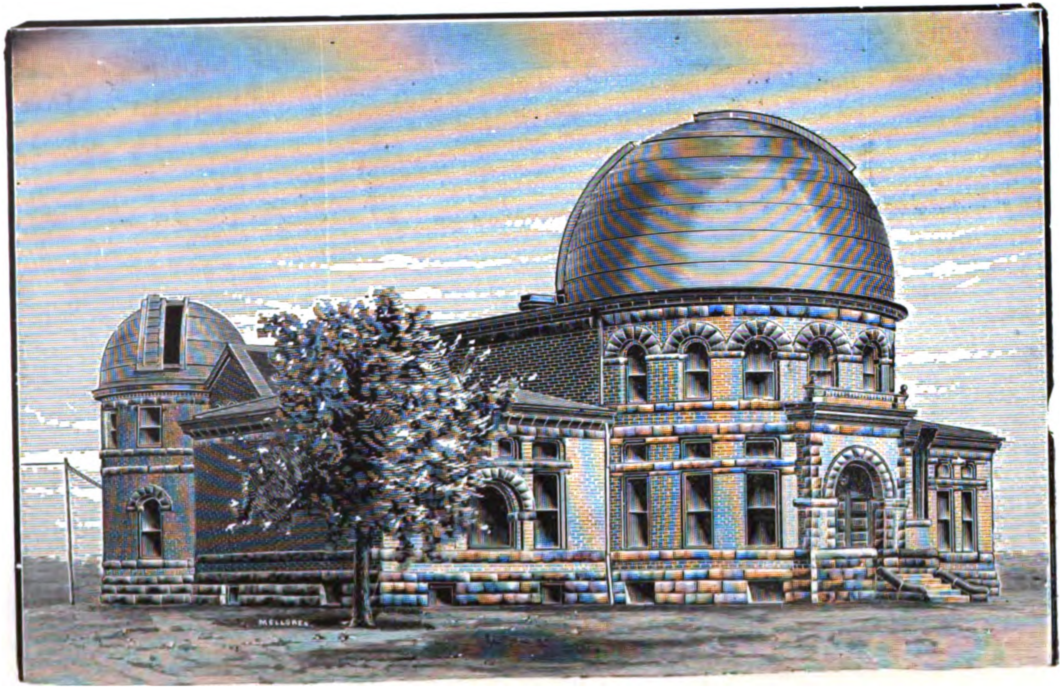
The second chapter is devoted to the relative merits of large and small telescopes, and it is a timely article on a theme that interests astronomers in all branches of work. The third deals more directly with telescopes and their accessories, and brings us a little nearer to the author's work as a painstaking observer. In this chapter he speaks of the choice of a telescope in the outset, compares refractors and reflectors, noting points of strength in each quite fairly, sets before the reader what the observer's aims should be, tells him how to test a telescope and its mounting, speaks of eye-pieces and how to use their varied powers after learning how to measure them, and a large number of other details about the working of a telescope that every obsevrer ought to know. Then follow chapters upon these themes: Notes on Telescopic Work; Sun; Moon; Mercury; Venus; Mars; Planetoids: Jupiter; Saturn; Uranus and Neptune; Meteors and Meteoric Observations; The Stars, Nebulæ, and Clusters of Stars; and Notes and Additions and Index.

This book is fully illustrated, well printed on strong white paper, and is a credit to the well-known publishing House of Messrs. Taylor & Francis.

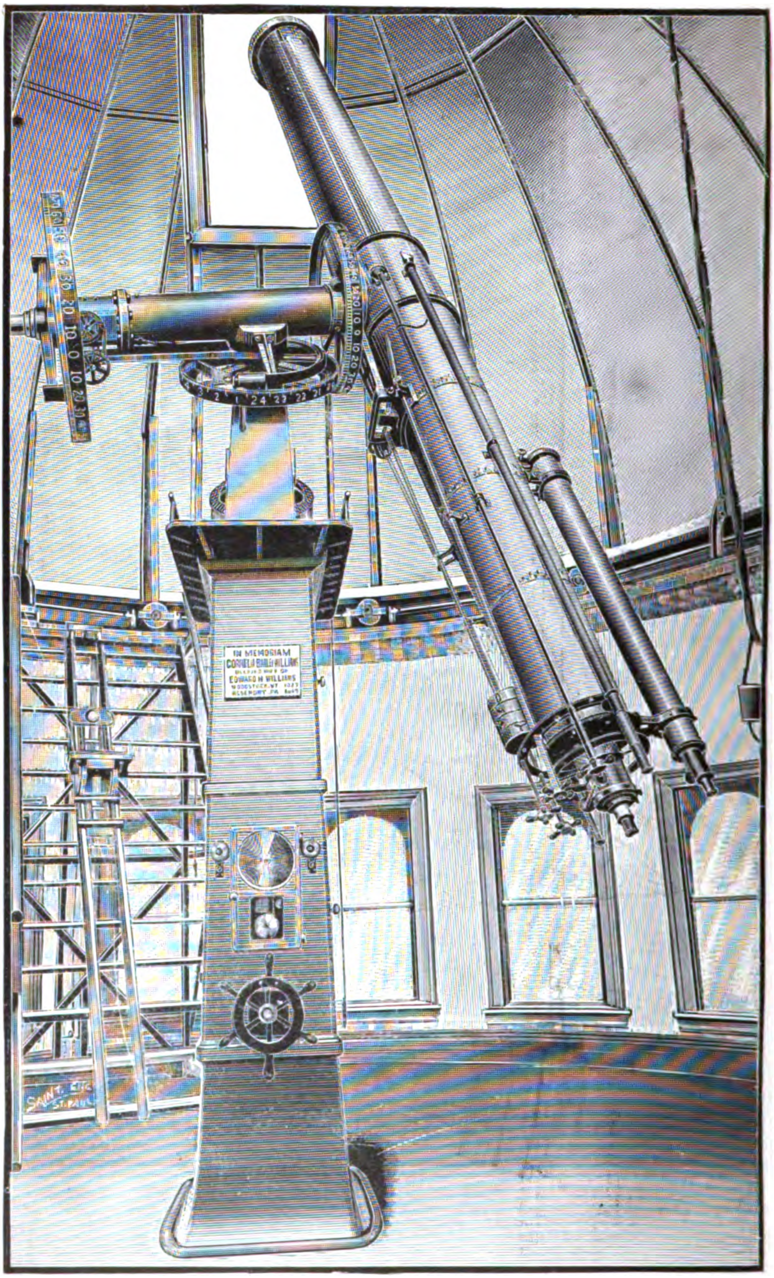
Optical Projection. A Treatise on the Lantern, in Exhibition and Scientific Demonstration. By Lewis Wright, Author Light; A Course of Experimental Optics, with 232 Illustrations. Publishers, Messrs. Longmans, Green & Co., London, and New York, 15 East Sixteenth street. 1891. All rights reserved. pp. 426. Price not given.

The author's account of the occasion of preparing the work before us is itself a sketch of work with commendable scientific zeal and persistence. After nearly forty years of experimental study, the results are gathered up and presented in a compact, readable way, with ample illustration which serves excellently to define the meaning of simple language in a book of this kind.

The author first considers the art of projection in the simplest way, and this necessarily involves a description of the principal parts of a lantern, the most important one of which is the radiant. The things needful for an effective radiant are stated, and then the best lights are compared, and the strong points of each emphasized. This study includes lanterns and their manipulation, screens and lantern accessories, slides, carriers and effects. Another prominent feature of the book is to show how to use the lantern for scientific demonstration. This includes a description of the projection microscope, demonstrations of apparatus in mechanical and molecular physics, and physiological demonstration by the aid of the microscope. Then, naturally follow themes for illustration from chemistry, sound, light, and its properties, the spectrum, interference of light, lantern polarizing apparatus, polarized light, heat, magnetism and electricity, and scientific diagrams of all kinds. From this broad range of topic, it will at once be seen, that almost every thing connected with the work of projection, that a student or operator wants to know, is touched upon, if not considered in a complete and exhaustive way. This is not a book of theories only, but it is intended to be a practical guide for those who wish to gain exact knowledge about projections, and instruments for such work, in such way as to be able to use their knowledge if occasion presents itself. We have found the perusal of this book very valuable. It has decided some important questions about means to an end which will save money, and therefore we commend its perusal to those interested in any line of work requiring lantern illustrations. American purchasers can procure this book from the publishers in New York.



GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.



THE WILLIAMS TELESCOPE OF GOODSELL OBSERVATORY.

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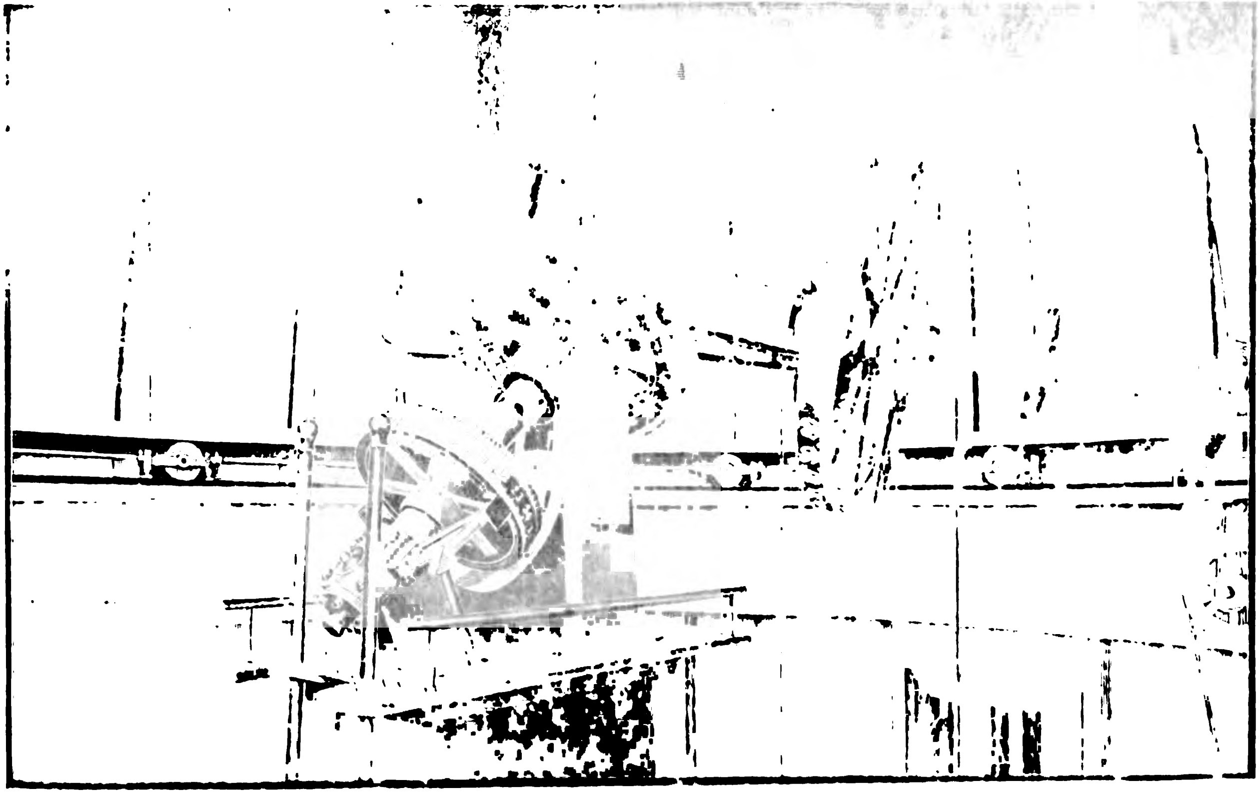

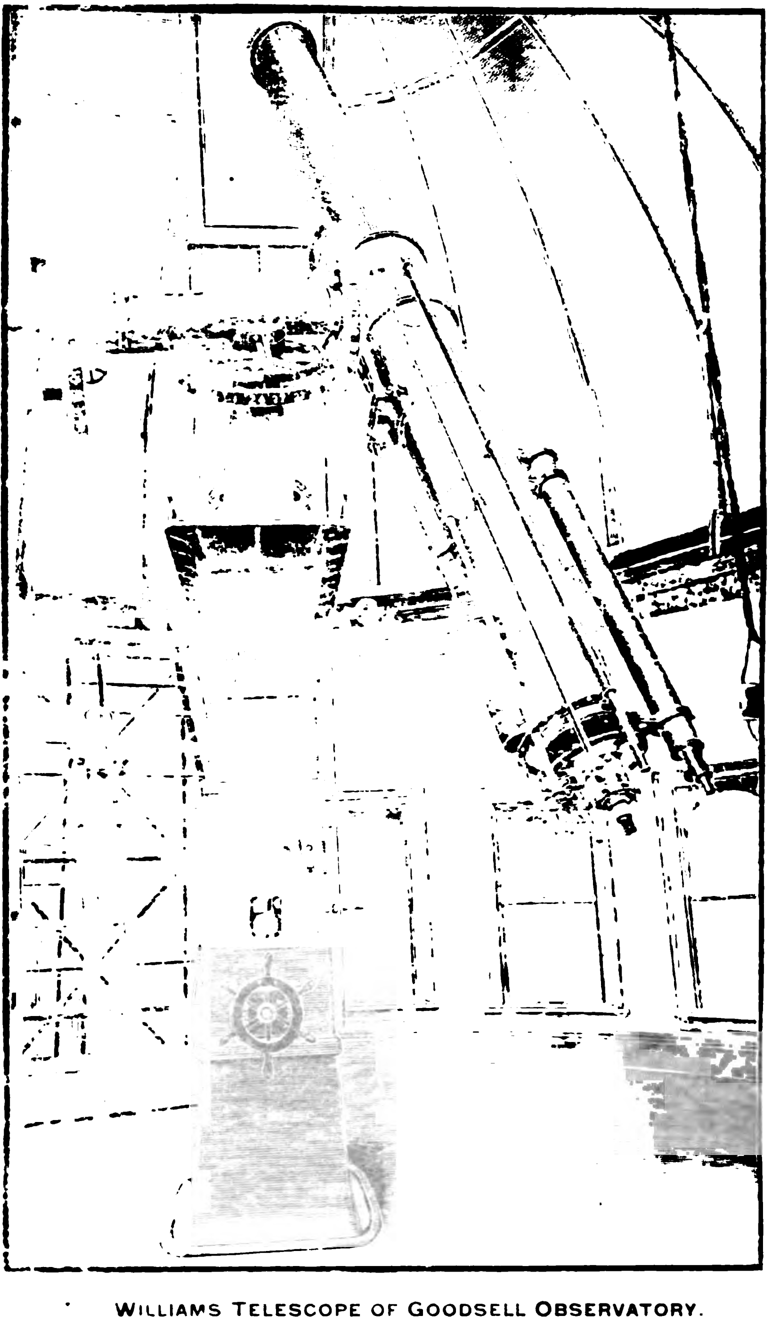

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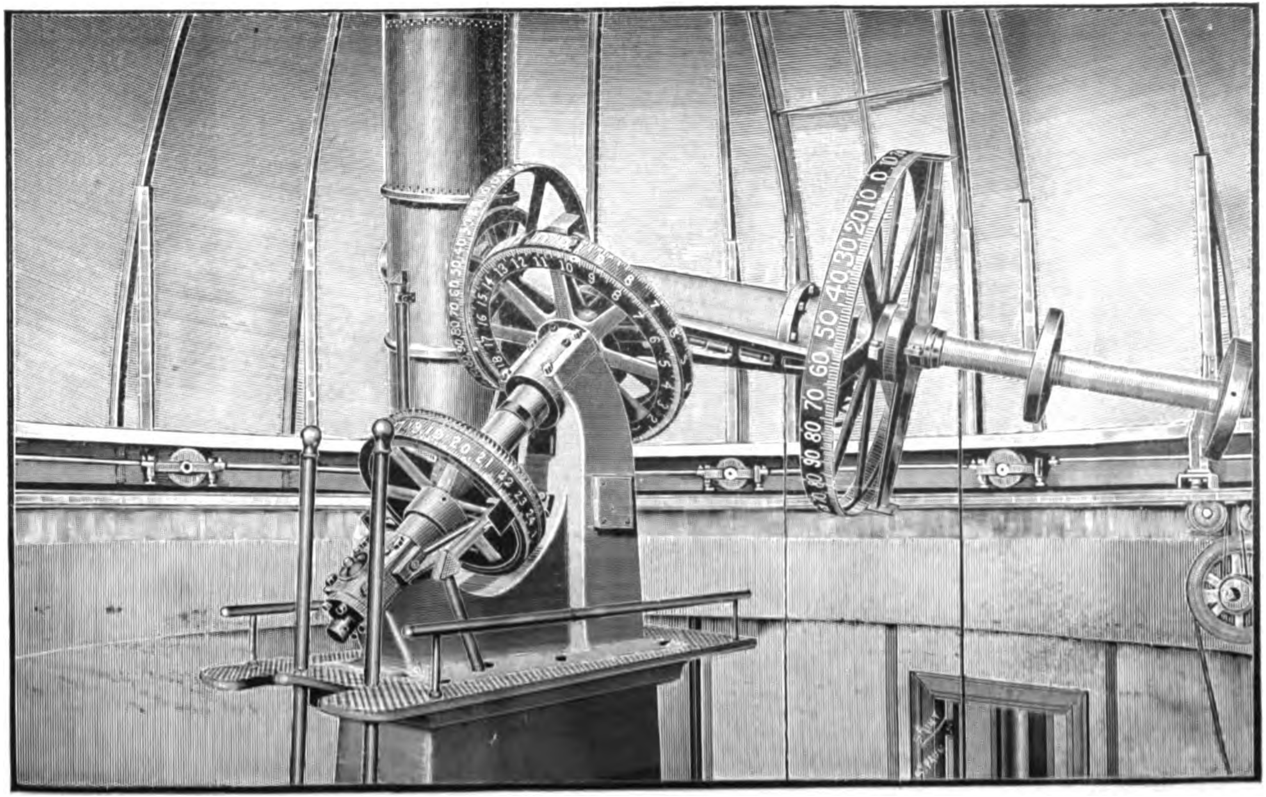

VIEW OF AXES AND CIRCLES OF THE WILLIAMS TELESCOPE.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

GOODSELL OBSERVATORY, CARLETON COLLEGE, NORTHFIELD, MINN.

VOL. 10, NO. 7. AUGUST, 1891. WHOLE NO. 97

Investigation of the Orbit of a Body whose mass is m, that of the sun being the unit, and which is supposed to be approaching the sun with a great velocity, while it is repelled by the sun with a force directly as the masses, and inversely as the square of their distance.

GEORGE W. COAKLEY.*

FOR THE MESSENGER.

The prevalent theory for the formation of the tails of comets is that the material constituting the tails is *repelled* by the sun. But it ought to be more distinctly recognized by astronomers than seems to be the case, that any material approaching the sun, and *repelled* by him, according to *any and every law of repulsion*, must describe an orbit CONVEX *to the sun*. The sun must be *outside the orbit*, not *within it*, so that the body cannot move *around the sun*, but can only *back up to him* within a certain distance and then depart again into space, along a curve *convex to the sun*, never again to return to his vicinity by action derived from him. This may be readily proved by supposing *repulsion* instead of *attraction*, in the same way that Newton, in the second section of his Principia, Proposition I, has proved that with *any law of attraction*, the curve described about the *center of attraction* is *always* CONCAVE *to that center*, in a *single plane*, and that *equal areas* are described in *equal times*. In the case of *repulsion* also according to *every law*, the orbit about a *center of such force* will *lie in one plane*, will be CONVEX *to the center of force* and the radius-vector will describe *equal areas* in *equal times*. The demonstration is about the same in the two cases.

The writer of this paper proposes, in a future number of THE MESSENGER, to consider the case of comets' tails, and

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* Professor of Mathematics and Astronomy, University of the City of New York.

how far there is any relation of repulsion between them and the sun. But he proposes to consider, as preliminary to that subject, the problem of the motion of a body towards the sun, under the influence of his *repulsion*, according to the law of directly as the masses, and inversely as the square of the distance. The writer has never met with any solution of this problem, though he has seen several statements of the result, namely: that the orbit is an *hyperbola convex to the sun.* He presumes therefore, that others would like to see the solution. The course of this investigation will closely imitate the steps of Professor James C. Watson, for the case of the sun's *attraction* of a body according to the Newtonian Law. The equations of the body's motion are derived from section 16 of Professor Watson's Theoretical Astronomy, equations (19), with proper modification for the case of *repulsion* instead of attraction. Professor Watson employs, for greater generality, three co-ordinate axes in space; but as it is only proposed to consider the orbit in its own plane, the two axes of x and y with their origin at the sun, and lying in the plane of the orbit, will suffice. At any moment let the body's distance from the sun be r, and its rectangular co-ordinates (x, y), and let $\theta =$ the angle which r makes with the axis of x. Then from Professor Watson's equations (19), the motion of the body will be determined by

$$\left.\begin{aligned} \frac{d^2x}{dt^2} &= + k^2(1+m).\frac{1}{r^2}.\cos\vartheta \\ \frac{d^2y}{dt^2} &= + k^2(1+m).\frac{1}{r^2}.\sin\vartheta \end{aligned}\right\} \qquad (1)$$

$$\text{when } \cos\vartheta = \frac{x}{r},\ \sin\vartheta = \frac{y}{r},\ \text{and } x^2 + y^2 = r^2. \qquad (2)$$

The sign + in the second members of equations (1) expresses the *condition* that the body, m, is *repelled*, since the force tends to *increase* the distance. If the body were *attracted*, instead of being repelled, the *minus sign* would be requisite, as in Professor Watson's equations, since the force would then tend to *diminish* the distance. Replacing $\cos\vartheta$, and $\sin\vartheta$ in (1) by their values in (2) gives:

$$\left.\begin{aligned}\frac{d^2x}{dt^2} &= +\,k^2(1+m).\frac{x}{r^3}\\ \frac{d^2y}{dt^2} &= +\,k^2(1+m).\frac{y}{r^3}\end{aligned}\right\}\qquad(3)$$

From equations (3) is derived $\frac{xd^2y - yd^2x}{dt^2} = 0$, which may be written $d.(\frac{xdy - ydx}{dt}) = 0$. (4.)

The integration of (4) gives $\frac{xdy - ydx}{dt} = \mathrm{C} = 2f$. (5)
C, or $2f$, being the constant of integration.

Hence: $xdy - ydx = 2f.dt$. (6).

But from equations (2) are derived:

$$x = r\cos\vartheta, \qquad y = r\sin\vartheta.$$

$$\therefore\quad \left.\begin{aligned}dx &= \cos\vartheta dr - r\sin\vartheta d\vartheta.\\ dy &= \sin\vartheta dr + r\cos\vartheta d\vartheta.\end{aligned}\right\}$$

$$\therefore\quad \left.\begin{aligned}xdy &= r\sin\vartheta\cos\vartheta dr + r^2\cos^2\vartheta d\vartheta\\ ydx &= r\sin\vartheta\cos\vartheta dr - r^2\sin^2\vartheta d\vartheta\end{aligned}\right\}$$

$$\therefore\quad xdy - ydx = r^2(\sin^2\vartheta + \cos^2\vartheta)d\vartheta = r^2d\vartheta\,,\qquad(7)$$

Hence, from (6) and (7): $r^2d\vartheta = 2f.dt$. (8.)

But $\frac{1}{2}r^2d\vartheta$ is the area described by the radius-vector, r, in the time dt. Hence, during the motion of the body, m, in its orbit, its radius-vector describes *equal areas* in *equal times.*

Multiply the members of equations (3) by $2dx$, and $2dy$, respectively, and add the results. Hence:

$$\frac{2dxd^2x + 2dyd^2y}{dt^2} = 2k^2(1+m).\frac{xdx + ydy}{r^3}.\qquad(9)$$

But from the last of equation (2), $xdx + ydy = rdr$. (10)

Hence (9) becomes $d.(\frac{dx^2 + dy^2}{dt^2}) = 2k^2(1+m).\frac{rdr}{r^3}$, or

$$d.(\frac{dx^2+dy^2}{dt^2}) = 2k^2(1+m).r^{-2}dr.\qquad(11)$$

The integral of this is:

$$\frac{dx^2+dy^2}{dt^2} = -\,2k^2(1+m).r^{-1} + h.\qquad(12)$$

h being the constant of integration. Equation (12) may also be written, in accordance with Professor Watson's form:

$$\frac{dx^2 + dy^2}{dt^2} + \frac{2k^2(1 + m)}{r} - h = 0. \quad (13)$$

From (5), by squaring the members, is obtained:

$$\frac{x^2dy^2 - 2xydxdy + y^2dx^2}{dt^2} = 4f^2. \quad (14)$$

And from (10), $\dfrac{x^2dx^2 + 2xydxdy + y^2dy^2}{dt^2} = \dfrac{r^2dr^2}{dt^2}. \quad (15)$

Adding the members of (14) and (15) gives:

$$\frac{(x^2 + y^2)(dx^2 + dy^2)}{dt^2} = \frac{r^2dr^2}{dt^2} + 4f^2, \text{ or}$$

$$\frac{r^2(dx^2 + dy^2)}{dt^2} - \frac{r^2dr^2}{dt^2} = 4f^2. \quad (16)$$

Multiplying the members of (13) by r^2 gives:

$$\frac{r^2(dx^2+dy^2)}{dt^2} + 2k^2(1 + m).r - hr^2 = 0. \quad (17)$$

Subtracting the members of (16) from those of (17) gives:

$$\frac{r^2dr^2}{dt^2} + 2k^2(1 + m).r - hr^2 = - 4f^2. \quad (18)$$

Or $\qquad \dfrac{r^2dr^2}{dt^2} = hr^2 - 2k^2(1 + m).r - 4f^2. \quad (19)$

Hence: $dt = \dfrac{rdr}{\sqrt{hr^2 - 2k^2(1 + m) - 4f^2}}, \quad (20)$

Substituting in (8) the value of dt from (20), and dividing by r^2, give:

$$d\vartheta = \frac{2f.dr}{r\sqrt{hr^2 - 2k^2(1+m).r - 4f^2}}, \quad (21)$$

Hence: $\dfrac{dr}{d\vartheta} = \dfrac{r}{2f}\cdot\sqrt{hr^2 - 2k^2(1 + m).r - 4f^2}, \quad (22)$

For each value of ϑ there will in general be two opposite radii-vectores, which will meet the orbit curve in opposite points, because of the double sign of the radical in (22). One of these values of r may be regarded as a maximum, the other as a minimun, for that value of θ. These maxima and minima, for each value of θ, will evidently be determined by making the second member of (22) equal zero. Hence:

$$hr^2 - 2k^2(1 + m).r - 4f^2 = 0. \quad (23)$$

Solving (23) as an equation of the second degree in r gives:

$$r = \frac{k^2(1+m)}{h} \pm \frac{\sqrt{k^4(1+m)^2+4hf^2}}{h}. \quad (24)$$

The maximum value of r is evidently the one with the sign $+$ between the terms, and the other is the minimum. Let $\vartheta = 0$, so that these values lie on the axis of x: and let $a(1+e)$, and $a(1-e)$ represent these maxima and minima respectively. Hence:

$$\left.\begin{aligned} a(1+e) &= \frac{k^2(1+m)}{h} + \frac{\sqrt{k^4(1+m)^2+4hf^2}}{h}. \quad (25)\\ a(1-e) &= \frac{k^2(1+m)}{h} - \frac{\sqrt{k^4(1+m)^2+4hf^2}}{h}. \quad (26)\end{aligned}\right\}$$

$$\therefore \quad a = \frac{k^2(1+m)}{h}, \ (27); \text{ and } ae = \frac{\sqrt{k^4(1+m)^2+4hf^2}}{h}.$$

$$\therefore \quad h = \frac{k^2(1+m)}{a}, \ (29); \ a^2h^2e^2 = k^4(1+m)^2+4hf^2 \ (30)$$

But from (27), $a^2h^2 = k^4(1+m)^2$; hence (30) becomes $k^4(1+m)^2.e^2 = k^4(1+m)^2 + 4f^2.\frac{k^2(1+m)}{a}$.

Hence, $a(e^2-1).k^2(1+m) = 4f^2$. (31).

If a is considered as positive, or measured along the axis of x, to *the right* from the sun, then (31) proves that $e > 1$, (32); since $k^2(1+m)$ and $4f^2$ are positive. Let $p = a(e^2-1)$ (33). Hence $4f^2 = pk^2(1+m)$, (34). Equation (21) will become, by substituting the values of h, and $4f^2$, or $2f$

$$d\vartheta = \frac{kp\sqrt{1+m}\,dr}{r\sqrt{\frac{k^2(1+m)}{a}r^2 - 2k^2(1+m).r - pk^2(1+m)}}. \quad (35)$$

By reduction this becomes:

$$d\vartheta = \frac{\sqrt{p}.dr}{r\sqrt{\frac{r^2}{a} - 2r - p}}. \quad (36)$$

But from (33), $\frac{1}{a} = \frac{e^2-1}{p}$; hence:

$$d\vartheta = \frac{\sqrt{p}.dr}{r\sqrt{\frac{r^2(e^2-1)}{p} - 2r - p}}. \quad (37)$$

Multiplying the numerator and denominator of (37) by $\sqrt{p}$ gives:

$$d\vartheta = \frac{pdr}{r\sqrt{e^2r^2 - r^2 - 2pr - p^2}} = \frac{pdr}{r\sqrt{e^2r^2 - (p + r)^2}}. \quad (38)$$

$$\therefore \quad d\vartheta = \frac{pdr}{er^2\sqrt{1 - (\frac{p}{e} \cdot \frac{1}{r} + \frac{1}{e})^2}} = \frac{\frac{p}{e} \cdot \frac{dr}{r^2}}{\sqrt{1 - (\frac{p}{e} \cdot \frac{1}{r} + \frac{1}{e})^2}} \quad (39)$$

But $\frac{dr}{r^2} = - d.\frac{1}{r}$; hence $d\vartheta = - \frac{\frac{p}{e} \cdot d \cdot \frac{1}{r}}{\sqrt{1 - (\frac{p}{e} \cdot \frac{1}{r} + \frac{1}{e})^2}}$ (40)

Equation (40) may also be written in the form:

$$d\vartheta = - \frac{d \cdot (\frac{p}{e} \cdot \frac{1}{r} + \frac{1}{e})}{\sqrt{1 - (\frac{p}{e} \cdot \frac{1}{r} + \frac{1}{e})^2}}. \quad (41)$$

Integrating (41) gives:

$$\vartheta = \cos^{-1} . (\tfrac{p}{e} \cdot \tfrac{1}{r} + \tfrac{1}{e}) \quad (42)$$

No constant of integration is needed, because ϑ will be counted from the axis of x.

From (42) is derived: $\cos \vartheta = \frac{p}{e} \cdot \frac{1}{r} + \frac{1}{e}$. (43)

$$\therefore \quad e \cos \vartheta = \frac{p}{r} + 1,$$

$$\therefore \quad r = \frac{-p}{1 - e \cos\vartheta} = \frac{-a(e^2 - 1)}{1 - e \cos\vartheta}. \quad (44).$$

As $e > 1$, as proved in (32), it follows that (44) is the polar equation of an hyperbola; the sun, at the pole is at the focus *outside* the orbit-branch, or at the focus *within* the opposite branch of the hyperbola from that on which the body, m, moves.

This orbit is necessarily *convex* to the sun, as must be every orbit described by his *repulsion*, according to *any law of repulsion*. If in (44) ϑ be assumed equal to zero, r will be the radius-vector of the orbit's intersection with the axis of x.

Hence: $r = \frac{-a(e^2-1}{1-e} = a\frac{1 - e^2}{1 - e} = a(1 + e)$. This is the Perihelion distance of the orbit. As ϑ increases from $\vartheta = 0$ to $\pm \vartheta = \cos^{-1}\frac{1}{e}$, or $\cos.(\pm \vartheta) = \frac{1}{e}$, r will be positive, and will increase from $r = a\,(1 + e)$ to $r = \infty$, when $\cos\,(\pm\,\vartheta) = \frac{1}{e}$. For example, suppose $e = 2$, then (44) becomes:

$$r = \frac{-\,a(4-1)}{1-2\cos\vartheta} = \frac{-\,3a}{1-2\cos\vartheta}, \; \frac{1}{e} = \frac{1}{2} = \cos\,(\pm\,60^\circ).$$

If $\vartheta = 0$, $r = 3a$, . $\cos\vartheta = 1$.

If $\cos(\pm\,\vartheta) = \frac{9}{10}$,

$$r = \frac{-\,3a}{1-\frac{9}{5}} = \frac{-\,3a}{-\frac{4}{5}} = \frac{15a}{4} = 3a + \frac{3}{4}a.$$

If $\cos(\pm\,\vartheta) = \frac{8}{10}$, $r = 5a$.

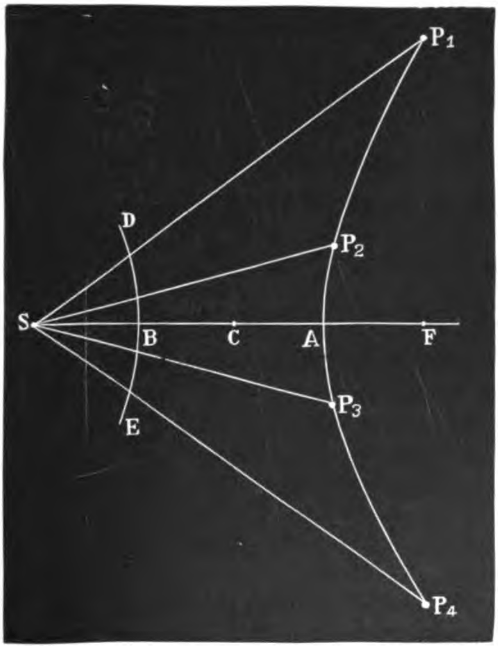
If $\cos(\pm\,\vartheta) = \frac{7}{10}$, $r = 7a + \frac{1}{2}a$

If $\cos(\pm\,\vartheta) = \frac{6}{10}$, $r = 15a$.

If $\cos(\pm\,\vartheta) = \frac{5}{10} = \frac{1}{2}$, $r = \infty$., or the radius-vector is parallel to the asymptote, and meets the orbit-curve only at infinity. The polar equation of the opposite branch of the hyperbola, in the focus of which the sun is situated, is evidently

$$r = \frac{+\,a(e^2-1)}{1+e\cos\vartheta},$$

(45). If $\vartheta = 0$, in this branch, $r = a(e-1)$, which is the distance from the sun at its nearest point. But the body, m, can never



get on to this branch since the two branches are discontinuous.

If in (44), $e = 2$, and $a = 1$, the preceding figure will represent the orbit of the body, m, in successive positions, P_1, P_2, P_3, P_4, as it approaches and recedes from the sun at S. $SA = 3a = 3$ is the perihelion distance; DBE is the opposite hyperbola upon which the body, m, cannot move. The sun S, is at the focus *within* this *concave branch*. F is the focus of the *convex branch*, or of the *actual orbit*.

ADDRESS AT THE DEDICATION OF THE KENWOOD OBSERVATORY.

PROFESSOR C. A. YOUNG.

It is a very great pleasure, ladies and gentlemen, to be here this evening at this dedication of this most complete and most admirably equipped of all private observatories. It reminds me very much of another Observatory which I visited some years ago where however, things were very different in a good many ways. It was the old Observatory at Peking, at one corner of the city upon its wall, which is about sixty feet high and so wide on top that four carriages can drive abreast around the city. In a little enclosure at the base of the wall are two ancient instruments, more than six hundred years old, one of them an equatorial in principle very much like this instrument before us, but of course carrying no telescope; the other is a large astrolabe. These two instruments were brought from Samarcand by the Tartars when they captured the city under Genghis Khan. In the Observatory proper, upon the top of the wall there are mounted a number of other instruments, more modern than these, though still very old. Some of them were brought from Paris about 1660, and two or three were made in China. They are all mounted in the open air, and are all in condition to be used, and might be used with only slight repairs. I presume Mr. Brashear could put them in two days into such condition that they could be used as well as ever. They were erected before the days of the telescope, and designed for use in the methods of the "old astronomy."

They were made for the purpose of observing simply the positions and motions of the stars.

In those days astronomy was believed to be an exceedingly "useful" science with a most immediate and direct bearing upon human affairs. Mr. Wells Williams was with us at the time of our visit, and translated for us the mottoes upon the tablets that hung upon the walls. On one of these tablets the legend was this: "By observing the constellations we fix the times," and "times" means opportunities. Watch the stars, and from them, according to the belief which then prevailed, you can tell whether it is a good time to do this thing or that. A second tablet read: "By observing the motions of the stars we apprehend what is suitable to the seasons"—the same idea in a little different form. And the third was: "By reverentially conforming to the revolutions of the heavenly bodies we avoid disaster." 'Disaster,' you know, is a purely astronomical word in its derivation. The point is that then astronomy was considered a directly 'useful' science. As the world has progressed, I suppose that we must give up that idea, to a very considerable extent. The old astronomy really had, and still has certain important practical uses. The great observatories of the world, Greenwich, Paris, Berlin, were founded especially to watch the motions of the moon and stars so as to provide means for determining the longitude at sea. Herein, however, lies about all the pecuniary value of astronomy so far as we know at present. It is not true that the stars exert any notable influence upon our affairs, or that their observation can be made directly profitable.

A new astronomy has sprung up, and now, instead of studying simply the motions of the heavenly bodies astronomy has come to pay very much more attention to the nature and character of them, and we are trying to utilize the stars, to a certain extent as laboratories and instruments for researches which we cannot manage in our terrestrial domes. In the stars we find higher temperatures and different conditions from any that are attainable on the earth, and it seems highly possible that we may thus learn something from the stars:—their light may bring us information that may be useful in terrestrial investigations.

Still I should be dishonest if I undertook to say that I really thought that even in this line there was very much money to be gotten from astronomical investigations. The great benefit, the great use of astronomy to the world, as I understand it, is intellectual;—culture to the individual and to the nation,—a very different thing from money—and a nobler. It is true that we must have our bread and butter *first* and earliest—that has to be provided for, just as must the foundation for the building, but the noblest part of the building is not the foundation. I know of no other science in which we so learn to look out of self and so far beyond self, and into the great outside universe—none that so promptly puts the man into his true relations of space and time and power. It is not so much knowledge—knowledge is power, good, excellent—but it is the LEARNING and the KNOWING after all that develop the man, and perfect the image of the Creator within him.

I am not going to take any great amount of time this evening, ladies and gentlemen, for I have nothing that really deserves to be called an address to present to you. Mr. Hale, has kept me so busy that I have not had time to write out anything; he has kept me interested and at work in one way or another ever since I came here. I never enjoyed two days in my life more than I have these last two, for I have seen science developing in the particular directions that have a special interest for me. Some years ago, if I may be allowed to make another personal allusion, I was out on the Mountains at Sherman Station, on the Union Pacific Railroad, observing the spectrum of the sun for the purpose of trying to find out what astronomical advantages were attained by getting up eight thousand feet above the sea level, and thus leaving a large portion of the air below. A government expedition had been organized of which I was a member, and I took out a nine-inch telescope —not so large a one as this is by considerable—and worked away upon the spectrum of the sun with my human eyes as well as I could. One of the most notable results was the discovery that in the solar spectrum the two great broad black bands known as H and K had each a bright line running through its center, whenever the telescope was directed at the edge of the sun or at the neighborhood of a sun-spot. This being so, it ought to be possible to study the prominences through these lines just as we do through the red C line of the solar spectrum. I did not think at that time that it would probably be practicable, though it might be possible, if our eyes were 'blue' enough, *i. e.*, if they were sensitive enough to that kind of light. Now here at the Kenwood Observatory, instead of using *eyes*, which do not see that kind of light very well—at least my own eyes do not—Mr. Hale uses photography, and with this admirable apparatus (the finest certainly for this purpose in existence), he has found that it is easily possible to photograph the bright lines in those two dark bands of the spectrum. This means that things which were very difficult to see, even with the help of mountain air, and the utmost protection to the eye, can be photographed here in Chicago perfectly and easily. I saw it done Saturday and again to-day, and I am confident that Mr. Hale is going to succeed in procuring pictures from day to day of the cloud-forms about the sun.

I suppose you know what I am talking about. The sun itself is a great ball of heated vapor, covered with an outside shell of cloud, which is the photosphere,—the sun we see. But over-lying the photosphere there is a stratum of gases heated like a sheet of flame that we call the 'chromosphere'; and reaching up to elevations sometimes four hundred thousand miles in height—that is very rare, but ordinarily, thirty, forty or fifty thousand miles—there are great clouds or flames called the solar prominences composed of heated hydrogen, and other gases mingled with it. They are wonderfully beautiful objects, but can be seen (except at eclipses) only by the help of the spectroscope; and they change so rapidly that it is extremely difficult to delineate them correctly by eye and hand. So you can imagine that astronomers greet with enthusiasm the prospect of securing their photographs.

There is also a great deal of special interest of a different sort connected with the H and K bands of the spectrum.

I am not going to undertake to explain them. I do not think people yet know all their secret. But the fact is that these two bands,—at least two black bands in just that position in the spectrum,—are found in the light produced by an electric spark as passed between the poles of calcium: two carbons are dampened with a solution containing calcium, and immediately when the electric arc passes between them, two bright lines appear that correspond precisely to the position of the middle of these bands in the solar spectrum. Hence it has been supposed very naturally, —and very likely the supposition is true, that calcium is the material that causes these bands in the solar spectrum. Still there are difficulties. It is strange, if that is so, that other lines of calcium do not show themselves in these solar prominences. So that if the H and K lines are really due to calcium, we have a puzzling problem. The calcium which produces H and K, is calcium in some different condition, or, at least, in some different state of excitement from the calcium which produces the hundreds of other calcium lines in the spectrum. I do not know that I even dare say that. It is *behaving* differently, at any rate, from the calcium that we work with on the earth's surface.

Then again we meet a very singular thing when we come to photograph the spectra of the great white stars. We find in the lower part of the spectrum a series of dark bands that correspond to the well known lines of hydrogen; and when we come to the H band we find there a wide dark black band, but K is absent; then in the ultra-violet there is another series of hydrogen lines; and all of these, including H, are spaced as regularly as the teeth of a cog-wheel. Evidently, according to that, H would seem to be a line of hydrogen, and I do not yet feel sure whether this H line that we see in the spectrum of a solar prominence is hydrogen or calcium. It may be both. I think Mr. Hale will be likely to find out by and by, and when he has found that out, he is likely to have opened a road to some new results with reference to the molecules of hydrogen and calcium and other substances; for this atmosphere of our sun is a very strange thing in many ways. If the earth is a chip of the old block, and I suppose it is, the sun ought to have oxygen in it, which composes over half of the mass of the earth: there is not a trace of oxygen in the sun that we can be sure of. You ought to have nitrogen there, the main constituent of our atmosphere: we do not find it. We ought to have chlorine there but it does not appear. We do find nearly all of the *metallic* elements there, but these non-metallic elements for some reason do not reveal themselves, if they are really there. It is quite likely that further researches of the kind to be prosecuted here will give us light in that department of physics; and I am sure that if we do learn in this way something about the relations of the ultimate molecules of matter, it will be exceedingly valuable scientific information. It may even turn out to have a 'bread-and-butter value' as bearing upon chemical theories, and, sooner or later it may affect human interests in many ways: still I cannot promise you that it will.

This is not by any means the first of the observatories of the new astronomy in the world, or even in this country. There have been predecessors in America and Europe, and there are now two observatories in Europe that are, in many respects, more fully equipped than this,—not more perfectly, however, for the one object that is just now aimed at. In Germany they have the great Astrophysical Observatory at Potsdam. Possibly some of you may have seen it: it will well repay a visit. During the last two or three winters they have been most successfully at work upon the spectra of the stars. They have done work upon the solar spectrum also, but only along old lines—no special advances have been made with respect to solar chemistry at Potsdam. Then there is the great French observatory at Meudon, which, when complete, will be perhaps on a still grander scale. They are proposing to have a great twin telescope, each of the "twins" having an object glass two feet in diameter, with a tube about thirty feet long, the two mounted side by side. With them they expect to go on both with photographic and spectroscopic investigations.

In England there is no National Physical Observatory. A certain amount of physical work is done at Greenwich, but that is a mere by-play to the main business of the Observatory, which is watching the motions of the planets and of the moon, and making star-catalogues. The private observatory of Dr. Huggins, however, must not be passed unmentioned: it was the birthplace of spectroscopic astronomy and is still in most active and effective operation. Mr. Lockyer also has a semi-private establishment for spectroscopic work; and Common and Roberts and one or two others have fine photographic telescopes.

I think, that the earliest of the physical observatories in this country was that of Mr. Rutherfurd of New York, and, in a good many ways, this Kenwood Observatory is its direct descendant. It was there that the first successful photographs of the moon were made. Some daguerrotypes had been obtained before at Cambridge with the old telescope, but that instrument was not designed for photographing, and did not give very perfect results. But in the sixties—Mr. Rutherfurd succeeded in getting photographs of the moon that, until within the last three years, had no superiors,—no rivals even, among those that have been made elsewhere. They remained in full possession of the field for at least fifteen years. But lately, both at Paris and at the Lick observatory, and perhaps at Cambridge, the new instruments and methods have gone beyond his best. You have seen down stairs a photograph made at the Lick Observatory.

Rutherfurd also took up the subject of Spectra, and ruled the first good "grating." I have to put in the qualifier "good," because gratings had before been used in Europe. Fraunhofer used a grating in some of his observations as early as 1820;—an actual grating of wires spaced one hundredth of an inch apart. And later Nobert—many of you have heard of him—succeeded in ruling lines very close together,—nobody has ever done better in that respect, and he made a few small plates where a space of about half an inch square was ruled with fine parallel lines, which ably used in the hands of Angstrom and others have yielded classical results.

Mr. Rutherfurd at first ruled a few gratings upon glass and afterwards substituted speculum metal. I remember well the first one that I ever saw about 1867, and a great astonishment it was to me. It was abont half an inch wide, and the lines were about an inch long; and it was an absolute amazement to me to find that it would give a spectrum vastly better than any prism or even than a train of five or six prisms. Indeed on going to Europe in 1870, in connection with an eclipse expedition, I found that many English astronomers and physicists whom I met then supposed that you could merely see the colors of the spectrum, in a diffraction grating, and had no idea that you could see the finer Fraunhofer lines. Later, Mr. Rutherfurd succeeded in ruling magnificent gratings in which the lines were about an inch and a half long, and the ruled space was one and one-half inches square. About eight or ten years ago Professor Rowland, of Baltimore, constructed a machine with which he rules lines four inches long, and covers spaces six inches wide with fine, even, parallel lines about one-fourteen thousandth of an inch apart. Such a grating makes a magnificent spectrum, and downstairs there is a beautiful specimen of a grating of this kind that is ruled upon a slightly hollow surface. And here, (pointing to the spectroscope) is a five-inch grating, as it is called, in the round box at the lower end of the spectroscope, which gives the most beautiful spectra I ever saw.

This explains what I mean by saying that this Observatory is a lineal descendent of Mr. Rutherfurd's. It is the diffraction grating that furnishes the analyzing power that breaks up the sunlight and makes possible the investigations that Mr. Hale is taking up. The telescope, too, is almost the same size as Mr. Rutherfurd's though longer; and it is much handsomer, for thanks to the abilities and workmanship of its makers, Mr. Brashear and Warner & Swasey, things are finished in a little more elegant style than in a machine which like Mr. Rutherfurd's,* was constructed, piecemeal, for the purpose in hand at the moment, a little one day and a little more the next.

Then came the Observatory of Dr. Henry Draper, who went into stellar spectroscopy. He was a professor in the University of New York, and was fortunate enough to marry a very lovely and, at the same time, very rich lady, who was extremely interested in the line of work that he took up, so that he was enabled to go on with his researches in an admirably fitted Observatory that he erected at Hastings-on-Hudson. His death in 1881 or '82, was, I think, one of the greatest losses that American science ever experienced. At the time he had just entered upon a course of conquest; he had begun to photograph the spectra of the stars with a success which had never been attained before.

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* Mr. Rutherfurd's Observatory was discontinued some years ago, on account of the owner's failing health. The telescope and most of the apparatus, was given to the Observatory of Columbia College, where it is now mounted.

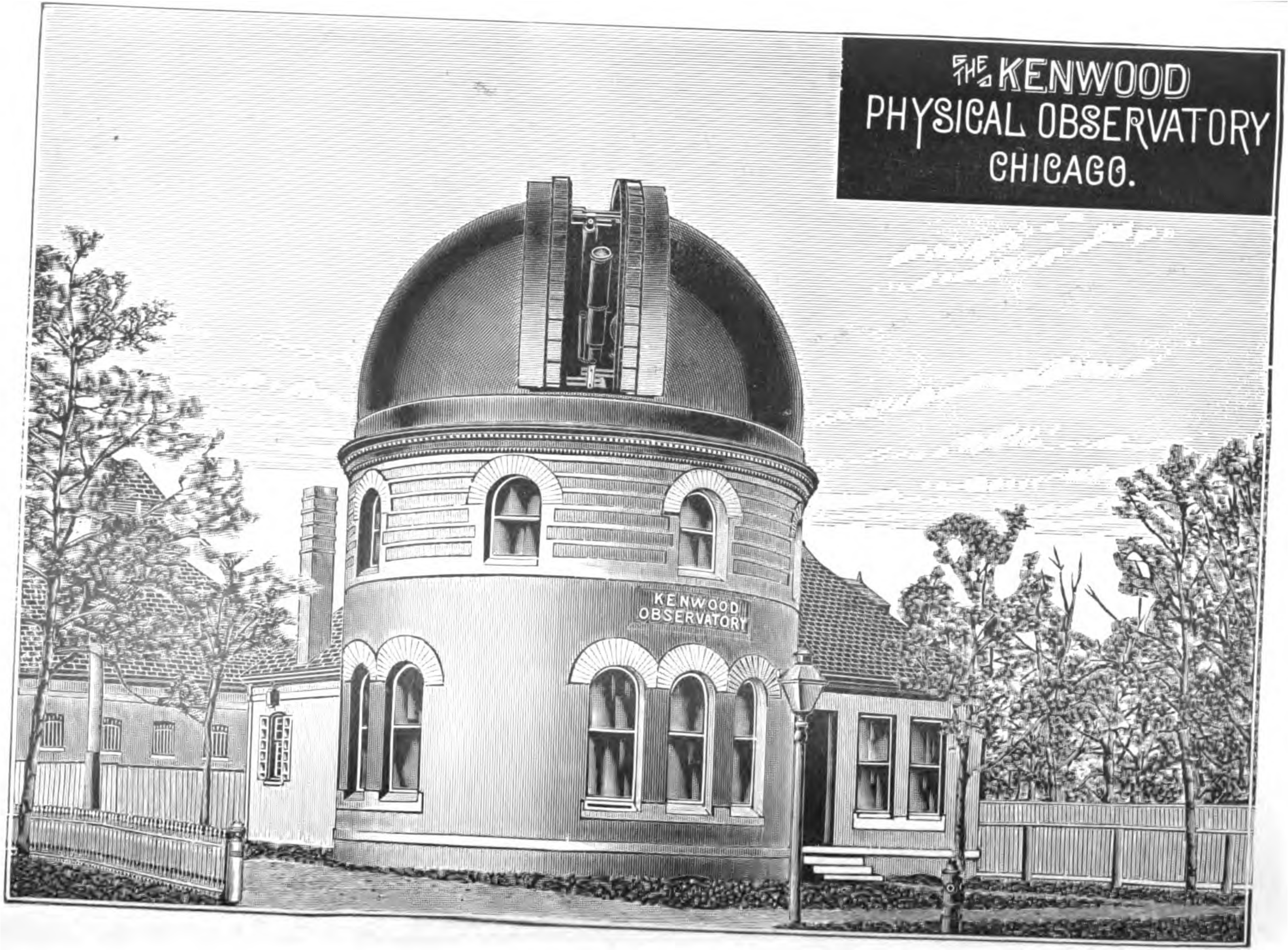
Since his death his work has been taken up at Cambridge. Mrs. Draper has turned over the instruments to the Observatory there, and has provided a liberal income—six or eight thousand dollars a year, and more when necessary—to aid in carrying on investigations in this line of stellar spectroscopy.

And now starts up this new Observatory in the line of solar work, and I am very confident that, if Providence is kind and permits Mr. Hale to go on, as there is every reason to hope will be the case, we shall soon have splendid results from it.

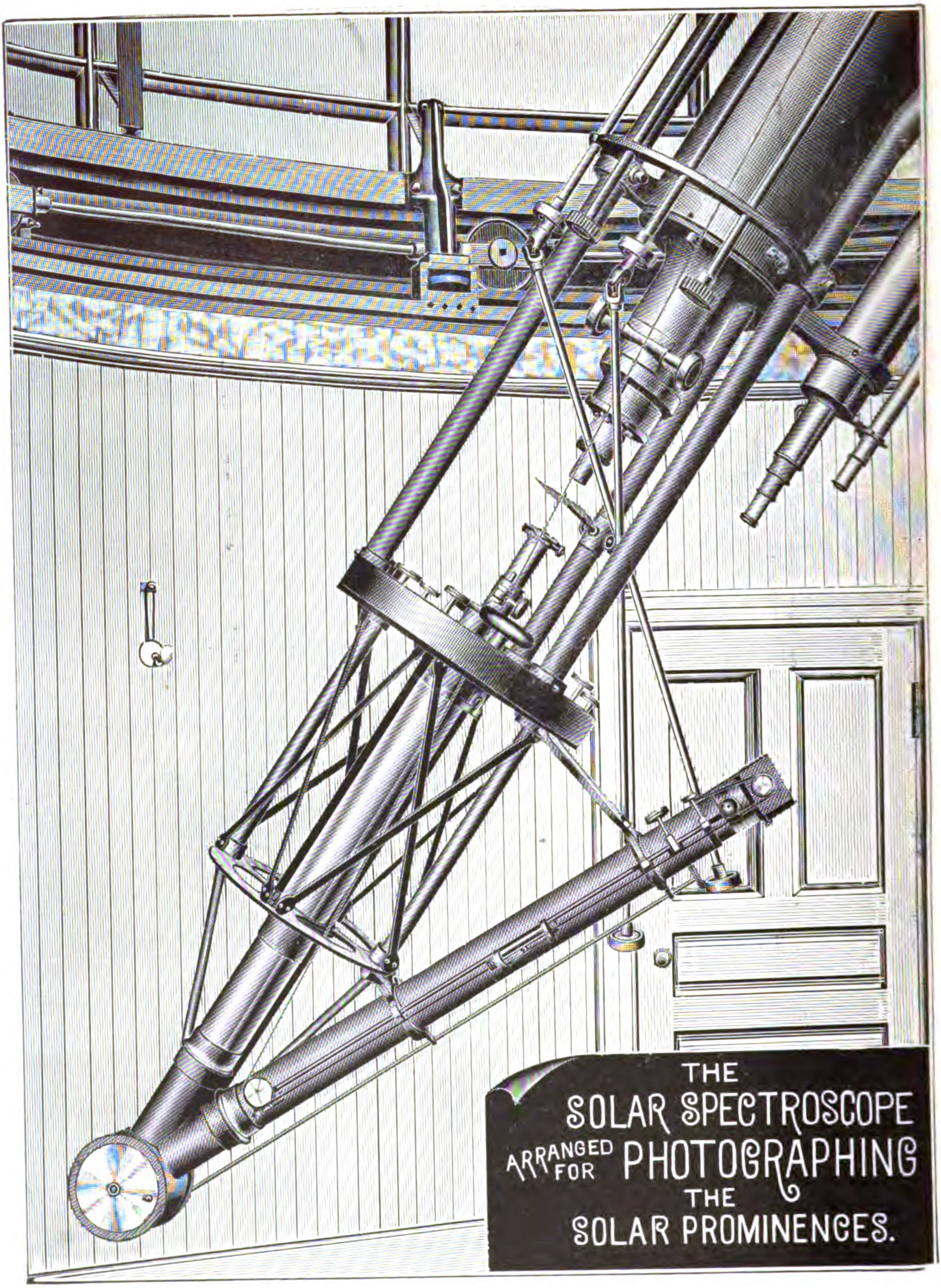
I will add that just before I left home I received notice that at Washington they are erecting an Observatory (which will be under government auspices) for astronomical physics, under the charge of Professor Langley. Its work will be mainly with a different instrument, the bolometer, for the purpose of measuring the distribution of heat over the surface of the sun, and moon, and possibly the heat from the stars. I do not think Professor Langley yet believes that stellar heat can be measured in this way, but I half think that he will succeed better than he expects.

And now let me close with a few words as to the relative advantages of public and private observatories.

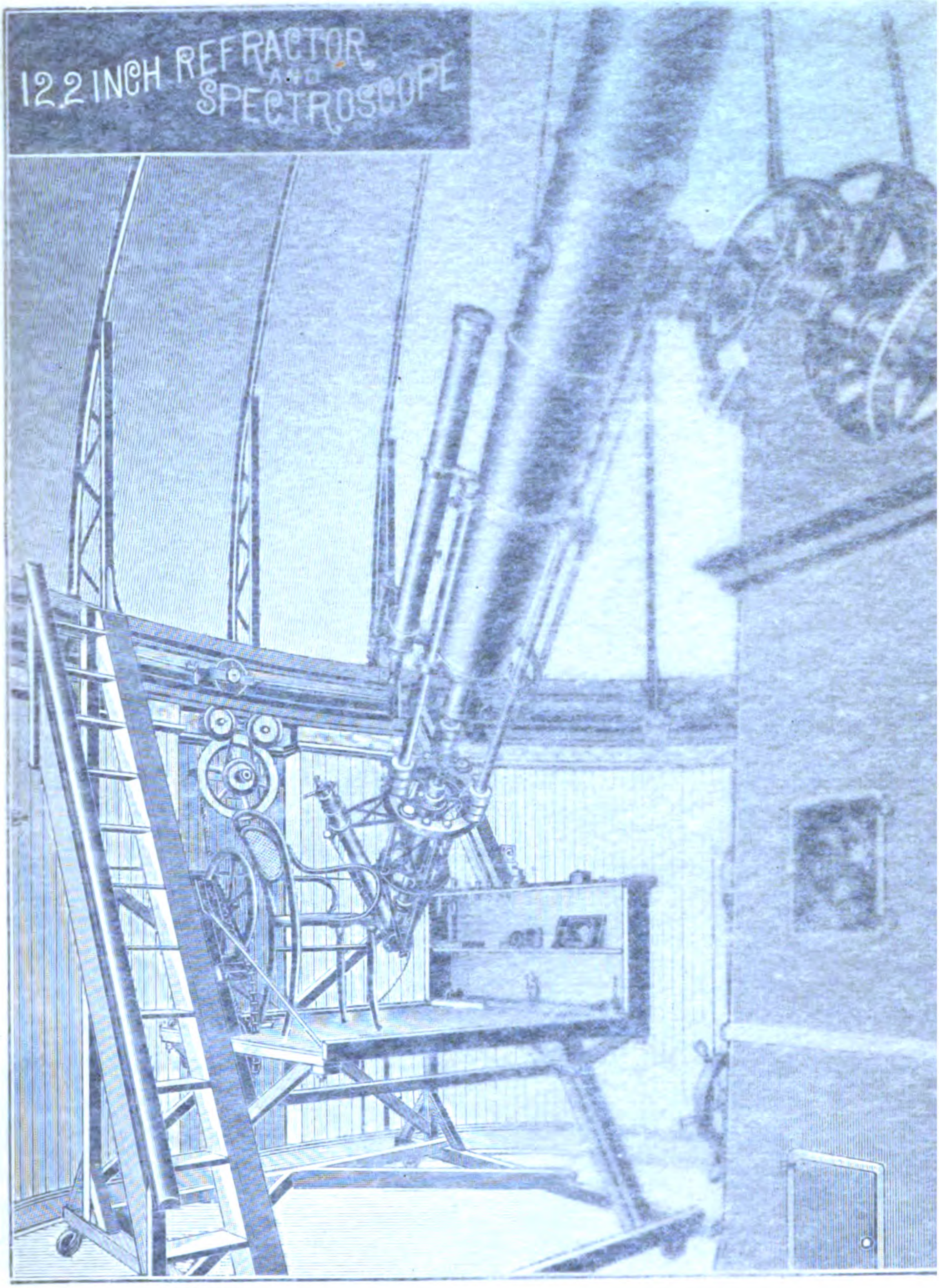
I am myself connected with an observatory which is a department of a college and certainly I have always been treated with the greatest liberality and freedom, but public institutions, are under boards of trustees who are administering trust-funds, and have their hands, to a certain extent, tied, and do not feel quite at liberty to try doubtful experiments. But here if Mr. Hale thinks it is well to try an experiment, with one chance in ten that it will prove a success, he is very likely to try it, and he has nobody to answer to if it fails, and that is a great advantage that a private institution, like this, has over a public one—the observers may use their instruments and funds in any line they please. They have the liberty of scientific exploration, and it is a great liberty. In public observatories we are and ought to be very much limited, and only carry on investigations which are reasonably sure to prove beneficial and fruitful. But I say this here because there are a good many private gentlemen present, who I presume, are interested more or less in



THE KENWOOD
PHYSICAL OBSERVATORY
CHICAGO.



THE SOLAR SPECTROSCOPE ARRANGED FOR PHOTOGRAPHING THE SOLAR PROMINENCES.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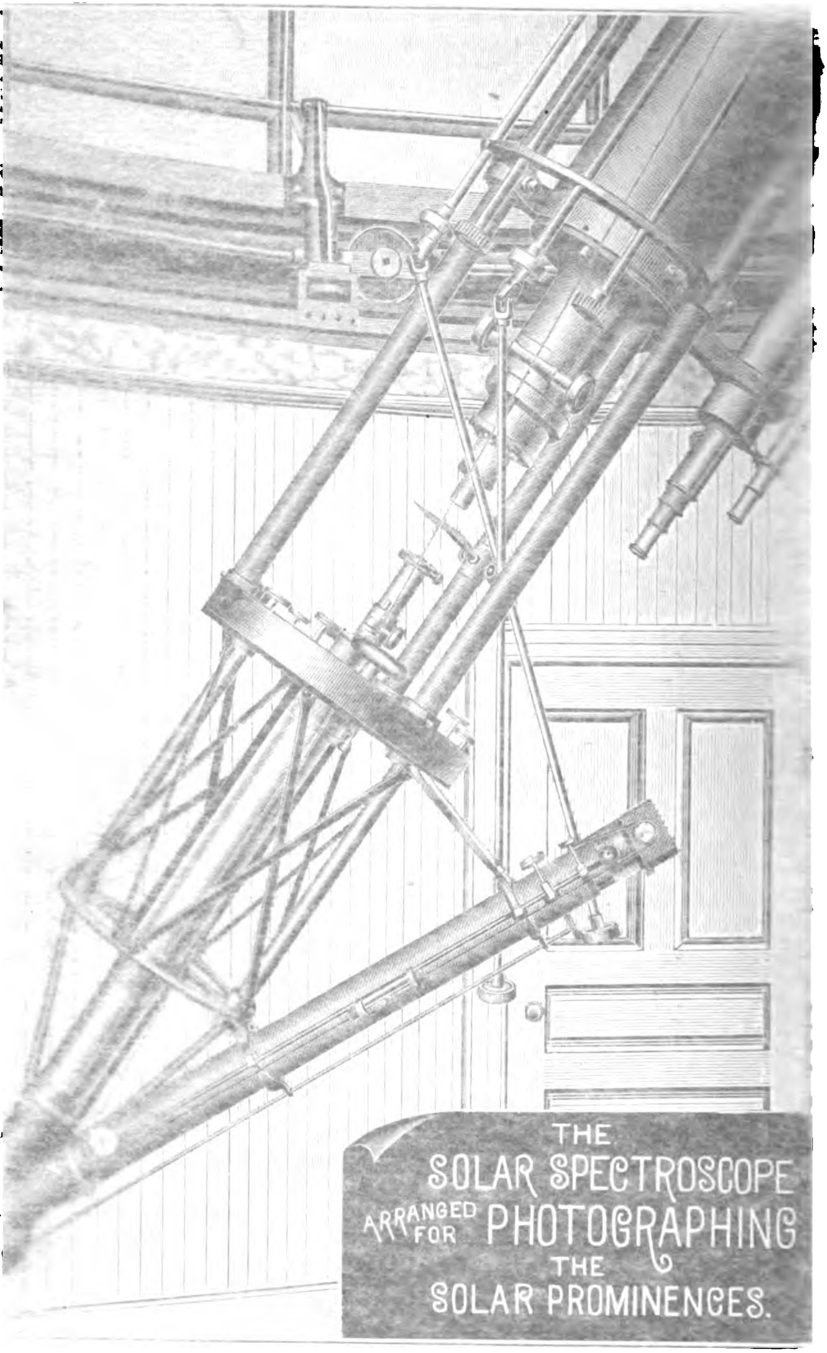

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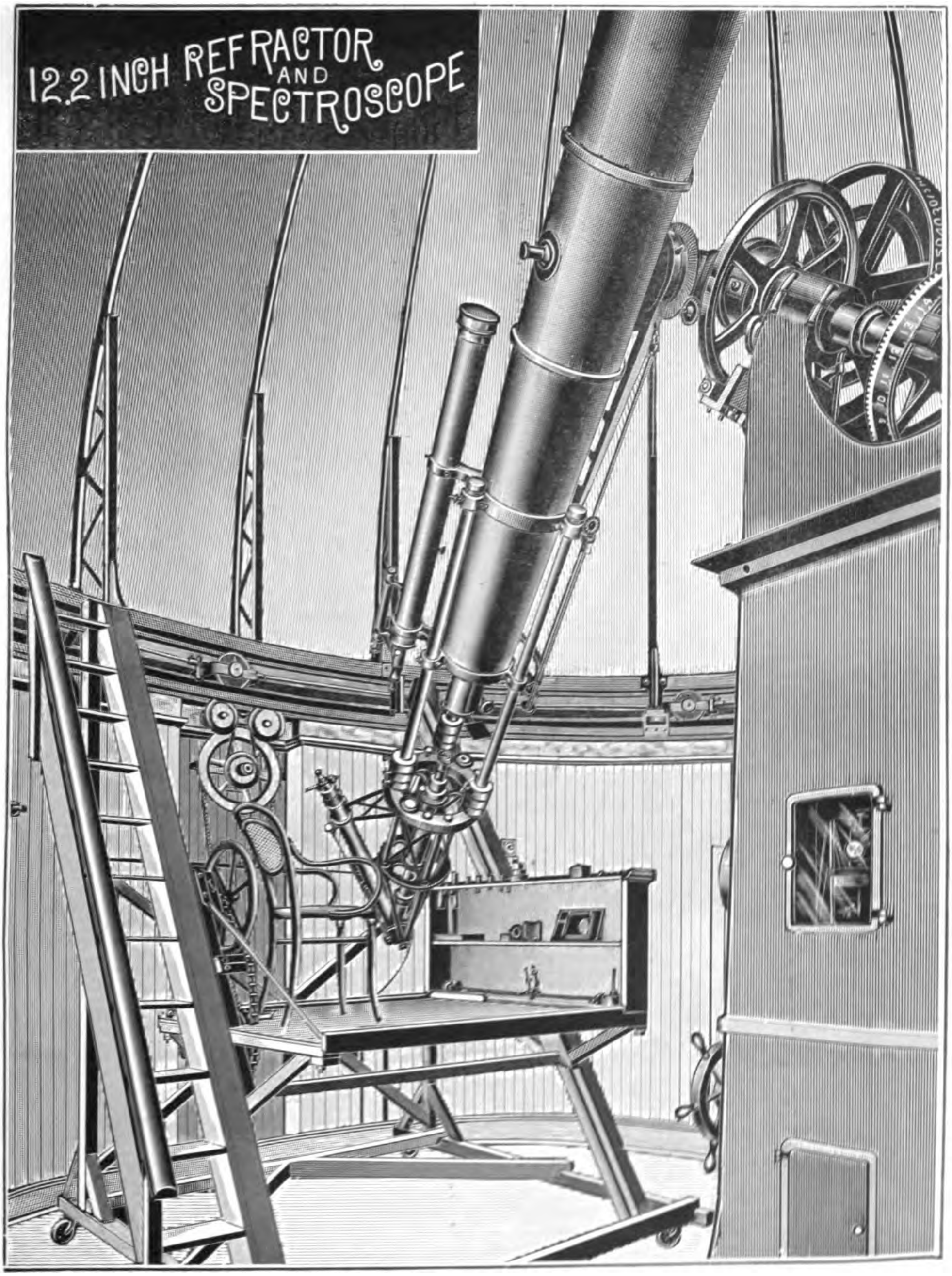

12.2 INCH REFRACTOR AND SPECTROSCOPE

science, and I am sure that private investigators in the scientific line have at least one very great advantage over public institutions. The fact is, that a large number of the most important astronomical and scientific discoveries have been made by those who are called amateurs, but "amateur," rightly interpreted, means, what it ought to mean and not what it is commonly understood to mean—it means a man who is a "lover" of the science, as he would be of a woman: devoted to it, as he would be to his wife: willing to spend and be spent for it. It does not mean a "dilettante," who delights a little with it—fools with it, as we say, in the language of college boys. The true "amateur" is one who is ready and willing to devote himself to the science he has chosen. And so from the character of my young friend here, and from your warm interest in him and his work I have my liveliest anticipations aroused and expect rich results. This has been one of the happiest occasions of my life—the three days that I have spent here. (Applause.)

THE KENWOOD PHYSICAL OBSERVATORY.

GEORGE E. HALE, DIRECTOR.

FOR THE MESSENGER.

The Kenwood Physical Observatory had its inception in a spectroscopic laboratory erected in Chicago in the summer of 1888. The addition of a tower and wing during the winter of 1890-91 brought the building to its present form, and it now includes a reception room, library, equatorial room, "slit room," "grating room," photographic dark room, general laboratory, and workshop, [Plate 1]. The grating room contains a four-inch concave grating of ten feet radius of curvature, mounted in the manner employed by Professor Rowland. A shorter girder allows the use of a grating of only five feet radius, in cases when the light source is too faint to admit of the highest dispersion. Sunlight is furnished by a heliostat on a pier some distance to the north of the building, while a Weston dynamo, driven by a gas engine of six horse-power, supplies the direct current used in spectroscopic studies of the electric arc. An alternating current of 52 volts is also supplied by the

Hyde Park Thompson-Houston Company, and this is especially useful in producing heavy electric sparks with a large induction coil, and in lighting the whole Observatory with incandescent lamps. A set of thirty-five Julien storage cells can be charged by the Weston machine, and used when desired.

The mounting of the equatorial was finished in March, 1891, by Messrs. Warner and Swasey, and the excellent 12.2-inch object-glass, figured from Dr. Hastings' calculations by Mr. J. A. Brashear, was in place and ready for use early in April, 1891 [Plate II]. The spectroscope is of very large size, and was also made by Mr. Brashear [Plate III]. A frame of strongly braced steel tubing carries the collimator and observing telescope, which make with each other a constant angle of 25°. The objectives are exactly alike, of 3¼ inches clear aperture and 42½ inches focus, corrected for work in the visual region. The grating is a 4-inch flat, and in many respects is the finest ruling I have ever seen. In addition to the grating there is a 30° white flint prism, silvered on the back, which is used in photographing the spectra of the fainter stars. The large size of the spectroscope, and the necessity of a perfectly rigid attachment to the equatorial, have caused us to mount the spectroscope and tube as if in one piece, the declination axis coming at the center of their combined lengths. As the object-glass of the equatorial has a focal length of 18 feet, the total length of the combination is 22 feet 9 inches. The mounting is built very large and heavy, and carries also a four-inch Clark telescope and a small finder. The rate of the driving clock can be controlled by electric connection with an excellent Howard clock.

As my recent photographic investigations of solar prominences and their spectra have shown the necessity of employing specially corrected objectives in a continuance of the research, it has been decided to supply the telescope with a photographic object-glass of exactly the same aperture and focal length as the present visual glass. A double tube will replace the single tube now used, and the object-glass will be so supported that either one may be used on either tube. The spectroscope will thus form a part of the instrument, as before, and the eye-end of the second tube will be left free for the attachment of any desired apparatus, such as an amplifying lens and camera for photographing sunspots on the Janssen method. Various improvements of the spectroscope will be made by Mr. Brashear, one of the most important being the construction of a new device of the writer's for prominence photography. A new observing telescope, with an objective of about six feet focus corrected for the K region is to be constructed for the spectroscope, and used for further study of the prominence and chromosphere lines recently discovered. Mr. Brashear also has the order for the twelve-inch photographic object-glass, for which the whitest possible flint will be secured from the Jena factories, while the crown will be furnished by Mantois. The writer will spend some time visiting the European observatories in search of new ideas in apparatus and methods of work, which will be embodied in the improved instruments.

The Kenwood Physical Observatory was dedicated to scientific research on June 15, 1891. Addresses were made by Professor C. A. Young, Professor G. W. Hough of the Dearobrn Observatory, Mr. J. A. Brashear, President E. D. Eaton, of Beloit College, and several others. Professor Young's address will be found in full on another page. The Observatory has been incorporated under the laws of the state of Illinois, and its control is vested in a board of trustees. The plan of work laid out for the future includes a thorough study of solar phenomena, and particular attention will be given to spectroscopic investigations of the spots, chromosphere, and prominences.

BROOKLYN, N. Y., June 29, 1891.

THE MOTION OF THE DOUBLE STAR, β 612.

S. W. BURNHAM.

For THE MESSENGER.

I discovered this pair in 1878 with the refractor of the Dearborn Observatory, and measured it on three nights with that instrument. It was also measured by Hall during the same year, and several years later by Engelmann. I have lately made another set of measures with the 36-inch, and a comparison of all the observations appears to show a very rapid movement in the angle. These measures are as follows:

1878.33	56°.1	0″.23	β 3n
1878.96	60 .5	0 .24	Hl 4n
1884.02	52 .4	0 .28	En 5n
1891.28	191 .1	0 .28	β 3n

This is a sixth magnitude star (B. A. C. 4559), and the components are so nearly equal that all of the measures, so far as the observations are concerned, might be in the same quadrant. That disposition of them, however, would seem to be improbable since it would require a large error in some of the measures. The two sets of measures in 1878, giving 58°.3 for the position-angle, by their agreement determine the place at the time with substantial accuracy; and measures on three nights this year, with the large refractor, must give the place with very little error. With all the angles in the same quadrant, the motion would be practically uniform, as there is but little change in the distance. If the first and last measured angles are assumed to be correct, then there would necessarily be an error of about 15° in Engelmann's angle, which is not probable in the work of this excellent observer. The first three measures all agree in placing the smaller component in the first quadrant, while in the later measures it was obviously in the third quadrant. If this arrangement of the angles is correct, the apparent ellipse is a very extraordinary one, since the primary star must lie very near its circumference in order to satisfy the law of equal areas in equal times, and, notwithstanding the rapid angular motion in the last seven years, the period must be rather long, probably more than one hundred years. In this case the change from this time will be comparatively slow. The measures of one more year will probably show conclusively whether any mistake has been made in the relative magnitudes of the components.

The place of this star (1880) is:

R. A. $13^h\ 33^m\ 40^s$
Decl. 11° 21′

LICK OBSERVATORY, June 15, 1891.

THE CAMERA FOR CELESTIAL PHOTOGRAPHY.

BY S. W. BURNHAM, LICK OBSERVATORY.

Every possessor of a good rectilinear lens and the ordinary landscape camera may not be aware of the fact that he has the best kind of an instrument for making pictures of the sky. The requirements in a lens for landscape photography are exactly the same as those which have to be considered in the department of celestial photography. About the same angle of aperture is desirable, and in a general way, the same class of lens as in landscape and out-door photography. To get a satisfactory picture of a portion of the heavens at night, as we see it with the naked eye, the picture should include an angle of not less than 30° or 40°. There is this difference between terrestrial and celestial pictures: in the former we rarely get as much as we can readily see with the naked eye from the point where the picture is taken, while in the latter we can easily get infinitely more by prolonging the exposure. If the exposure is much extended in daylight work, the plate is hopelessly fogged, and instead of increasing the details in the darker portions of the picture, nearly all delicate details are lost, and the negative becomes flat and valueless; but with the plate exposed to the dark sky of a clear night, where the light emanates only from minute points, the exposure may be continued for hours, and when the plate is developed it will be almost clear glass except where those specks of light have made their impression. Negatives of this character possess this unique peculiarity, that no matter how long the exposure may be continued, they are always under-exposed with reference to the great majority of the stars shown; and at the same time, unless the exposure is very short, they are over-exposed with regard to the brighter stars visible to the eye. The longer the exposure, the more stellar points we get on the plate, and this could probably be continued far beyond the time one would be likely to give to the following of the stars as they move across the face of the sky.

Almost every amateur photographer has a lens and camera well adapted to do this work, but unfortunately not many have the means of mounting such an instrument so as to hold the stars fixed on the plate during the necessary time of the exposure. For this purpose an equatorial mounting, driven by clock-work, is indispensable. In other words, the photographer must have the use of an equatorially mounted telescope of some kind, with a driving-clock so adjusted as to compensate for the revolution of the earth on its axis, and keep the camera and the stars relatively fixed, the telescope itself being used as a sort of a finder, to keep the star, selected for following exactly in the same place in the instrument by changing the position of the telescope and the camera attached to it with the slow motions with which all such instruments are provided. No driving-clock, however perfectly made and adjusted, can be trusted to hold the star exactly on the fine wire or spider-web in the focus of the telescope for any considerable length of time. This must be done by watching the finder, and whenever the star shows a tendency to get ahead or fall behind the bisecting wire, bringing it back to position by the slow motions which move the instrument independently of the clock. Everything depends on careful following and keeping the images of the stars all the time on exactly the same places on the plate. If this is not attended to, the stars will be elongated in the direction of their motion across the plate, and the negative will be unsatisfactory for any purpose. In addition to this, the fainter stars will be lost by the images spreading over the greater area on the plate. If the following is perfect, and the camera is accurately focussed, the smaller stars will be exceedingly minute specks, and if the exposure is an hour and upwards, there will be thousands of these tiny points scattered over the plate where perhaps only a score or two of stars are visible to the naked eye, while not a dozen of them could be seen at all on the ground glass of the camera.

Of course not many photographers have the necessary facilities for making pictures of this kind. If, however, some friend or good-natured astronomer has a small telescope of the kind referred to, which can be made available, the thing is easily managed. The camera can be strapped or tied to the tube of the telescope in a few minutes, and then everything is ready to proceed with the exposure. The camera should be focussed previously with the utmost care, using the full aperture on a well-defined distant object, and then marked or clamped in such a way that nothing can be changed when the camera is attached to the telescope. It is almost indispensable that the full aperture should be used if the exposure is to be continued long enough for the fainter stars, as otherwise the time would be greatly increased, with very little corresponding gain. Any good rectilinear lens will give sharp images over a sufficient portion of the plate, provided it is accurately focussed. In most uses of the lens this is not an important matter, because any ordinary error is corrected by the use of stops, but in stellar pictures a small error in the position of the lens will utterly spoil a plate which otherwise would have been entirely satisfactory.

It will be found very convenient to have one of the common simple shutters attached to the camera lens, with a tube and bulb running down to the eye-piece, so that the lens can be closed in an instant if anything goes wrong. The clock may need winding, and the dome shifted from time to time, and, although with a good driving-clock the observer can leave the instrument long enough to attend to such matters, it is safer to be able to shut off the light in the event of the clock stopping, or any accident occurring, Then the instrument can be brought back to the original place, and when everything is all right, the exposure continued as long as may be desired.

It is perhaps now generally known that the exquisite pictures of the Milky-Way, and other portions of the heavens, made by Professor E. E. Barnard of the Lick Observatory, were made with an ordinary portrait lens tied to the tube of a six-inch telescope. These pictures have never been excelled by anyone ,and rarely, if ever, equalled. They show, as pictures taken with no photographic telescope could, the wonderful structure of the invisible heavens with the millions of stars lying beyond the reach of the unaided eye. The number of individual stars shown on a single 8 × 10 plate, and that of a region not in the Milky-Way, and in which but few stars are seen with the eye, is estimated to be not less than 60,000. This required an exposure of about four hours, using an aperture of about one-sixth of the focal length of the lens. Such pictures require the greatest care in making the exposures, and extreme skill in developing the plate to get the best results. But very interesting pictures can be made in less time. With an hour or an hour and a half, a vast number of telescopic stars will be shown, and such a negative of a prominent constellation, like Orion or Ursa Major, will repay the amateur for all the trouble it may cost to get it. Lantern slides from such negatives are more wonderful and interesting than any other stellar photographs. When thrown upon the screen, it is difficult for many to believe that such a wilderness of stars could be really photographed with a lens, through which not one in a thousand could be seen on the ground glass.—*From Anthony's International Annual of Photography, 1891.*

ON THE ORBITS OF METEORS.

W. H. S. MONCK, DUBLIN, IRELAND.

FOR THE MESSENGER.

The recent work of Dr. Kleiber on the orbits of meteors is probably the fullest that has yet appeared. It has two disadvantages: first that it is written in Russian with the exception of an English abstract (on which alone, together with the figures, I have rèlied) and secondly that it is full of typographical errors which are by no means completely corrected in the table of errata. The computation of orbits corresponding to Mr. Denning's 918 radiants, however, was a gigantic task, and can hardly fail to prove an useful one. Mr. Denning's Catalogue, I should observe, is not very suitable for drawing inferences as to the properties of radiants generally, because it contains numbers of determinations of the same radiant in different years. But when we come to deal with the results numerically we often find contrasts much too great to be accounted for in this way.

I cannot find that Dr. Kleiber's results afford any explanation of stationary radiants, and their existence appears so certain as a fact (if, indeed, all radiants are not stationary) that this defect seems to me to show that the current theory on the subject is incomplete—in other words that the motions of meteors in the air depend in part on some cause which has not yet been detected. I suggested the impulse of the air on the meteor as the cause which had been neglected, but this does not seem very satisfactory. The problem has yet to be solved.

Dr. Kleiber's results were supposed to confirm the shifting of the Perseid radiant which Mr. Denning had inferred from his observations. This seems somewhat doubtful. Dr. Kleiber's idea is that the Perseid meteors form a ring having a definite orbit in space. In this case the elements *i* and $\pi - \Omega$ in the computed orbits ought to be constant—which condition Dr. Kleiber thinks Mr. Denning's Perseids fulfil "tolerably well." It is at all events not more than "tolerably" well, seeing that for the first radiant in his catalogue which Mr. Denning calls a Perseid the value of *i* is 107°.9 and of $\pi - \Omega$ 162°.1*, while for the last Perseid radiant the corresponding values are $i = 113^\circ.5$, $\pi - \Omega = 142^\circ.7$. It may be worth noting that at an ascending node, where the orbit passes from the S. to the N. of the ecliptic, the meteor-tracks, if projected backwards, must intersect to the S. of the ecliptic; while for a similar reason at the descending node they must intersect to N. of it. Hence a northern radiant (a radiant with N. latitude) implies that the meteor is seen at the descending node, and a southern radiant implies that it is seen at the ascending node. An observer in the latitude of Bristol naturally sees a larger number of meteors belonging to northern than to southern radiants; and of Mr. Denning's 918 radiants only 96 appear to be southern. This peculiarity, however, probably depends on the observing station and does not indicate any law of the distribution of radiants.

If I walk along a train-line I meet a larger number of trains than those which overtake me, and for the same reason we might expect to encounter more meteors whose motions were retrograde than those whose motions were direct; the difference being more marked at small inclinations. Dr. Kleiber's Catalogue, however, shows the contrary. Orbits with direct motion predominate especially at small inclinations. For inclinations of less than 10° more than two-thirds of the meteors are direct. This reminds us of the comets of short period whose motions are in almost all cases direct and their inclinations small, and meteors of this class are worth watching to see whether they exhibit a six or seven years' periodicity like the comets in question.

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* Whether designedly or by a typographical error Dr. Kleiber omits the letter P. (Perseid) after this radiant.

The Catalogue exhibits some very remarkable features with regard to the value of $\pi - \Omega$. Among 918 radiants we should expect to find about 150 with a value of 0° to 60° for $\pi - \Omega$. There are in fact only 17. But this is not all; 15 of the 17 are among those in which the meteors are seen at the ascending instead of the descending node. In no case where the meteors are at the descending is $\pi - \Omega$ less than 36°. Moreover the same deficiency occurs for meteors at the ascending node when the value of $\pi - \Omega$ is between 180° and 240°. Nor does the deficiency cease at these points. For values of $\pi - \Omega$ between 60° and 120° we have only about 60 orbits instead of 150, and in more than one-half of these 60 the meteors were seen at the ascending node. For values of $\pi - \Omega$ between 300° and 360° there is also a deficiency (the number being again about sixty), but the great majority of these showed meteors at the descending node. There is, of course, a corresponding crowding for values of $\pi - \Omega$ between 120° and 300°. The result appears to be that meteors are not seen unless the node is tolerably near the perihelion. In fact, if V stands for the node which we are considering, the chance against seeing any meteors is enormous if $\pi - V$ lies between 180° and 240°, while it is considerable for all values of $\pi - V$ between 120° and 300°. I fail to see any physical cause capable of explaining this singular state of things, and can only suggest that the force (whatever it be) that has been neglected in these computations has the effect of making the node appear to be nearer to the perihelion than it really is.

Another remarkable fact is that during the first six months of the year, when the earth is receding from the sun, the direct orbits out-number the retrograde in the proportion of four to one, while the retrograde orbits are more numerous during the latter half-year.

Having touched on the question of meteoric rings I may mention that such rings appear to be more strongly indicated by Dr. Kleiber's figures in some other cases than in that of the Perseids. Here is one for instance:

No. in lat.	Radiant.	i	$\pi - ☊$	Date.
119	272 + 21	92.9	236.9	Apr. 25.
208	329 + 36	92.4	237.4	July 12.
493	16 + 54	94.0	243.1	Sept. 5.
521	20 + 56	90.6	240.2	Sept. 13.
672	70 + 65	94.0	243.7	Oct. 15.
812	140 + 65	87.0	239.7	Nov. 25.
873	161 + 58	90.9	237.2	Dec. 9.
909	177 + 49	92.8	243.0	Dec. 28.

This of course is only intended as a specimen. There would seem to be a grand ring with a radiant situated not far from the pole of the ecliptic into which most of the Draconids enter.

In conclusion I may notice that as the tangent at the perihelion is perpendicular to the line joining the perihelion to the sun, any force perpendicular to the line joining the meteor to the sun will make the perihelion seem nearer than it is. But the earth's orbit being nearly circular a force directed along it will be nearly perpendicular to this line. Consequently a force directed along the earth's orbit, and neglected by the computer, will, I think, account for the peculiar features exhibited by Dr. Kleiber's Catalogue; and perhaps the conjecture which I hazarded as to the effect of the impulse of the air upon the meteor may not be so wide of the mark as my mathematical friends imagine.

PHOTOGRAPHING WITH A NON-PHOTOGRAPHIC TELESCOPE.

PROFESSOR E. E. BARNARD, LICK OBSERVATORY.

We are familiar with the fact that when a ray of white light passes through a prism, it is separated into a band of brilliant colors, red at one end and blue or violet at the other. This is called a spectrum. It has been found that different portions of this spectrum have vastly different effects upon the ordinary photographic plate when exposed to its action. This effect is called *actinic energy*. The greatest actinic energy comes from the ultra violet, in the region of the hydrogen line G. It diminishes rapidly in going down the spectrum, and ceases near the line F. Still further down the spectrum occurs the brightest part in the yellow near the sodium line.

All lenses act more or less as prisms, and the light passing through them is separated into the primary colors, and these are each refracted differently, and come to a focus at different points along the optical axis. By the proper combination of glasses of different refractive indices, and by grinding the surfaces of the lenses to certain curvatures, opticians have been able to re-combine a few of these rays, and to bring them to one focus to form a sharp image, but it is impossible to bring all the rays together again.

As the yellow region of the spectrum will give the brightest image, all telescopic object-glasses are so constructed as to utilize that particular portion. Hence, in making an object-glass, the extreme ends of the spectrum are neglected, and those rays are either scattered, or have their focus at some other point than that occupied by the visual image.

In the photographic lenses that are in every-day use, opticians have been able to make the visual and the chemical foci coincide more or less accurately by averaging the foci of the different parts of the spectrum, so that when the image is sharp on the ground glass, it will give a sharp impression on the sensitive plate.

When, however, a telescopic object-glass is constructed, other requirements enter into consideration. The image must be more perfect than in the photographic lens, as it will have to be greatly magnified. Every ray, therefore, that goes to make up the image must come exactly to the same focal point; any deviation from this and the result would be blurred. On account of the longer focus in the telescopic objective, the visual and the chemical foci are hopelessly separated.

This yellow region, from which the visual image is formed, is devoid of actinic energy (hence the yellow light for dark rooms). If the image in the telescope is sharply focussed on a ground glass, it will not give a sharp picture, for the visual image will have no effect on the plate; there will be a blurred impression, however, from the actinic image, which will be out of focus at that point. Hence telescopes that are used for celestial photography must be specially corrected for the actinic rays, and are worthless for visual purposes. The great 36-inch refractor of the Lick Observatory has a "correcting lens" which, when placed over the visual objective, converts it into a photographic lens by bringing the chemical rays to a sharp focus. When this correcting lens is on, the telescope cannot be used visually.

A good many people have, perhaps, tried to photograph with a non-photographic telescope, and have been disappointed with the result because the image was blurred. It is possible, nevertheless, to get extremely satisfactory pictures with any good refracting telescope, but as the visual and chemical foci do not coincide, it is necessary to find the position of the latter with reference to the visual focus. The actinic image is totally invisible on the ground glass, and we have to grope for it in the dark as it were. Its position can easily be found by experiment. Perhaps the following is the best method with a large and properly mounted telescope. A suitable attachment is made to carry the ground glass and plate holder; this takes the place of the eye-piece, and is supposed to be adjusted for changing the focus. If the telescope is directed to a star and allowed to remain stationary, the star will pass across the field of view by the rotation of the earth. Focus the image carefully on the ground glass. It should appear as a tiny point of light. Record this position of the tube. Substitute now the sensitive plate, and adjust the instrument so that the star shall cross the field; give an exposure of, say, half a minute, the telescope remaining stationary. Draw the tube out now about 0.05 of an inch and repeat the exposure. Continue this a number of times, taking care after each exposure to shift the telescope in altitude so that successive trials shall not fall on each other. When the plate is developed it will contain a series of lines or trails produced by the light of the star as it crossed the plate. Some of these will be blurred, but it will be seen that they successively become sharper until one is found that is perfectly sharp (if the experiment has been carried far enough). This will have been made at the chemical focus. The record for this trail compared with the reading when the image was in focus on the ground glass will be the correction to the visual to obtain the chemical focus. Hence, when a photograph is to be made, the image is sharply focussed on the ground glass, the telescope is then adjusted to the chemical focus, and the resulting picture should be sharp. I have said to move the plate away from the object glass in the search for the actinic focus, because in my experience with four different telescopes, the chemical focus was outside the visual in each case. This focus, may, however, prove to be inside or towards the objective. To identify the first or last trail on the plate, it is only necessary to cover the objective for several seconds during the first or last exposure, and then, by breaking the trail, identify it with certainty.

I have thus experimented with four telescopes and found that in each case they gave very satisfactory photographs at the chemical focus. These were the 6-inch Cooke equatorial, of the Vanderbilt University, Nashville, Tenn., (the chemical focus of this instrument is 0.17 inches outside the visual); a 3¼-inch Clark objective (0.10 inches outside); a 6½-inch Clark equatorial (0.12 inches outside); a 12-inch Clark equatorial (0.24 inches outside). The last three are of the Lick Observatory.

When the amount of light is not of special importance, as in the case of the sun (at an eclipse) or the moon, the image is very much improved by reducing the aperture. Thus with a 3¼-inch Clark objective, reduced to 1¾ inches, photographs were obtained of the corona of the total eclipse of the sun of January 1, 1889, that were comparable in quality with those made at the same eclipse with a 13-inch, specially corrected, photographic telescope. And with the 6½-inch telescope, cut down to 3 inches, Mr. Burnham secured admirable photographs of the corona at Cayenne, South America, during the total eclipse of Dec. 22, 1889. With the same instrument (6½-inch) and an hour and a half's exposure (full aperture) perfectly satisfactory pictures of thirteenth magnitude stars were obtained. These stars were just visible to the eye in the same instrument. Very satisfactory photographs of the moon have been made with the 12-inch, though none of these telescopes are corrected for the chemical rays, and are called non-photographic.

In these experiments a small, flat brass box to carry the plate holder, and fitted to screw onto the telescope in place of the eye-piece holder, was used. This had a narrow slit through which a cardboard slide, with an exposing aperture, could be shoved across in front of the plate in making the exposure.

For the brighter naked-eye stars, an instantaneous exposure is necessary. For the moon, one or two seconds when half full, and 0.2 or 0.3 of a second when full. For making direct enlargements in the telescope, an ordinary negative or positive eye-piece can be employed, but the tube carrying the plate-holder must be very much longer. The correction from the visual to the chemical focus will be the same whether an enlarging lens is used or not. When other than instantaneous exposures are required, it is necessary that the telescope be made to follow the object accurately throughout the exposure.—*From Anthony's International Annual of Photography, 1891.*

THE HISTORY OF THE TELESCOPE.*

PROFESSOR C. S. HASTINGS, YALE UNIVERSITY.

There is no instrument which has done so much to widen the scope of human knowledge, to extend our notions of the universe, and to stimulate intellectual activity, as has the telescope, unless the microscope be regarded as a successful rival. But even admitting a parity in scientific importance, the former instrument is incomparably more interesting in its history, in the same degree that its history is more simple and more comprehensible. To trace its development from a curious toy in the hands of its discoverer, for we shall see that this term is more appropriate than inventor, to the middle of this century, is to be brought into contact with most of the great philosophers from the time of the renaissance, who have achieved greatness in physical science, Galileo, Torricelli, Huyghens, Cassini, Newton, Halley, Kepler, Euler, Calaiault, the Herschels, father and son, Fraunhofer, Gauss—from only a portion of the list of great names. Its growth towards perfection has constantly carried with it increased precision in the applied sciences of navigation and of all branches of engineering. It would be easy to show that even pure mathematics would be in a far less forward state had there been no problems of astronomy and physics

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* Address delivered at the dedication of the Goodsell Observatory of Carleton College, Northfield, Minn., June 11, 1891.

which were first suggested by the employment of the telescope. It is to this history that I venture to invite your attention this evening. I purpose to review succinctly the origin and development of this potent aid in the study of nature, to name some of the more important achievements depending upon it, and to trace its gradual improvement to the magnificent and complicated instrument which constitutes the modern equatorial. After this sketch I shall try to give an idea of the imperfections which the conscientious artisan has to contend with in attaining perfection, and to make clear the methods which have been employed in reducing these imperfections in the noble instrument now erected at this institution,* and explain why its possessors are so hopeful of gratifying success.

Galileo learned in 1609, while visiting Venice, that a marvelous instrument had been invented the preceding year in Holland, which would enable an observer to see a distant object with the same distinctness as if it were only at a small fraction of its real distance. It required but little time for the greatest physicist of his age to master the problem thus suggested to his mind, and after his return to Padua, where he held the position of professor of mathematics in the famous university of that city, he set himself earnestly to work making telescopes. Such was his success that in August of the same year he sent to the Venetian Senate a more perfect instrument than they had been able to procure from Holland; and in January of the next year, by means of a telescope magnifying thirty times, he discovered the four satellites of Jupiter. This brilliant discovery was followed by that of the mountains in the moon; of the variable phases of Venus, which established the Copernican theory of the solar system as incontestible; and of the true nature of the Milky Way, together with many others of less philosophical importance. Though Galileo did not change the character of the telescope as it was known to its discoverer in Holland, he made it much more perfect, and, above all, made the first and most fertile application of the instrument to increase the bounds of human knowledge, so that it is inevitable that his name should be indissolubly connected with the instrument. Thus the form which he used is to this day known as the Galilean telescope.

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* Carleton College.

Considering the enormous interest excited throughout intellectual Europe by the invention of the telescope, it seems surprising that its early history is so confused. Less than two years after it was first heard of, a discovery, perhaps the greatest of a thousand years in the domain of natural philosophy, had been made by its means. Notwithstanding these facts, the three contemporary, or nearly contemporary, investigators assign the honor to three different persons, and if we should write out the names of all those to whom more modern writers have attributed the invention the list would be a long one. The surprise will not be boundless, however, if we consider the task before a historian in the next century who undertakes to justly apportion the honor of the invention of the telephone among its numerous claimants. The analogy, though suggested in the obvious fact that the telephone is to hearing just what the telescope is to sight, may be made much closer if we could imagine the future historian deprived of all but verbal description, that contemporary diagrams and models were wholly wanting. Under such conditions it is difficult to believe that the historian would easily escape antedating the discovery of the telephone proper on account of descriptions, generally imperfect, of the acoustic telephone. But this would fairly represent the condition of the material at the command of an investigator of the present day into a question of science of the early part of the seventeenth century. No wonder, then, that the invention has been attributed to Archimedes, to Roger Bacon, to Porta, and to many others who have written on optics; but to find the name of Satan in the list is certainly surprising. Still we read that a very learned man of the 17th century, named Arias Montanus, finds in the fourth chapter of Matthew, eighth verse, evidence that Satan possessed, and probably invented a telescope; otherwise, how could he have 'shown Him all the kingdoms of the world and the glory of them'?* It seems to be well established now, however, that Franz Lippershey, or Lippersheim, a spectacle maker at Middleburg, was the real inventor of the telescope, and that Galileo's first telescope, avowedly suggested by news of the Hollander's achievement, was an independent invention.

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* The history of the telescope is admirably treated in Poggendorff's Geschichte der Physik, from which the statements above are taken.

That this discovery was really an accident we may be quite sure, for not only was there no developed theory of optics at that time, but even the law of refraction, which lies at the basis of such theory, was quite unknown. So, too, it seems to me quite certain that Galileo's invention must have been empirical and guided by somewhat precise information, such as that the instrument consisted essentially of two lenses of which one was a magnifying, and the other a diminishing lens. At least, that Galileo's telescope was like that of the Hollander; that, theoretically considered, it is not so simple as that made of two magnifying lenses, as is evinced by the fact that Kepler, the first philosopher to establish an approximate theory of optical instruments, only two years later, invented the latterand prevailing form; and, finally, that Galileo published no contributions to the theory of optics, seem quite sufficient reasons for such a belief. But, in any case, Galileo's merit is in no wise lessened by having failed to do what could not be done at that time, and the value of his discoveries in emancipating men's minds from authority in matters of pure reason is incalculable.

No other discoveries of great moment were made until over a generation after Galileo proved the existence of spots on the sun in 1611. This cessation of activity was doubtless owing to the difficulty of securing telescopes of greater efficiency than that possessed by Galileo, and which he would hardly have left until its powers of discovery had been fully exhausted in his own hands. By the middle of the 17th century, however, several makers of lenses had so far improved the methods of grinding and polishing, that telescopes notably superior in power to that of Galileo were procurable. Of these Torricelli, Divini, and Campani, all Italians; Auzout, who constructed a telescope 600 feet in length, though no means was ever found for directing such an enormous instrument towards the heavens; but above all, Huyghens, have won distinction as telescope makers. The last named philosopher discovered by means of a telescope of his own construction, the largest satellite of Saturn in 1655, thus adding a fifth member to the list of planetary bodies unknown to the ancients. But his most important astronomical discovery, made also in 1655, was the nature of the rings of Saturn. This object had greatly puzzled Galileo, to whose small telescope the planet appeared to consist of a larger sphere flanked on either side by a smaller one; but when in the course of the orbital motion of Saturn the rings entirely disappeared he was wholly unable to suggest an explanation. This planet had thus presented a remarkable problem to all astronomical observers for more than forty years, and the records of the efforts to solve it during that interval afford us a most excellent means of judging the progress in practical optics. Huyghens announced these discoveries early in 1656, but that relating to the ring was given in the form of an anagram, the solution of which was first published in 1659. This discovery was contested in Italy by Divini but was finally confirmed by members of the Florentine Academy with one of Divini's own telescopes.

A few years later the famous astronomer Cassini, having come to Paris from Italy as Royal Astronomer, commenced a series of brilliant discoveries with telescopes made by Campani of Rome. With these, varying in length from 35 feet to 136 feet, he discovered four satellites to Saturn in addition to the one discovered by Huyghens. The whole number was increased by Herschel's discovery of two smaller ones in 1789, a hundred and five years after Cassini's last discovery, and again by Bond's discovery of an eighth in 1848. The Saturnian system, to which the telescope has doubtless been directed more frequently than to anything else, thus serves as a record of the successive improvements of the telescope. Highly significant is the fact that the discoveries of the 18th century were made with a reflecting telescope, the others all being with refracting instruments.

Cassini's discovery in 1684 of the two satellites now known as Tethys and Dione, was not accepted as conclusive until long afterwards, when Pound in 1718 with a telescope 123 feet in length, which Huyghens had made and presented to the Royal Society, saw all five. This particular instrument is of especial interest because it is the only one of those of the last half of the 17th century which has been carefully compared with modern instruments. Moreover, it is without doubt quite equal in merit to any of that period. But we find that, although it had a diameter of six inches, its performance was hardly better than that of a perfect modern telescope of four inches in diameter and, perhaps, four and a half feet in length, while in regard to convenience in use the modern compact instrument is incomparably superior.

Another notable discovery of this period was that of the duplicity of the rings of Saturn by the Ball brothers in 1665, though its independent discovery by Cassini ten years later first attracted the attention of astronomers. The earlier discovery was made by means of a telescope 38 feet long which seems to have been of English manufacture. We must regard Cassini's discovery of the third and fourth satellites of Saturn, however, as marking the very farthest reach of the old form of telescope; a century was to elapse and an entirely new form of telescope was to be developed before another considerable addition to our knowledge of the aspect of the heavenly bodies was to be made. It is true larger telescopes were made, and Huyghens invented a means by which they could be used without tubes, but notwithstanding this improvement they proved so cumbersome as to be impracticable.

The older opticians had found that if they attempted to increase the diameter of a telescope they were obliged to increase its length in a much more rapid ratio to secure distinct vision. The reason of this was not clearly understood, but it was supposed to be owing to the fact that a wave front, changed in curvature by passing through a spherical surface, is no longer strictly spherical. This deviation in shape of the refracted wave from a true sphere is called spherical aberration. When the refracting surfaces are large and of considerable curvature this soon becomes very serious, but by using small curvature, which, in a telescope, obviously corresponds to great length, the effects of the error can be made insensible. Newton's discovery of the composite nature of light and of the phenomenon of dispersion enabled him to explain the true cause of indistinctness in short telescopes; namely, that the refraction by the objective varies for different colors; consequently, if the ocular is placed for one particular color, it will not be in the right position for any of the others, whence the image of a star or planet will seem to be surrounded by a fringe of colored light. Newton found this source of indistinctness in the image, which is now known as chromatic aberration, many hundred times as serious as the spherical aberration. As he was persuaded by his experiments that this obstacle to further improvement in the refracting telescope was insuperable, he turned his attention to a form of telescope which had been suggested a number of years earlier in which the image was to be formed by reflection from a concave mirror, and constructed a small one with his own hands which is still in the possession of the Royal Society. This little instrument seems to have been of about the same power as Galileo's instrument with which he discovered the satellites of Jupiter, but it was hardly more than six inches in length.

Since that time the reflecting telescope has had a remarkable history of development in the hands of a number of most skilful mechanicians, who have also for the most part been distinguished by their discoveries in physical astronomy; we may, therefore, advantageously depart from the chronological treatment and follow the history of this type of instrument. This course is the more natural because we may probably regard the supremacy of the reflector, undisputed a century ago, as passed away forever.

Even after Newton's invention was made public little was done towards the improvement of telescopes for half a century, until Hadley presented a reflector of his own construction to the Royal Society in 1723 which was found to be equal to the Huyghens refractor of 123 feet in length. From this time we may date the beginning of the superiority of reflectors. A few years later Short commenced his career as a practical optician, and for thirty years he was unapproached in the excellence of his instruments. During this time many telescopes, more powerful than the best of the previous century and infinitely more convenient in use, had been made and scattered throughout Europe, but during this period also there was a singular dearth of telescopic discovery. Perhaps men thought that the harvest had already been gathered; or, perhaps we may find the explanation in that the great cost of telescopes so restricted their use that the impulse to discovery by their means was confined to a very small class. In view of the remarkable manner in which the stand-still in this branch of science was finally followed by a brilliant period of discovery, rivalled alone by that of Galileo, we might well regard the latter cause as the chief one.

William Herschel was born in 1738 in Hanover. In 1755 he left his native country, and, going to England, secured a position as organist in Octagon Chapel, Bath, where we find him in 1766. Here he became so profoundly interested in the views of the heavens which a borrowed telescope of moderate power yielded, that he tried to purchase one in London. The cost of a satisfactory instrument proving beyond his command, he determined to construct one with his own hands. Thus he entered upon a course which was to reflect honor upon himself, his country, and his age, and which was to add more to physical astronomy than any other one man has added before or since. With almost inconceivable industry and perseverance he cast, ground, and polished more than four hundred mirrors for telescopes, varying in diameter from six to forty-eight inches. This in itself would imply a busy life in any artisan, but when we remember that all this was merely subsidiary to his main work of astronomical discovery, we cannot withhold our admiration.

Fortunately for science as well as for himself, he made early in his career a discovery of the very first importance which attracted the attention of all Christendom. On the night of March 13, 1781, Herschel was examining small stars in the constellation of Gemini with one of his telescopes of a little more than six inches in diameter, when he perceived one that appeared "visibly larger than the rest." This proved to be a new world, now known as Uranus. The discovery led in the following year to his appointment as astronomer to the king, George III, with a salary sufficient to enable him to devote his whole time to astronomy.

One of the fruits of this increased leisure was the construction of a telescope far more powerful than had been dreamed of by his predecessors, namely, a telescope four feet in diameter and forty feet in length. Commenced in 1785, Herschel dated its completion as Aug. 28, 1789, when he discovered by its means a sixth satellite of Saturn and, less than a month later, a seventh, even closer to the planet and smaller than the sixth. We may regard this achievement as marking the limit of progress in the reflecting telescope, for although at least one as large is now in use, and one even half as large again has been constructed, it is more than doubtful whether they were ever as perfect as Herschel's at its best.

There has been one improvement, however, in the reflecting telescope since the time of Herschel which ought not to be left unnoticed here, namely, that of replacing the heavy metal mirror by one of glass, made even more highly reflective than the old mirrors by a thin coating of silver deposited by chemical methods upon the polished glass. The great advantage of this modern form of reflector lies, not so much in the greater lightness and rigidity of the material as in that the surface when tarnished can be renewed by the simple process of replacing the old silver film by a new one; whereas, in the metal reflectors, a tarnished surface required a repetition of the most difficult and critical portion of the whole process of construction. The construction is also so comparatively simple that an efficient reflector is far less expensive than are refracting telescopes of like power, so that this may be regarded as particularly the amateur's telescope. On the other hand, such telescopes are, like their predecessors, extremely inconstant, and they require much more careful attention to keep them in working order. It is for these reasons, doubtless that silver-on-glass reflectors have done so little for the advancement of astronomical discovery. In astronomical photography, however, they promise to do much, and indeed at the present date by far the best photographs we have of any nebulæ have been made by Mr. Common's magnificent reflector of three feet in diameter, and by the twenty inch reflector of Mr. Roberts.

We must go back now to a quarter of century before Herschel discovered the new planet—to the very year, indeed when that great astronomer first set foot on English soil—in order to trace the history of another form of telescope which has remained unrivaled for the last half centnry in the more difficult fields of astronomical research, and which to-day finds its most perfect development in the instruments at Mt. Hamilton, at Pulkowa, at Vienna and at Washington.

Newton had declared that, as a result from his experiments, separation of white light into its constituent colors was an inevitable accompaniment of deviation by refraction, and consequently the shortening of the unwieldy refractors was impracticable. The correctness of the experiments remained unquestioned for nearly a century, but a famous German mathematician, Euler, did question his conclusion. His argument was, that since the eye does produce colorless images of white objects, it might be possible by the proper selection of curves to so combine lenses of glass and of water as to produce a telescope free from the color defect. Although Euler's premise was an error, since the eye is not free from dispersion, his efforts had the effect of leading to much more critical study of the phenomena involved. In this John Dolland, an English optician, met with brilliant success. Repeating an experiment of Newton's with a prism of water opposed by a prism of glass, he found that deviation of light could be produced without accompanying dispersion into prismatic colors. More than this, he found that the two varieties of glass, then as now common in England,—crown, or common window glass, and flint glass, which is characterized by the presence of a greater or less quantity of lead oxide,—possessed very different powers in respect to dispersion. Thus, of two prisms of these two varieties of glass which would deflect the light by the same angle, that made of flint glass would form a spectrum nearly twice as long as the other. Hence, if a prism of crown glass deflecting a transmitted beam of light say ten degrees, were combined with one of flint glass which would deflect the beam of light five degrees in the opposite direction, there would remain a deflection of five degrees without division into color. It also follows that a positive lens of crown combined with a negative lens of flint of half the power would yield a colorless image. Such combinations of two different substances are called achromatic systems.

It is a singular fact, worth noting in passing, that more than twenty years before Dolland's success, Mr. Chester More Hall had invented and made achromatic telescopes, but this remained unknown to the world of science until after Dolland's telescopes became famous.

For a long time this ingenious invention remained fruitless for astronomical discovery, though they were early applied to meridian instruments, on account of the impossibility of securing sufficiently large and perfect pieces of glass, more particularly of flint glass. Not until after the beginning of this century was any real advance in this branch of the arts exhibited. Even then success appeared, not in England or France where most strenuous efforts had been made to improve the quality of optical glass, but in Switzerland. There a humble mechanic, a watch-maker named Guinaud, spent many years in efforts, long unfruitful, to make large pieces of optical glass. What degree of success he attained there during twenty years of experiment, we do not know, though from the fact that during that peroid good achromatic telescopes of more than five inches in diameter were unknown, we must conclude that his success was limited. In 1805 he joined the optical establishment of Fraunhofer and Utzschneiden in Munich. Here he remained nine years and with the increased means at his disposal and the aid of Fraunhofer, he perfected his methods so far that the production of large disks of homogeneous glass became only a matter of time and cost; that is to say, all of the large pieces of optical glass which have since been produced, whether in Germany, France, or England, have been made by direct heirs of the practical secrets of this Swiss watchmaker.

Fraunhofer was a genius of a high order. Although he died at the early age of thirty-nine, he had not only brought the achromatic telescope to a degree of optical perfection which made it a rival of the most powerful of the reflector type, and so far improved its method of mounting that his system has replaced all others, but he also made some capital discoveries in the domain of physical optics. His great achievement was the construction of an archromatic telescope, nine and six-tenth inches in diameter, with which the elder Struve made at Dorpat his remarkable series of discoveries and measurement of double stars. The character of Struve's work demonstrates the excellence of the telescope and shows us that it is to be ranked as the equal of all but the very best of its predecessors. Indeed, it may fairly be concluded that not more than one or two telescopes, and those made and used by Herschel, had ever been of greater power, while in convenience for use the new refractor was vastly superior.

For a long time Fraunhofer and his successors, Merz and Mahler, from whom the great telescopes of Pulkowa and of the Harvard Observatory were procured, remained unrivaled in this field of optics. But they have been followed by a number of skilful constructors whose products have, since the middle of the century, been scattered all over the world. In Germany, Steinheil and Schröder; in France, Canchois, Martin and the Henry brothers; in England, Cook and Grubb; and in this country the Clarks and Brashear, each has produced one or more great telescopes which has rendered his name familiar to all readers of astronomical history. Of these the Clarks, father and son, have beyond a doubt won the first place, whether determined by the character of the discoveries made by means of their instruments or by the fact that the two most powerful telescopes in existence were made by them, namely, the new refractor of thirty inches in diameter at Pulkowa and the great refractor of three feet diameter of the Lick Observatory in California. The most notable discoveries made with their telescopes are the satellites of Mars and the companion to Sirius; but besides these there is a long list of double stars of the most difficult character discovered by the makers themselves, by Dawes, in England; by Burnham, in our own country, and by a number of other observers.

We ought not to terminate our review of the development of the telescope without a reference to the parallel development of the mounting of great telescopes. Indeed, did this not lead us too far from the immediate aim in view, we might find a great deal of interest and be brought into agreeable contact with some of the cleverest mechanicians and engineers of two centuries, by tracing its course. We should meet with Huyghens, as the inventor of the aerial telescope, and perhaps consider the claims of his contemporary Robert Hook, as a rival inventor, for we may be sure that nothing which brings us to a study of that curious and able philosopher would fail to possess interest. We should find Herschel confronted with the problem as to how he should use his great forty-foot telescope, and the study of his solution would guide us in valuing the results of the subsequent efforts of Lassel and Rosse. The same line of study would bring us to Grubb's clever and interesting equatorial mounting of that anachronism, the four foot Melbourne reflector. But we should find nothing of very notable interest in the mounting of refractors, after the time of Huyghens and Hook, until Fraunhofer invented a type of mounting for the famous Dorpat equatorial which still remains in its essential features as the type in universal use. With the increase in size of the telescopes to be directed towards the heavens, however, the number and complexity of the mechanical problems to be solved has been vastly increased, so that they have taxed the best powers of some of the ablest mechanicians. The Repsolds of Germany and Sir Howard Grubb of Dublin have specially distinguished themselves in this field of activity. But it seems to me that none have shown greater fertility of resources, greater skill in the solution of every problem affecting the comfort and efficacy of the observer, and greater taste combined with accurate workmanship, than have the celebrated firm which has mounted the telescope at Mt. Hamilton and that at Carleton College.

We come now to a consideration of the present state of the art of lens making. We ask why such a very large proportion of the telescopes in existence are bad; why there was a time, brief it is true, during which the glass maker was certainly in advance of the demands of telescope makers; and why, finally, the first of the great modern objectives was in the hands of the most skilful optician in Great Britain for seven years, and even then this maker asserted that it was incomplete.

These questions cannot be answered in a word, but we can, at least, gain much in perspicuity by recognizing that the reasons are of two distinct kinds, namely, purely technical and theoretical, and by regarding them briefly in succession.

The art of lens making can be certainly traced back to the 13th century though the methods at a much later day than that were so rude that, as we have seen, Galileo had the utmost difficulty in making a lens good enough to bear a magnifying power of thirty times. At the present day there is little difficulty in selecting a spectacle glass which would rival that most famous of all telescopes. Not until after another generation of effort was there such notable improvement in the technique of lens making that further astronomical discovery was possible. The reasons for this slow progress are to be found in the extremely critical requirements for a good lens. A departure by a fraction of a hundred-thousandth part of an inch from a correct geometrical surface will greatly impair the performance of an objective. But even at this day the limit of accurate measurement may be set at about a one-hundred-thousandth of an inch, while it is quite probable that ten times that value was vanishingly small to the artisans of a century or more ago. It was necessary, therefore, to devise a method of polishing—for it is a comparatively simple matter to grind a surface accurately—which should keep the surface true within a limit far transcending the range of measurements. Huyghens is the first who seems to have done this, by polishing upon a paste which was formed to the glass and then dried, and by using only the central portion of a large lens. In Italy Campani developed a system which he most jealously guarded as a secret until his death, consisting of polishing with a dry powder on paper cemented to the grinding tools. This method still survives in Paris to the exclusion of almost all others, and it is probably the best for work which does not demand the highest scientific precision.

Newton, however, was the first to introduce a method which has since been developed to a state of surprising delicacy. Casting about for a means which should be sufficiently "tender", to use his own expression, for polishing the soft speculum metal, he fixed upon pitch, shaped to the mirror while warm as a bed to hold the polishing powder. But the enormous value of this substance lies not so much in the comparative immunity which it gives from scratching, but in the fact that under slowly changing forces it is a liquid, but under those of short duration it behaves like a hard and brittle solid. Thus it is possible to slowly alter the shape of a lens while polishing, in any desired direction. It was only after the practical recognition of this fact that really excellent lenses were much more than a question of good fortune. The perfecting of this method belongs without doubt to the English of the last century and the early part of this. In the Philosopical Transactions we find many long papers relating to this art, contributed by skilful and successful amateurs. We may, therefore, regard the technique of the art of lens making as practically complete at the middle of this century and as common property, so that success no longer depends upon the holding of some special or secret method.

We are now, after this, I fear, somewhat dry discussion of a necessary point, in a condition to explain the differences between the processes pursued by most telescope makers and that of the maker of the Carleton College telescope.

This is the ordinary method: After securing perfect pieces of glass, crown and flint, as like as possible to those generally used, and having fixed upon the general shape of the lenses, a guess is made as to the proper radii of the four surfaces to determine the desired focal length and corrections both for color and spherical aberration. The success of this guess has much to do with the necessary outlay of labor, and therefore past experience is of great value as a guide. After working the four surfaces to the dimensions provisionally adopted so far as to admit of fairly good seeing through the objective, an examination of the errors is made. Should the errors of color be so small that their final correction will not make the telescope more than from three to ten per cent. greater or less than the desired focal length, the crown lens will probably be completed in accordance with the provisional figures. Then the flint lens will be modified in such a direction as will tend to correct the observed errors of color and figure, until, by a purely tentative process, the color error is practically negligible and the error of figure is small. Then follows a process when the qualities of skill, conscientiousness and perserveance have full scope. This process first introduced, or at least made public by Foucault, is known as local correcting. It consists in slowly polishing away portions of the lens surfaces so that errors in the focal image become so small, not that they cannot be detected, but that one cannot determine whether they are on the one side of truth or the other. Local correcting has always seemed to me to be eminently unscientific and unnecessary. It is a process of making small, errors which ought not to exist.

Mr. Brashear's method is essentially different from this. Before the glasses are touched every dimension and constant of the finished objective is known with great accuracy. His whole aim is to make the surfaces geometrically perfect; and by ingnious polishing machinery which embodies twelve years of his thought and experience, he is enabled to do this with truly astonishing exactness. All the surfaces which admit of investigation—usually three in his ordinary construction—are made rigidly true without regard to the character of the focal image. This leaves only one surface which is known to be very nearly a sphere but probably deviating slightly within in the direction of a prolate or oblate spheroid. A glance at the character of the focal image will determine this point. Then the polishing machine is adapted to bring about a change in the proper direction and, after action during a measured interval of time, the image is again examined and from the observed change in character the necessary time for complete correction by the same or contrary action may be deduced. It will be observed that by this means it is quite possible to correct errors which are much too small to betray their nature, since a step in the wrong direction carries with it no consequences of the slightest moment, since any step may be retraced.

When we learn that Mr. Brashear's telescope objectives have always had a focal length differing only from one-tenth to one one-hundred and eightieth of one per cent. of the value prescribed, we have a suggestion of the success of his efforts. But adding to that the fact that he is absolutely untrammelled by purely mechanical considerations, either as to the shape of his lenses or the character of his materials, leaving these questions to be decided alone by the requirements of the astronomer, it seems to me that we may fairly accord to him the merit of the most important improvements introduced into his art for a very long period.

I shall not venture to demand much of your time in considering the purely theoretical difficulties in telescope construction, not merely because the subject has already taxed our patience, but because it would be of almost too technical a character did we allow ourselves to regard anything but the most general features.

The obvious requirements are that in a good objective the light coming from a point in the object should be concentrated at a point in the image; but this, combined with a prescribed focal length, may be reduced to three conditions: first, a fixed focal length; second, freedom from color error;

third, freedom from spherical aberration for a particular color or wave-length of light. Now let us catalogue what provisions we have for satisfying these conditions. They are, four surfaces, which must be spherical but may have any radii we please, the two thicknesses of the two lenses, and the distance which separates the lenses; that is, *seven* elements which may be varied to suit our requirements. As a matter of fact, however, on account of the cost of the material and the fact that glass is perfectly transparent, for powerful telescopes we must make the lenses as thin as possible; and we shall find also that separating the lenses introduces errors away from the axis which are, to say the least, undesirable. We have left, therefore, only the four radii as arbitrary constants. These however are more than enough to meet the three requirements. To make the problem determinate we must add another condition. The suggestion of this fourth condition and carrying the problem to its solution is the work of the great mathematicians who have directed their thought to it. Clairault proposed to make the fourth condition that the two adjacent surfaces should fit together and the lenses be cemented. This condition would be doubtless of great value were it possible to cement large lenses without changing their shapes to a degree which would quite spoil their performance. Sir John Herschel published a very important paper in 1821 in which he made the fourth condition that the spherical aberration should vanish for objects at a very great distance but also for those at a moderate distance. In this paper he computed a table, afterwards greatly extended by Professor Baden Powell, for the avowed purpose of aiding the practical optician. It was this feature undoubtedly which brought his construction, not at all a good one as we shall see, into more general use than any other for some time. But, as all Herschel's tables were derived from calculations which wholly disregard the thickness of the lenses, I am quite unable to see how they could have been of any material aid, and am inclined to suspect that the discredit with which opticians have received the dicta of mathematicians concerning their instruments may have been due in part to this very fact. It is a singular fact for which I have in vain sought the explanation that Fraunhofer's objectives are of just such a form as to comply with the Herschelian solution although they must have been made quite independently.

Gauss made the fourth condition that another color or wave-length of light should be also free from spherical aberration. This seems to have been a *tour de force* as a mathematician, not as a sober suggestion of an improvement in construction, for in point of fact the construction is very bad. It was generally believed that this condition could not be fulfilled, therefore Gauss, who was particularly fond of doing what all the rest of the world believed impossible, straightway did it. There has been only one effort to carry out this suggestion of Gauss, and that forty years later by Steinheil, but it proved a disappointment. A much larger objective made by Clark a few years ago of the general form of Gauss's objective probably does not meet the Gaussian condition—at least this condition is extremely critical and I believe it is not asserted that the objective was ever thoroughly investigated. It has been the father of no others.

It is hardly surprising, since none of these forms have any real merit, that the practical optician has, following the line of least resistance, adopted a form which costs him less labor than those heretofore mentioned and is quite as good. By making the curve equi-convex the trouble and expense of making one pair of tools is saved, although this would hardly appear a satisfactory reason for choice of a particular form to the astronomer, who simply demands the best possible instrument of research.

The reason for so much futile work on the theory of the telescope objective is not far to seek. It had always been tacitly assumed that the condition of color correction, one of those which serves to determine the values of the arbitrary constants, was readily determinable—in fact, one of the *donne* of the problem, whereas, it is just this datum which has offered peculiar difficulties. Fraunhofer brought all the resources at the command of a genius to bear upon this point, and frankly failed although in the effort he made a splendid discovery which has assured a permanence to his fame no less than that of the history of science itself—the discovery of the dark or Fraunhofer lines, in solar and stellar spectra. Gauss proposed the condition that the best objective is that which produces the most perfect concentration of light about the place of the geometrical image of a point, just as the best rifle practice is that which produces the maximum concentration of hits about the center of the target. That this is a false guide appears at once from the consideration that if we take even as much as ten per cent. of the light from an object and diverted from the image so far that it cannot be found the telescope may still be practically perfect; all of Herschel's did much worse than this. But if you take that same ten per cent. and concentrate it very close about the image, the telescope will be absolutely worthless.

The true difficulty with most of the theorists is this: There is no recognition of the *relative weight* or importance of unavoidable errors. The optician is confronted at the very outset by the fact that absolute elimination of color error is impossible for certain physical reasons which we have not time for considering farther. He can reduce the color error of the old single lens type of telescopes hundreds of times, and hence the length of the telescope tens of times. It is this fact which prevents the still farther shortening of telescopes, which keeps the ratio of length to diameter not less than fifteen to one in large telescopes. This restriction being recognized let us revise our limiting conditions. They now become, first, fixed focal length; second, best color correction; third, freedom from spherical aberration for a particular wave-length of light. We therefore, have still one arbitrary constant undetermined. How shall we fix its value and thus solve the problem completely? Surely there is only one rational guide. Consider the residual errors and make the fourth condition such as to reduce these errors as far as possible. Now the only remaining errors are secondary color error, and spherical aberration for colors other than that for which it is eliminated, or, more scientifically, chromatic difference of spherical aberration. Which of these is the gravest defect? Our answer must depend upon the use to which the objective is to be put. If it is a high power microscope objective it is certainly the second. If it is an objective to be used for photographing at considerable angular distances from the axis, our question loses its physical significance since we have excluded the consideration of excentric refraction. But if the objective is to be for a visual telescope there is no question that the defect of secondary color error is indefinitely the most serious. Our fourth and determining condition must, therefore, be *better* color correction.

These are, therefore, the considerations which have served as guides in the construction of the Carleton College objective. First, the selection of the materials which, in the present condition of the art of optical glass making, possess in the highest degree the desired physical properties. Second, a general discussion of every *possible* combination of these two pieces of glass and a selection of the forms which yield the best attainable results. This conscientious strife after scientific perfection, the unexcelled skill with which the results of analysis have been interpreted into the reality of substance, the gratifying identity of predicted and realized values of physical characteristics—all of these have led some of those who have watched the growth of this new instrument of research with the most solicitous attention to the belief that although not the most powerful in existence it may well be the most perfect great telescope yet made. Let us therefore congratulate the possessors of this noble instrument, wish them God speed in their search after knowledge, while we remind them that although no astronomer can ever make another discovery which will rival that made by the insignificant tube first directed towards the heavens by the Paduan philosopher, yet no mind can weigh the importance of any truth, however trivial in appearance, which may be added to that store which we call *science*.

Appendix will appear in Observatory Publication, No. 3.

THE WILLIAMS TELESCOPE OF GOODSELL OBSERVATORY.

The new Williams equatorial telescope has its name as a memorial to Mrs. Cordelia Bailey Williams late wife of Dr. Edward H. Williams, of Philadephia, who generously provided the money for the purchase of the same, amounting to $15,000.

The clear aperture of the object-glass of the telescope is 16.2 inches, its focal length is 22 feet and its working powers range between 136 and 1,600 diameters. Theory claims that 100 diameters to the inch of diameter of the object-glass is the highest that a telescope will bear. This new instrument, under a power of 1,600, gives good images of stars, in the best 'seeing' and easily separates surprisingly close double stars. Definite results of work in this kind will soon be published that others may judge of its character.

The computations for the curves of the objective were made by Dr. C. S. Hastings, of Yale University, New Haven, Conn., on a new plan, and it is the largest glass that has ever been figured by the new method. His method is radically different from all others now in use. It is based on a careful and exhaustive study of the kinds of optical glass that can be procured anywhere abroad, in order to determine what qualities of glass would fulfill the best conditions for color correction that images seen through the telescope should be true and colorless, as far as possible. After a full discussion of all the available combinations of the different grades of crown and flint glass, involving laborious computations, it was decided to use for the Williams' objective a certain grade of crown glass obtained from Mantois in Paris, and a particular kind of flint glass secured from the works of Schott & Co., Jena, Germany. In this new instrument the per cent. of merit for color correction and blackness of field is claimed by the makers to be much higher than that of any other process of construction now in use. The figures of comparative merit on color correction in the four important modes of object-glass making, *viz.*: that of Gauss, Herschel, equi-convex and Hastings, are respectively 1.00; 1.61; 1.61 and 2.11; figures and names to be taken in the order given. It appears that the Hastings' method is more than 30 per cent. higher in merit than the best previously known. A full statement of the results of the computations by which these figures of merit are reached are already in hand and will soon be published.

The grinding and polishing of the lenses were given to J. A. Brashear, Allegheny City, Pa., to whom there is not a superior in the world, as a maker of perfect surfaces either plane or curved. An instance of his skill is shown in his making four curved surfaces 12 inches in diameter on two discs to work together on a focal length of 18 feet and to come out within five one-hundredths of an inch of the focal length predicted. Dr. Hastings said: "I do not believe there is another man in the world who could have done that." As far as our tests have gone, the Hastings-Brashear glass for the Williams telescope is equally perfect.

The mounting of this instrument was done by Messrs. Warner & Swasey, Cleveland, Ohio, and its general appearance is the same as that of the Lick telescope. The driving clock is also of the same pattern and provided with electrical attachment that acts as a control for any rate of movement desired by the observer. The right ascension clock, electric lamps, glasses and other conveniences for setting the telescope and reading the circles are all that could be desired but the arrangements for slow motions of the telescope are the best we have ever seen.

Telescope Goodsell Observatory, Carleton College (Apertue 16.2 Inches).

Weight of Tube	725 lbs.
" " " including all parts attached except declination axis	1300 "
Declination Axis	350 "
" " including circles, extension, balance weight, etc.	700 "
Total weight moved in declination 1300 + 700	2000 "
Weight of polar axis with circles and gears	725 "

Weight of polar axis with circles and gear, declination sleeve and attachments	1650 lbs.
Total weight moved with polar axis 2000 + 1650 equals	3650 "
Weight of Clock	160 "
Clock Weights	400 "
Weight of column and all stationary parts, etc.	9500 "
Total weight of Telescope	12700 "

The new universal spectroscope by Mr. Brashear is arranged to be attached to the telescope for study of the physical characteristics of the celestial bodies, or, equally well for use in the physical laboratory. It is provided with electric lamp attachments for comparison spectra and measurements, photographic apparatus, prisms and grating. This fine instrument is adapted to a very wide range of work in the delightful fields of the "New Astronomy" that is claiming so much of the attention of scientists at the present time.

A BRIEF BIBLIOGRAPHY OF ASTRONOMICAL LITERATURE FOR THE YEAR 1890, JULY TO DECEMBER.[*]

COMPILED BY WILLIAM C. WINLOCK.

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CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at greatest elongation east from the sun, 27° 25′, on Aug. 16, when he will be visible to the naked eye for a short time after sunset. He will be at inferior conjunction with the sun Sept. 12, at midnight, and at greatest elongation west, 17° 53′, Sept. 28.

Venus is too nearly in line with the sun to be seen well. Venus and Mars will be in conjunction Aug. 22 at 2 A. M., the apparent distance between the two planets being less than one minute of arc Venus and Saturn will be in conjunction Sept. 14 at 5^h 32^m P. M., Venus being then 32′ south of Saturn. Venus will be at superior conjunction with the sun Sept. 18, at 9^h06^m A. M. The planet will then be 1° 17′ north of the sun. This will be a good time to make observations on the crescent of light about the planet, to see if it extends more than 180° around the planet's disk. The observations previously made indicate that the crescent can be seen to extend about three-fourths of the circumference of the disk and on one occasion Professor Lyman was able to distinguish the complete circle. This would indicate that the planet has an atmosphere of considerable density.

L'Astronomie, for July, 1891, contains an article on some recent observations of Venus, illustrated by a map of the planet, drawn by M. Niesten, of Brussels, from drawings made by M. Stuyvaert. M. Niesten arrives at a different conclusion from that reached by Schiaparelli and thinks that the period of rotation derived by De Vico, 23^h20^m, is nearly correct.

Mars will not be observable during the remainder of the year.

Jupiter is at his best position for this year during August and September. He will be at opposition Sept. 5, rising then at half past six in the evening and setting at half past five in the morning. He is moving slowly westward among the stars of Aquarius and far exceeds them in brightness. That brilliant star which one sees a little south of east in the evening is the planet Jupiter. He is a superb object in the telescope, with his four bright satellites and ruddy colored belts. The great red spot is more conspicuous this year than it has been for several years. It has the same shape of an oval ring, drawn out to a point at each end. The color is a bright pink, decidedly lighter than that of the great southern belt. The central area is white. The spot was on the central meridian of Jupiter a little before midnight, Aug. 3.

Saturn is so nearly in line with the sun that satisfactory observations are impossible. This is much to be regretted, since the phenomena attendant upon the disappearance of the rings will be wholly hidden by the solar rays and atmospheric tremors. Saturn will be in conjunction Sept. 13 at 7 A. M. The earth will pass through the plane of the rings Sept. 22, after which, until Oct. 30, the dark side of the rings will be toward the earth.

Uranus is getting too near the sun to be observed.

Neptune is coming out of the morning twilight, but is not yet in good position for observation.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Sept. 5	11 41.2	− 2 41	6 50 A. M.	12 42.9 P. M.	6 36 P. M.
15	11 10.4	+ 2 27	5 20 "	11 32.8 A. M.	5 46 "
25	11 06.0	+ 6 17	4 21 "	10 49.1 "	5 17 "
Oct. 5	11 50.3	+ 3 07	4 38 "	10 54.0 "	5 10 "
15	12 52.0	− 3 45	5 28 "	11 16.2 "	5 05 "
			VENUS.		
Sept. 5	10 45.9	+ 9 21	5 07 A. M.	11 47.7 A. M.	6 28 P. M.
15	11 32.1	+ 4 33	5 33 "	11 54.4 "	6 16 "
25	12 17.7	− 0 29	5 59 "	12 00.0 P. M.	6 02 "
Oct. 5	13 03.4	− 5 32	6 25 "	12 06.9 "	5 49 "
15	13 50.0	− 10 24	6 52 "	12 14.1 "	5 36 "
			MARS.		
Sept. 5	10 12.5	+ 12 20	4 21 A. M.	11 14.5 A. M.	6 08 P. M.
15	10 36.6	+ 10 01	4 16 "	10 59.2 "	5 43 "
25	11 00.4	+ 7 37	4 10 "	10 43.6 "	5 17 "
Oct. 5	11 23.9	+ 5 08	4 04 "	10 27.7 "	4 51 "
15	11 47.3	+ 2 36	3 58 "	10 11.6 "	4 25 "
			JUPITER.		
Sept. 5	22 59.6	− 8 03	6 28 P. M.	11 59.3 P. M.	5 31 A. M.
15	22 54.7	− 8 33	5 46 "	11 15.2 "	4 45 "
25	22 50.2	− 9 00	5 04 "	10 31.4 "	3 59 "
Oct. 5	22 46.3	− 9 22	4 22 "	9 48.2 "	3 14 "
15	22 43.5	− 9 38	3 41 "	9 06.0 "	2 31 "
			SATURN.		
Sept. 5	11 24.3	+ 5 55	5 59 A. M.	12 26.0 P. M.	6 53 P. M.
15	11 28.9	+ 5 26	5 26 "	11 51.2 A. M.	6 16 "
25	11 33.5	+ 4 57	4 54 "	11 16.5 "	5 39 "
Oct. 5	11 38.0	+ 4 29	4 21 "	10 41.8 "	5 03 "
15	11 42.4	+ 4 02	3 48 "	10 06.8 "	4 26 "

URANUS.

Date. 1891	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5	13 48.2	− 10 37	9 28 A. M.	2 49.5 P. M.	8 11 P. M.
15	13 50.0	− 10 48	8 52 "	2 12.1 "	7 32 "
25	13 52.2	− 10 00	8 15 "	1 34.9 "	6 54 "
Oct. 5	13 54.4	− 11 12	7 39 "	12 57.8 "	6 16 "
15	13 56.7	− 11 25	7 03 "	12 20.8 "	5 39 "
NEPTUNE.					
Sept. 5	4 30.5	+ 20 15	10 00 P. M.	5 29.3 A. M.	12 58 P. M.
15	4 30.5	+ 20 14	9 21 "	4 50.0 "	12 19 "
25	4 30.3	+ 20 13	8 42 "	4 10.5 "	11 39 A. M.
Oct. 5	4 29.8	+ 20 12	8 02 "	3 30.7 "	10 59 "
15	4 29.2	+ 20 10	7 22 "	2 50.8 "	10 19 "
THE SUN.					
Sept. 5	10 56.8	+ 6 44	5 28 A. M.	11 58.6 A. M.	6 30 P. M.
15	11 32.8	+ 2 57	5 39 "	11 55.1 "	6 11 "
25	12 08.7	− 0 56	5 51 "	11 51.6 "	5 52 "
Oct. 5	12 44.9	− 4 50	6 03 "	11 48.4 "	5 34 "
15	13 21.7	− 8 37	6 15 "	11 45.8 "	5 16 "
CERES.					
Sept. 3	22 00.0	− 27 44	7 07 P. M.	11 07 P. M.	3 07 A. M.
27	21 45.1	− 28 06	5 20 "	9 18 "	1 16 "
Oct. 21	21 43.3	− 26 52	3 37 "	7 42 "	11 47 P. M.
PALLAS.					
Sept. 3	19 24.0	+ 11 27	1 43 P. M.	8 32 P. M.	3 21 A. M.
27	19 24.6	+ 6 44	12 28 "	6 58 "	1 28 "
JUNO.					
Sept. 3	21 24.5	+ 6 49	4 02 P. M.	10 32 P. M.	5 02 A. M.
27	21 14.2	+ 10 32	2 01 "	8 47 "	3 33 "
Oct. 21	21 19.9	+ 12 51	12 24 "	7 19 "	2 14 "

Configuration of Jupiter's Satellites at 10 p. m., for an Inverting Telescope.

Sept. 1	2 1 ○ 3 4	Sept. 16	2 ○ 1 3 4	Oct. 1	1 ○ 3 2 4
2	2 ○ 1 4 3	17	1 3 ○ 2 4	2	3 ○ 1 2 4
3	3 4 1 ○ 2	18	3 ○ 1 2 4	3	3 2 1 ○ 4
4	3 4 ○ 2 ♃	19	3 2 1 ○ 4	4	3 2 ○ 1 4
5	4 3 2 ○ ●	20	4 3 2 ○ ♃	5	● ○ 3 4 2
6	4 1 3 ○ 2	21	4 ○ 1 3 2	6	1 4 ○ 2 3
7	4 ○ 1 2 3	22	4 1 2 ○ 3	7	4 2 ○ 1 3
8	4 1 2 ○ 3	23	4 2 ○ 1 3	8	4 1 ○ 2 3
9	4 2 ○ 1 3	24	4 1 ○ 2 ♃	9	4 3 ○ 1 2
10	4 1 3 ○ 2	25	4 3 ○ 1 2	10	4 3 1 2 ○
11	● 3 ○ 1 2	26	3 4 2 1 ○	11	4 3 2 ○ 1
12	3 2 ○ 4 ●	27	3 4 2 ○ 1	12	4 1 ○ 3 2
13	3 1 ○ 4 ●	28	○ 1432	13	4 ○ 1 2 3
14	○ 1234	29	♃ 1 ○ 4 3	14	2 4 ○ 1 3
15	1 2 ○ 3 4	30	2 ○ 1 3 4	15	● 1 ○ 3 4

Phases and Aspects of the Moon.

		Central Time. d	h	m	
New Moon	Sept.	3	2	16	A. M.
Apogee	"	4	2	12	P. M.
First Quarter	"	11	5	08	A. M.
Full Moon	"	17	11	04	P. M.
Perigee	"	18	12	24	A M.
Last Quarter	"	24	5	07	P. M.
Apogee	Oct.	1	3	48	"
New Moon	"	2	6	58	"
First Quarter	"	10	4	57	"

Jupiter's Satellites.

		Central Time. h m		
Sept.	4	1 31	A. M.	I Ec. Dis.
		3 50	"	I Oc. Re.
		10 41	P. M.	I Sh. In.
		10 43	"	I Tr. In.
	5	12 46	A. M.	II Sh. In.
		12 49	"	II Tr. In.
		1 00	"	I Sh. Eg.
		1 01	"	I Tr. Eg.
		3 39	"	II Sh. Eg.
		3 40	"	II Sh. Eg.
		7 58	P. M.	I Oc. Dis.
		10 16	"	I Oc. Re.
	6	7 11	"	II Oc. Dis.
		7 27	"	I Tr. Eg.
		7 29	"	I Sh. Eg.
		10 03	"	II Ec. Re.
		11 51	"	III Oc. Dis.
	7	3 18	A. M.	III Ec. Re.
	11	3 16	"	I Oc. Dis.
		6 24	"	IV Oc. Dis.
		11 38	P. M.	IV Ec. Re.
	12	12 26	A. M.	I Tr. In.
		12 36	"	I Sh. In.
		2 44	"	I Tr. Eg.
		2 55	"	I Sh. Eg.
		3 05	"	II Tr. In.
		3 24	"	II Sh. In.
		9 42	P. M.	I Oc. Dis.
		6 52	"	I Tr. In.
		7 05	"	I Sh. In.
	13	1 10	A. M.	I Ec. Re.
		9 10	P. M.	I Tr. Eg.
		9 24	"	I Sh. Eg.
		9 24	"	II Oc. Dis.
	14	12 38	A. M.	II Ec. Re.
		3 06	"	III Oc. Dis.
		6 38	P. M.	I Ec. Re.
	15	7 04	"	II Tr. Eg.
		7 36	"	II Sh. Eg.
	17	6 00	"	III Sh. In.
		8 07	"	III Tr. Eg.
		9 26	"	III Sh. Eg.
	19	2 10	A. M.	I Tr. In.
		2 31	"	I Sh. In.
		11 26	P. M.	I Oc. Dis.
	20	2 05	A. M.	I Ec. Re.
		3 10	"	IV Tr. In.
		8 36	P. M.	I Tr. In.
		8 59	"	I Sh. In.
		10 54	"	I Tr. Eg.
		11 18	"	I Sh. Eg.
		11 38	"	II Oc. Dis.
	21	3 14	A. M.	II Ec. Re.
		5 53	P. M.	I Oc. Dis.
		8 34	"	I Ec. Re.
	22	5 47	"	I Sh. Eg.
		6 30	"	II Tr. In.
		7 22	"	II Sh. In.
		9 21	"	II Tr. Eg.
		10 14	"	II Sh. Eg.
	24	8 05	"	III Tr. In.
		10 03	"	III Sh. In.
		11 27	"	III Tr. Eg.
	25	1 28	A. M.	III Sh. Eg.
	26	3 55	"	I Tr. In.
	27	1 11	"	I Oc. Dis.
		4 00	"	I Ec. Re.
		10 21	P. M.	I Tr. In.
		10 54	"	I Sh. In.
	28	12 39	A. M.	I Tr. Eg.
		1 13	"	I Sh. In.
		1 54	"	II Oc. Dis.
		5 49	P. M.	IV Ec. Re.
		7 38	"	I Oc. Dis.
		10 29	"	I Ec. Re.
	29	7 05	"	I Tr. Eg.
		7 42	"	I Sh. Eg.
		8 48	"	II Tr. In.
		10 00	"	II Sh. In.
		11 40	"	II Tr. Eg.
	30	12 52	A. M.	II Sh. Eg.
Oct.	1	7 07	P. M.	II Ec. Re.
		11 25	"	III Tr. In.
	2	2 05	A. M.	III Sh. In.
		2 48	"	III Tr. Eg.
	4	2 57	"	I Oc. Dis.
	5	12 06	"	I Tr. In.
		12 49	"	I Sh. In.
		2 24	"	I Tr. Eg.
		3 07	"	I Sh. Eg.
		7 21	P. M.	III Ec. Re.
		9 24	"	I Oc. Dis.
	6	12 24	A. M.	I Ec. Re.
		5 45	P. M.	IV Tr. In.
		6 33	"	I Tr. In.
		7 18	"	I Sh. In.
		8 51	"	I Tr. Eg.
		9 36	"	I Sh. Eg.
		9 38	"	IV Tr. Eg.
		11 08	"	II Tr. In.
	7	12 38	A. M.	II Sh. In.
		12 48	"	IV Sh. In.
		2 00	"	II Tr. Eg.
		3 30	"	II Sh. Eg.
		6 53	P. M.	II Ec. Re.
	8	5 19	"	II Oc. Dis.
		9 43	"	II Ec. Re.
		2 49	A. M.	III Tr. In.
	12	1 53	"	I Tr. In.
		2 44	"	I Sh. In.
		7 55	P. M.	III Oc. Re.
		8 11	"	III Ec. Dis.
		11 10	"	I Oc. Dis.
		11 23	"	III Ec. Re.
	13	2 20	A. M.	I Ec. Re.
		8 19	P. M.	I Tr. In.

	Central Time. h m	
	9 13 P. M.	I Sh. In.
	10 37 "	I Tr. Eg.
	11 31 "	I Sh. Eg.
14	1 28 A. M.	II Tr. In.
	3 17 "	II Sh. In.
	5 37 P. M.	I Oc. Dis.

	Central Time. h m	
	8 49 P. M.	I Ec. Re.
	11 30 "	IV Oc. Dis.
15	3 28 A. M.	IV Oc. Re.
	6 00 P. M.	I Sh. Eg.
	7 39 "	II Oc. Dis.

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A..............$0^h\ 52^m\ 32^s$
Decl..............+ 81° 17′
Period..........$2d\ 11^h\ 50^m$

Sept. 2	10 P. M.
7	10 "
12	10 "
17	9 "
22	9 "
27	9 "
Oct. 2	8 "
7	8 "
12	8 "

ALGOL.

R. A.............$3^h\ 01^m\ 01^s$
Decl..............+ 40° 32′
Period..........$2d\ 20^h\ 49^m$

Sept. 12	3 A. M.
14	midn.
17	8 P. M.
Oct. 2	4 A. M.
5	1 "
7	10 P. M.

λ TAURI.

R. A..............$3^h\ 54^m\ 35^s$
Decl..............+ 12° 11′
Period.........$3d\ 22^h\ 52^m$

Oct. 2	3 A. M.
6	2 "
10	1 "
13	midn.

U CORONÆ.

R. A............$15^h\ 13^m\ 43^s$
Decl...............+ 32° 03′
Period $3d\ 10^h\ 51^m$

Sept. 21	11 P. M.
28	8 "

U. OPHIUCHI.

R. A...........$17^h\ 10^m\ 56^s$
Decl...............+ 1° 20′
Period........$0d\ 20^h\ 08^m$

Sept. 4	10 P. M.
10	7 "
15	8 "
20	9 "

U OPHIUCHI, Cont.

Sept. 25	9 P. M.
30	10 "
Oct. 5	11 "
11	8 "
16	9 "

Y CYGNI.

R. A............$20^h\ 47^m\ 40^s$
Decl............+ 34° 15′
Period........$1d\ 11^h\ 57^m$

Sept. 2	1 A. M.
5	1 "
8	1 "
11	1 "
14	1 "
17	1 "
20	1 "
23	1 "
26	1 "
29	1 "
Oct. 1	midn.
4	"
7	"
10	"
13	"

COMET NOTES.

Wolf's comet is becoming an easy object for small telescopes. With our 16-inch it has a sharp stellar nucleus of about 12th magnitude, with a considerable condensation about it and a tail about 5′ in length. Prof. Barnard, at Lick Observatory, has picked up Encke's comet in the place predicted by Backlund, whose ephemeris we give below. We have twice looked for the Temple-Swift comet, but have not yet been able to detect it. It was in 1880 a faint, diffuse object several minutes in diameter. It ought soon to be picked up by some one. It will be nearest the earth in November.

Ephemeris of Comet 1891 (Wolf's Periodic Comet).

Gr. M. T.	App. R. A. h m s	App. Decl. ° ′	log Δ	log r	Br.
Aug. 10	2 38 42	+ 28 9.2			
11	41 21	28 5.2	0.0832	0.2068	5.7
12	43 59	28 0.8			
13	46 37	27 55.0			
14	49 14	27 50.5			

Gr. M. T.	App. R. A.	App. Decl.	log Δ	log r	Br.
	h m s	° '			
15	51 51	27 44.7	0.0707	0.2053	6.0
16	54 27	27 38.4			
17	57 2	27 31.6			
18	2 59 36	27 24.3			
19	3 2 10	27 16.6	0.0581	0.2041	6.4
20	4 43	27 8.4			
21	7 14	26 59.7			
22	9 44	26 50.5			
23	12 14	26 40.9	0.0455	0.2032	6.8
24	14 43	26 30.8			
25	17 10	26 20.1			
26	19 36	26 9.0			
27	22 0	25 57.3	0.0329	0.2026	7.3
28	24 23	25 45.2			
29	26 46	25 32.5			
30	29 7	25 19.3			
31	31 26	25 5.6	0.0204	0.2022	7.7
Sept. 1	33 44	24 51.3			
2	36 0	24 36.6			
3	38 15	24 21.3			
4	40 28	24 5.6	0.0080	0.2022	8.2
5	42 39	23 49.3			
6	44 49	23 32.4			
7	46 57	23 15.0			
8	3 49 2	+ 22 57.1	0.9957	0.2024	8.6

Ephemeris of the Temple-Swift Periodic Comet.

(Continued from page 287.)

1891	App. R. A.	App. Decl.	log Δ	Ab. T.	$\frac{1}{r^2 \Delta^2}$
	h m s	° '		m s	
Sept. 4	21 33 02	− 2 18.2	9.6353	3 35	2.66
8	27 45	− 1 43.9			
12	22 41	− 1 08.0	9.5946	3 16	3.50
16	17 58	− 0 30.0			
20	13 52	+ 0 10.4	9.5587	3 0	4.49
24	10 25	+ 0 53.6			
28	07 55	+ 1 40.0	9.5265	2 48	5.65
Oct. 2	06 24	+ 2 30.1	9.5114	2 42	6.30
4	06 04	+ 2 56.8			
6	06 02	+ 3 24.8	9.4965	2 36	7.01
8	06 19	+ 3 54.0			
10	06 55	+ 4 24.7	9.4817	2 31	7.77
12	07 51	+ 4 56.9			
14	09 09	+ 5 30.8	9.4667	2 26	8.61

Ephemeris of Encke's Comet for 1891.

	App. R. A.	App. Decl.	log Δ	log r	Ab. T.
	h m s	° '			
Aug. 10	4 26 10	+ 32 0.0	0.1972	0.1525	
11	4 30 25	32 14.2	0.1429	0.1476	11 39
12	4 24 47	32 28.2	0.1385	0.1416	
13	4 39 17	32 42.0	0.1340	0.1356	11 20
14	4 43 55	32 55.4	0.1294	0.1296	
15	4 48 37	33 8.6	0.1248	0.1236	11 2
16	4 53 28	33 21.4	0.1201	0.1176	

	App. R. A.	App. Decl.	log Δ	log r	Ab. T.
	h m s	° ′			
17	4 58 27	33 33.9	0.1153	0.1115	10 44
18	5 3 34	33 45.9	0.1104	0.1054	
19	5 8 50	33 57.4	0.1054	0.0993	10 21
20	5 14 14	34 8.0	0.1003	0.0932	
21	5 19 46	34 18.8	0.0952	0.0871	10 9
22	5 25 27	34 28.5	0.0900	0.0811	
23	5 31 17	34 37.3	0.0847	0.0751	9 52
24	5 37 17	34 45.4	0.0793	0.0691	
25	5 43 27	34 52.6	0.0737	0.0630	9 36
26	5 49 47	34 58.8	0.0680	0.0571	
27	5 56 18	35 3.8	0.0622	0.0512	9 20
28	6 2 59	35 8.0	0.0563	0.0454	
29	6 9 50	35 10.7	0.0504	0.0396	9 6
30	6 16 51	35 11.9	0.0443	0.0339	
31	6 24 1	35 11.6	0.0380	0.0284	8 52
Sept. 1	6 31 22	35 9.5	0.0316	0.0229	
2	6 38 53	35 5.5	0.0251	0.0176	8 39
3	6 46 34	34 59.9	0.0184	0.0124	
4	6 54 25	34 52.8	0.0115	0.0074	8 26
5	7 2 24	34 43.5	0.0045	0.0025	
6	7 10 31	34 31.8	9.9974	9.9978	8 15
7	7 18 45	34 17.6	9.9901	9.9935	
8	7 27 7	34 0.5	9.9826	9.9891	8 5
9	7 35 36	33 40.9	9.9749	9.9850	
10	7 44 11	33 18.9	9.9671	9.9813	7 57
11	7 52 32	32 54.6	9.9590	9.9779	
12	8 1 37	32 28.0	9.9508	9.9747	7 50
13	8 10 25	31 58.4	9.9424	9.9719	
14	8 19 15	31 25.1	9.9336	9.9693	7 44
15	8 28	30 49.3	9.9246	9.9671	
16	8 36 58	30 10.9	9.9154	9.9653	7 40
17	8 45 49	29 29.7	9.9060	9.9638	
18	8 54 39	28 45.5	9.8964	9.9629	7 37
19	9 3 28	27 58.5	9.8864	9.9623	
20	9 12 15	27 9.0	9.8761	9.9620	7 36
21	9 20 59	26 16.9	9.8655	9.9626	
22	9 29 38	25 22.5	9.8546	9.9634	7 37
23	9 38 11	24 25.8	9.8434	9.9644	
24	9 46 38	23 26.7	9.8319	9.9656	7 40
25	9 55 0	22 25.7	9.8200	9.9677	
26	10 3 16	21 22.9	9.8078	9.9700	7 44
27	10 11 26	20 18.4	9.7953	9.9728	
28	10 19 30	19 12.2	9.7823	9.9760	7 51
29	10 27 27	18 4.7	9.7689	9.9797	
30	10 35 18	16 55.8	9.7552	9.9838	7 59
Oct. 1	10 43 3	15 45.8	9.7410	9.9883	
2	10 50 43	14 34.7	9.7267	9.9931	8 10
3	10 58 18	13 22.6	9.7120	9.9983	
4	11 5 48	12 9.8	9.6968	0.0039	8 22
5	11 13 14	+ 10 56.2	9.6814	0.0098	

Ephemeris of Comet a 1891. (*Barnard Mar. 29.*) From the elements of my orbit as given in THE SIDEREAL MESSENGER for June, p. 288, I have computed the following ephemeris:

Gr. M. T.	App. R. A.	App. Decl.	Log r	Log Δ	Light.
	h m s	° ′			
July 1.5	8 35 8	− 50 29	0.1699	0.1183	0.25
2.5	8 42 53	50 25			

Gr. M. T.		App. R. A.			App. Decl.		Log r	Log Δ	Light.
		h	m	s	°	′			
July	3.5	8	50	23	−50	20			
	4.5	8	57	40	50	14			
	5.5	9	4	43	50	7	0.1893	0.1448	0.21
	6.5	9	11	31	49	59			
	7.5	9	18	7	49	51			
	8.5	9	24	32	49	41			
	9.5	9	30	43	49	31	0.2076	0.0715	0.17
	10.5	9	36	40	49	21			
	11.5	9	42	26	49	10			
	12.5	9	48	2	48	58			
	13.5	9	53	27	48	46	0.2248	0.1980	0.14
	14.5	9	58	42	48	34			
	15.5	10	3	46	48	22			
	16.5	10	8	40	48	11			
	17.5	10	13	26	47	59	0.2413	0.2240	0.11
	18.5	10	18	2	47	47			
	19.5	10	22	29	47	35			
	20.5	10	26	49	47	24			
	21.5	10	31	1	47	12	0.2569	0.2492	0.09
	22.5	10	35	4	47	1			
	23.5	10	39	1	46	50			
	24.5	10	42	53	46	39			
	25.5	10	46	38	46	28	0.2719	0.2737	0.08
	26.5	10	50	14	46	17			
	27.5	10	53	46	46	6			
	28.5	10	57	13	45	56			
	29.5	11	0	36	45	46	0.2861	0.2970	0.07
	30.5	11	3	56	45	35			
	31.5	11	7	13	− 45	25	0.2930	0.3085	0.06

O. C. WENDELL

HARVARD COLLEGE OBSERVATORY, June 10, 1891.

ASTRONOMY FOR AMATEURS.

How to See the Solar Prominences with a Grating Spectroscope.

E. E. READ, JR.

FOR THE MESSENGER.

Recently I have received several inquiries, mostly from amateurs, asking for instruction in the use of the grating spectroscope. They all complain that there is a lack of definite and condensed directions in that line. On account of these inquiries I have written the following paper, which is entirely for the use of amateurs, containing as it does only the most elementary and simple matters in relation to seeing and measuring the solar prominences:

FIRST, INSTUMENTAL REQUISITES.

A.—The plane of the slit plate and the plane of the grating must be normal to the line passing through the center of the lens of the equatorial and the lens of the collimator. This line must pass through the center of the slit and center of the grating.

B.—The angle between the collimator and the observing telescope must be as small as possible.

C.—The equatorial must be run with some kind of clock-work. I find that one of the most general inquiries is, "Can I see the solar prominences with a portable equatorial without clock-work?" Upon the whole I should say that a clock-work is an indispensible accessory to good spectroscopic work. The clock need not, however, be an expensive nor elaborate one. Of course an electrically controlled clock connected with the Sidereal clock is the most desirable of all, and to do the most exact work is the only thing, but for the ordinary purposes of amateur work any arrangement by which the equatorial is carried with a regular and steady motion will suffice. Mr. Hopkinson, of Renovo, Pa., has an arrangement that, while costing but a trifle performs quite satisfactorily. He connects a large iron weight by a rope or wire to the axis of the telescope and this he rests on a rubber bag filled with air. A small rubber tube leading from the bag to his hand controls the outlet of the air and the consequent fall of the weight and motion of his telescope. If the telescope is moving too slowly he simply lets more air out and the weight falls faster and the rate of his "clock" is increased. With this arrangement he tells me that he is able to hold a star in the field of view for more than an hour. Then he simply again fills up the rubber bag with air and his "clock" is wound up. With such an arrangement as this an amateur could do very satisfactory prominence work.

SECOND, ADJUSTMENTS.

A.—Detach the observing telescope from the spectroscope and focus it for parallel rays by observing some distant object. This object, if terrestial, should not be less than a mile distant, but if the observer will focus at night upon a star he will then be sure to get parallel rays. Let this focus be marked by means of a scratch or other such mark upon the draw tube.

B.—With the telescope thus focused and again attached to the spectroscope view the image of the slit as it is reflected from the face of the grating. Move the slit plate in or out until the image of the slit is perfectly sharp. Professor Young suggests that a better plan is if practicable to have the spectroscope so constructed that the observing telescope can be swung around far enough to look directly through it into the collimator. Then if the grating is removed the slit can be seen directly and the slit plate moved until the slit is sharp. This plan does away with the reflection entirely. Mark the slip tube of the collimator when this adjustment has been completed as in the case of the observing telescope.

C.—With the instrument thus focussed and collimnated place it so that the slit plate is exactly in the focus of the equatorial. This can be done either by direct observation of the solar image on the slit plate or by viewing the spectrum of the limb of the sun through the telescope. This latter plan is carried out as follows—with the slit radial to the sun the solar image is allowed to fall on it so that only half of the slit is covered, then the observer looking into the observing telescope will see only half the field filled with the spectrum and the line of division will be the spectrum of the sun's limb. If, now, the spectroscope is moved until this line is perfectly sharp the plane of the slit will be in the focal plane of the equatorial for those rays which the observer is using.

If the former method is used it is well to protect the eyes from the glare of the solar image by means of colored glass of some sort. I use a pair o ordinary "London smoke" eye glasses.

4.—Move the equatorial until the solar image is exactly tangential to the slit, and in the C line the chromosphere ought to be seen, together with any prominences that happen to be at the point of observation. The C line of the second order is the line most generally used for this part of the work.

The observer will soon find that one side of his grating will give him better results than the other, the image will be brighter and the light better. It is well to begin operations upon the north and south limbs of the sun because any irregularities of the clock will merely carry the solar image along the slit instead of across it, and in this latter case the light of the photosphere would at once blot out the feeble light of the prominences. The observer will find what width he can open the slit. This depends upon several factors, the most important of which is the atmosphere.

THIRD, CAUSES OF FAILURE.

A.—Air currents of unequal temperature. There is nothing that sooner feels the influence of poor definition than the spectroscope. The heating of the air in the upper part of the Observatory, or even the heating of that in the tube of the equatorial is sufficient to render observations useless. To overcome the former I find that the best time to observe, especially in summer, is the very early morning. My own Observatory is in the heart of a city and unless I make my observations during the summer before eight o'clock, the heat so ruins the definition that seeing is impossible. If the observation is a prolonged one the air in the tube will become so heated that this will affect the seeing. When this happens the only thing to do is to stop work, revolve the roof until the sun no longer falls on the tube of the equatorial and give the air time to cool off.

B.—Moisture in the atmosphere. If the sky is covered with a thin white haze it is useless to attempt to see any prominences. The best sky, however, I find, is not one that is perfectly free from clouds but rather one that is filled with those great masses of snow white cumuli leaving here and there between them patches of sky of an intense blue. These clouds seem to gather up all the moisture that is in the air and leave the clear places perfectly dry and pure. Upon such occasions as these I have obtained the best results.

C.—A dirty object-glass in the equatorial or a dirty grating. The way to clean the latter is to wipe it in the direction of the ruling with a cloth wet with bi-sulphide of carbon.

D.—Lack of sufficient care in the matter of focusing. This is, I find, one of the most usual causes of failure. The observer is too easily satisfied that he has placed the spectroscope so that the focal plane and the slit plate are coincident.

Nor, however, is it always the fault of the observer. If the lens of the equatorial is not well corrected for spherical aberration there is no single point where all the rays come to a focus, and instead of there being a focal plane there is, so to speak, a focal cylinder and all the observer can do is to find the point where he will get the best results. Professor Young's method for final adjustment in the focal plane is as follows: "I always make the final adjustment of slit in focal plane by help of the eye-piece of the view telescope. I close the slit and focus just as sharply as I can on the Fraunhofer lines. Then I open the slit a little and look at the prominences, running the view telescope eye-piece in and out a little. If the eye-piece shows them best a little inside the focus for the Fraunhofer lines, then I move the spectroscope closer to the telescope, and vice versa if the prominences show best by pulling out the eye-piece beyond the focus of the Fraunhofer lines. The motion of the slit plates should be just half the displacement of the eye-piece between the focus for lines and for prominencs, *i. e.*, it should be so if collimator and view telescope have the same focal length."

FOURTH, MEASUREMENT OF PROMINENCES.

A.—Position Angle. Allow the sun to run along the slit plate and revolve the spectroscope until the north and south limb of the sun is exactly tangential to the slit during the entire passage across the plate. This will then be the zero point, provided, of course, that the north limb of the sun is made use of. Around the eye-end of the tube of the equatorial I have a circle divided to half degrees. Connected with the spectroscope is a pointer that points to the readings on the circle. The pointer is so set that it is directed to 360 when the north limb of the sun is exactly tangential to the slit. Then as the spectroscope is revolved the pointer marks exactly what is the position-angle of the portion of the sun under observation. This reading can be afterwards reduced to latitude, if desired, by means of the solar ephemeris in "The Companion to the Observatory," or the table in Secchi's "Le Soleil."

B.—Measurement of height of Prominences. This can be done either by means of the micrometer or by means of the slit. If the slit is controlled by a screw with a micrometer head the value of the revolution of the screw can be ascertained in about the same method as is used in the ordinary stellar micrometer. The slit can be opened a certain and well ascertained width, say five revolutions of the screw, then the grating having been removed the observing telescope is revolved so that it looks directly through the collimator and equatorial and a star can be allowed to drift across the slit; its time changed to equatorial time and multiplied by fifteen will give the value of the five revolutions of the screw of the slit.

If the cob-web micrometer is used the method is about the same. The spectroscope is arranged as is for the examination of the Fraunhofer lines. The slit is placed parallel to a circle of declination and the wires separated by an integral number of revolutions of the screw. Then as the sun crosses the slit plate let the observer note the interval between contact of the spectrum with the first wire and contact with the second. This interval changed to seconds of arc will be the value of the integral number of revolutions of the screw and the value of a single revolution or fraction thereof can be at once found.

In cases where the prominences are too high to admit of being seen and measured by means of the micrometer and tangential slit other methods must be used. One of the simplest is to place the slit radical to the sun at the point at which the prominence is located and measure its height by means of the micrometer. This method is exact but slow, and if quicker work is desired recourse can be had to the method of the screen placed behind the finder, or, to refraction of the solar image by means of a plate of thick glass placed at an angle before the slit plate. Both these methods are decribed at length in Secchi, (Le Soleil Vol. II, page 24).

School of Pure Mathematics and Practical Astronomy.

COURSE OF STUDY (PROVISIONAL).

FIRST YEAR.

Fall Term, Fifteen Weeks.

1. Chauvenet's Trigonometry; three hours per week.
2. Analytic Geometry (Howison or Equivalent); two hours per week.
3. [Theory of Equations, Salmon's Higher Plane Curves; Ball's History of Mathematics.]
4. French or German, with Translations from Current Periodicals.
5. Practical Astronomy, Observing Exercises from Webb, Oliver and others; Instruments: Opera Glass, Sextant, and Portable Equatorial Telescopes; Principal Themes: Occultations and Variable Stars

Winter Term, Ten Weeks.

1. Analytic Geometry (including Three Dimensions), three hours per week.
2. Differential Calculus, two hours per week.
3. French or German with Translations from Current Periodicals.
4. [History of Astronomy; Grant; Determinants].
5. Computations; four hours per week.
6. Practical Astronomy; Principal Theme, Time and the Care of Clocks; Instruments: Portable Transit and the Meridian Circle.

Spring Term, Eleven Weeks.

1. Integral Calculus; three hours per week.
2. Analytic Mechanics; two hours per week.
3. [History of Astronomy of the Nineteenth Century; Clerke; Quaternions.]
4. Computations; four hours per week.
5. Astronomy, Chauvenet Vol. I; three hours per week.
6. Observing two nights per week; Theme: Latitude; Instruments: Portable Transit and Zenith Telescope.

SECOND YEAR.

Fall Term, Fifteen Weeks.

1. Astronomy, Chauvenet Vol. 1 completed; two hours per week.
2. Analytic Mechanics; three hours per week.
3. Computation of Orbits, Oppolzer, French or German edition, Klinkerfues and Watson.
4. [Ferris' Spherical Harmonics and Frost's Curve Tracing.]
5. Observing two nights per week. Theme: Double Stars. Instruments: Clark's 8¼-inch Equatorial; Williams 16.2-inch Equatorial; Working Lists from Gledhill, Chambers and Burnham.

Winter Term, Ten Weeks.

1. Astronomy, Chauvenet Vol. II begun; three hours per week.
2. Computation of Orbits, Oppolzer, continued.
3. Laboratory work in Physics, Light and Heat, three hours per week.
4. Observing two nights per week. Theme: Differential Observations of Planets; Equatorial Telescope with Micrometer.
5. [Differential Equations; Reference Books: Boole, Johnson and Craig.]

Spring Term, Eleven Weeks.

1. Computations of Orbits, Oppolzer, continued.
2. Astronomy, Chauvenet, Vol. II. completed; two hours per week.
3. [Differential Equations, continued.]
4. Observing two nights per week, Meridian Circle.
5. Laboratory Work in Physics, Electricity and Magnetism.

THIRD YEAR.

Fall Term, Fifteen Weeks.

1. Spectrum Analysis, Scheiner, Spectral Analyse der Gestirne; three hours per week.
2. Theme for Original Investigation in some branch of Mathematics or Astronomy.
3. Elliptic Functions.
4. Observing two nights per week, Meridian Circle.
5. [Figure of the Earth, Pendulum Observations; Pratt, Clarke and other books of reference.]

Winter Term, Ten Weeks.

1. Spectrum Analysis continued; Laboratory Work with the Universal Spectroscope aided by Photography; three hours per week.
2. Celestial Photography; Themes; Reference Papers in the Library; Instruments: Photographic Telescopes.
3. Theme for Original Investigation in some branch of Mathematics or Astronomy.
4. Observing two nights per week; Equatorial Telescope.
5. [Elliptic Functions, continued.]

Spring Term, Eleven Weeks.

1. Theme for Original Investigation in some branch of Mathematics or Astronomy.
2. Celestial Photography continued; Instruments: Photographic Telescopes and Cameras.
3. Calculus of Variations by Topics; Books of Reference: Todhunter, Jellett and other authors.
4. Observing two nights per week; Equatorial Telescope.
5. [Memoirs of Sir Isaac Newton by Brewster, and Dreyer's Tycho Brahe].

NOTE.—The themes in brackets are to be read by the student under the direction of the instructor.

Any student who has received the degree of Bachelor of Arts or Bachelor of Science, and who has completed the above course of study and presented a thesis showing ability in original investigation will be recommended by the Faculty of the College to the Board of Trustees for the degree of Doctor of Philosophy.

GOODSELL OBSERVATORY OF CARLETON COLLEGE, August 1, 1891.

NEWS AND NOTES.

Vacation months for this year are July and September. Hence the next issue will be for October, and it will be mailed the last week of September.

The size and quality of this number of THE MESSENGER, it is hoped, will be a pleasant surprise to our readers. It is partly due to pressure of useful matter when a vacation month comes.

The attention that has recently been given to studies by the spectroscope has interested a number of the best astronomers in this country and Europe in THE MESSENGER, and arrangements are now in progress for a large, full, and more general discussion of the varions branches of astroomical work due to the spectroscope, in future numbers of this publication.

Kenwood Physical Observatory.—On another page will be found a description of the new Kenwood Physical Observatory, of Chicago. The cuts accompanying the article give a very correct idea, in outline, of this new Observatory, and Professor Young's address, at its dedication, well indicates the auspicious beginning which it has already made. Professor Geo. E. Hale, its director, is now in Europe for study, and at this writing is at Mr. Lockyer's Observatoy. He will be abroad at least a year, and in the mean time he is having some new astronomical instruments constructed for his new Observatory in Chicago.

Professor George Davidson, of the United States Coast and Geodetic Survey, has just received a letter from his colleague John E. McGrath in charge of the boundary survey party on the Yukon river near its crossing of the 141st meridian, in which McGrath reports that he observed the first interior contact of Mercury and the sun's limb on the 9th of May; and that on the 6th of June he observed the solar eclipse. He took photographs of both these phenomena. Camp Davidson, where McGrach made these observations, is in 65° latitude and 141° longitude.

Allegheny Observatory.—At a meeting of the Board of Trustees of the Western University of Pennsylvania, on May 11, 1891, J. E. Keeler, of Lick Observatory, was elected Professor of Astro-physics in the University and Director of the Allegheny Observatory. Mr. F. W. Very is associated with him as Adjunct Professor of Astronomy. It is expected that the Observatory will continue its researches on important problems in the domain of Astro-physics, and he asks that astronomers generally will, as heretofore, favor the Observatory with the communication of such memoirs or shorter papers as may be published under their direction.

Goodsell Observatory, Carleton College.—Our readers will notice that the Observatory has received a new name since our last publication. It was given in comemoration of Mr. C. F. Goodsell, the real founder of Carleton College. A full account of the earnest work and self-denying service of this good man, to found a Christian College in the Northwest, will be given in Observatory Publication No. 3, which will appear soon. This name was given in connection with the reception exercises for the new large equatorial and the formal opening of the School of Pure Mathematics and Practical Artronomy, as part of the proposed work of the Goodsell Observatory. The dedication and reception exercises were held on and about the east porches of Gridley Hall, Carleton College, June 11, 1891. A special free train from the cities of St. Paul and Minneapolis was provided for the occasion, and nearly 100 invited guests from the cities spent the day and evening in witnessing the various exercises of Commencement Day and the interesting views of celestial objects at the Observatory during the evening by the aid of the large telescope. The occasion was one of great interest to the College and to the Observatory. The persons who shared in the special exercises before referred to, were President Stiong, the Director of the Observatory, Professor Goodhue, Profesor Huntington, Professor J. L. Noyes and Mr. M. W. Skinner, all of Carleton College; Professor C. S. Hastings of Yale University, Mr. Warner of Cleveland, Ohio, Rev. E. H. Avery of Iowa, Hon. M. H. Dunnell of Owatonna, Mr. H. S. Fairchild of St. Paul, Rev. S. S. B. Spear of Minneapolis. As indicated above, a very full account of these special exercises will be given in the next Observatory Publication.

Professor L. G. Weld of the State University of Iowa spent a few days with us at the Observatory trying the instruments and looking up points of interest.

Professor W. A. Crusenbury, Department of Mathematics and Astronomy, Callinan College of Drake University, Des Moines, Ia., is spending a part of his vacation at the Goodsell Observatory in regular work with the astronomical instruments.

Camberlin Observatory.—Under date of June 19, Professor H. A. Howe, Director of the Chamberlin Observatory, Denver, Colo., writes that "the plasterers begin to-morrow their work in the new observatory building." that the dome is almost done, the objective is completed and that the mounting for the 20-inch glass is likely to be completed during the present summer. At last writing Professor Howe was testing his new 6-inch equatorial telescope.

Students' Observatory, at Berkley, Cal.—Roger Sprague, who is spending his vacation at the Students' Observatory, of Berkley, California, describes at length the defining power of the fine six-inch telescope at that place. He calls attention to the "granular appearance" of the principal condensation as being peculiar, and suggests that this part of the nebula possibly might be watched with profit. This granular appearance has before been noticed, but later study is quite decisive in the view that the condensed portions of the nebula are not resolvable.

The Proper Motion of Σ *1321.* The expression Mr. Burnham uses in the SIDEREAL MESSENGER p. 171, "only optically double." is likely to be misleading, as not used, as it appears to me, in the usual sense given by astronomers to it. He uses it in the cases of stars which, like 61 Cygni and Σ 1321, though physically connected, have not been proved to have any motion around each other, and therefore are not called "binary;" but my impression is that astronomers generally use the expression to mean stars which are nowhere near each other in space, but only happen accidentally to lie nearly in the same line of sight.

As an illustration, I believe it would generally be said that five of the bright stars in Ursa Major, β, γ, δ, ε, ζ are "physically connected," and are not "only an optical group;" but that α and η are probably not physically but "only optically" connected with the others.

T. W. BACKHOUSE.

West Hendon House, Sunderland, England, July 14, 1891.

Another Iowa Meteorite.—What is supposed to be a meteoric stone fell five miles north and four and a-half miles east of Alta, Iowa, about 3:15 A. M. of the 2d of June. The person who found the stone thus described the circumstances of its fall to me: "A bright flash of red light was first seen, followed by a buzzing sound and a very loud report which was said to be much louder than thunder, immediately something appeared to hit the side of the house (possibly gravel). The occupants (two women) at first thought the house had been struck by lightning, and, being frightened, did not venture out until morning, when, looking around, they found, embeded a few inches in the sand and gravel quite near the house, the aerolite. It was covered with a black substance, had a strong smoky and sulphurous odor. They washed it and brought it to town. I examined it and found it of a concavo-convex shape, nearly round, being about four inches by three and three-fourths inches and two inches high in the center, weighing one pound and fifteen ounces avoirdupois. The concave side is partly stone and metal and the convex side is completely covered with a small crystalline, yellowish-green metal, partly fused by heat on one side. It looks as if it might have been globular and been shattered in two.

DAVID E. HADDEN.

Transit of Mercury. The transit of Mercury was successfully observed at the Observatory of the University of Mississippi on the 9th day of May. An equatorial by Merz of 11.6 cm. aperture (with screen of 8.9 cm. aperture) was used. The eye-piece had a magnifying power of 177. The day was cloudless and conditions all favorable excepting nearness to the horizon, and excessive quivering due to rapid warming of the ground. Time of first contact was lost by imperfect adjustment of wire in eye-piece. Second contact was noted at G. M. T. $11^h\ 57^m\ 31^s$. The first flash of light behind the planet was seen at this time, and it was continuous after this. A "black drop" appearance lasting not more than a second was noted about five seconds before the first flash of light behind the planet. No indications of atmosphere were noted. The planet was watched until sunset. Weather on this occasion, as on the occasion of the transits of Mercury in 1878 and Venus in 1882, was all that could be desired. R. B. FULTON.

University of Mississippi.

Jupiter. The great red spot on Jupiter has again become very conspicuous. Its outline is sharply defined and its color a deep pink, similar to its appearance in 1879-80. Another reddish spot has been observed in latitude 9 seconds south of the equator, and following the great red spot about five hours in time. This object has a length at mean distance of 7″.5 and a breadth of 1″. In 1890 *five* small reddish spots were observed in the north margin of the equatorial belt, 5″ north of the equator, the approximate rotation period being 9^h 55^m 34^s. One of these spots was observed on July 9, preceding the great red spot 2^h 07^m of time. I presume others will become visible during the opposition. The oval white spots which I have observed every year on belt No. 6, 9″ south of the equator, owing to the more favorable position of the planet, will be more readily seen than for some years past. These spots are usually found in groups of three or more and give a rotation period approximately the same as the great red spot. The most conspicuous spot of a group is now visible, following the great red spot 3^h 40^m time.

G. W. Hough.

Photographic Chart of the Sky. We have just received the report of the last reunion of the International Committee on the photographic chart of the sky. This report is full of interesting matter on the subject of stellar photography, and covers 135 pages. The eighteen observatories are all ready to begin the actual work, having already taken a number of satisfactory trial plates.

The following table gives the list of Observatories, their latitudes, the zone of sky assigned to each and the number of plates required to cover each zone:

Observatories.	Latitude.	Zone in Decl.	Number of Plates.
Greenwich	+ 51°29′	+ 90° to + 65°	1149
Rome	+ 41 54	+ 64 “ + 55	1040
Catane	+ 37 30	+ 54 “ + 47	1008
Helsingfors	+ 60 09	+ 46 “ + 40	1008
Potsdam	+ 52 23	+ 39 “ + 32	1232
Oxford	+ 51 46	+ 31 “ + 25	1180
Paris	+ 48 50	+ 24 “ + 18	1260
Bordeaux	+ 44 50	+ 17 “ + 11	1260
Toulouse	+ 43 37	+ 10 “ + 5	1080
Alger	+ 36 48	+ 4 “ − 2	1260
San Fernando	+ 36 28	− 3 “ − 9	1260
Tacubaya	+ 19 24	− 10 “ − 16	1260
Santiago	− 33 27	− 17 “ − 23	1260
La Plata	− 34 35	− 24 “ − 31	1360
Rio-de-Janeiro	− 22 54	− 32 “ − 40	1376
Cape of Good Hope	− 33 56	− 41 “ − 51	1512
Sydney	− 33 52	− 52 “ − 64	1400
Melbourne	− 37 50	− 65 “ − 90	1149

H. C. W.

Lightning Spectra. We have been greatly interested in the study of lightning spectra, as carried on by Mr. W. E. Wood, of Washington, D. C. Below we give a portion of a recent private letter from him on this subject. Although not written for publication we are sure it will interest students in spectroscopy, and probably lead some of the more experienced workers to aid him by answering his pertinent queries:—

In the August (1890) number of THE MESSENGER, place was given to some "preliminary" observations on "Lightning Spectra," made by the Browning spectroscope. Since that time, I have pursued the subject, and with the assistance of a well supplied laboratory belonging to Mr. W. K. Carr of this city, and which has an imposing array of electrical appliances, Geisler tubes, etc., I have considerably advanced my knowledge of electric spectra of all kinds, and which I find exceedingly interesting. But to be brief—I must modify somewhat the earlier observations, which, it will be remembered, were preliminary only. I am now prepared to say, that lightning spectra present but the characteristic lines of oxygen, hydrogen, nitrogen, and carbonic acid, and—what was puzzling to me—the line of the vapor of sodium. The absorption bands, which I find in lightning spectra, I think might be produced by the moisture in the air, a large quantity being present during thunder storms. I can account for the sodium line in several ways, namely:

1st. Dust, containing earthly vegetable matter, held in suspension in the atmosphere.

2d. Vapor carried by winds from the ocean, into the vortex of the storm and containing salty material.

3d. The presence of sodium as an element of the atmosphere.

I favor this point because I can get the sodium line not only by means of an electric flash in any state (with the exception possibly of the spark in vacuo which I have not yet obtained,) in the atmosphere, but I have noticed that in purest states of the air, when, I considered the presence of dust of any kind to be almost beyond detection, that a Bunsen burner will give the D line many times during a period of one minute. Of course the line given was extremely faint, but certainly present.

4th. It might be finally ascertained that the sodium line was a feature of the electric spark in all of its various apparitions. This is not improbable, for, if the two poles of a weak battery be brought in contact with the tongue, while no shock might result, a pecular taste is left, proving some chemical action. Since the spark of an electric machine gives the sodium line equally with the spark from a chemical solution battery, it would be unwise to say that the sodium line originated from the chemicals composeing the battery solution. The greatest obstacle appears to be, the production of a spark free from metallic influences originating from the electrodes; for no matter how we produce the spark it will be subject to the influences of whatever electrode we use. At present I can think of nothing suitable to use for the purpose. Perhaps some one might suggest something out of which to form the electrodes, and which would positively give off no sodium vapor. If so, I shall be pleased to continue the investigation, for I am anxious to find whether or not the origin of the D line visibility lies in the electric spark.

5th. The last I shall offer, and to me the most reasonable of all, is this: It is an accepted fact that there is precipitated on the earth's surface, daily, great quantities of meteoric matter, popularly called "star dust." Such spectroscopic examinations as have been made of some of this meteoric matter by Lockyer and others, have shown,—if I remember correctly—that sodium vapor is always present. Now, much of this stellar dust is. on account of its extreme fineness, held in suspension in the atmosphere; and those particles which obstruct the passage of the electric spark, in the case of lightning are readily vaporized, and the familiar sodium line attests the presence of these particles. Accepting the theory that the atmosphere is at all times laden with meteoric particles in a state more or less densely situated, we need not wait for lightning to prove it, but we can with an ordinary Bunsen burner, at well chosen times of serenity of the atmosphere, attest the evidence of lightning spectra. In order to more fully investigate this point, I shall continue a series of observations with the Bunsen burner, and, if possible, with the electric spark, in this manner: I shall arrange an apparatus at the top-most platform of the dome of the capitol building, and shall choose an early morning hour—say from two to four o'clock—at such time as the atmosphere shall have been in a quiescent state for some hours One can readily see, that by such an arrangement I shall attain the most perfect results. The dust raised from the earth by vehicles and winds during the day will, with a few hours, atmospheric rest, to a great extent—if not wholly—subside, and come to rest at the earth's surface. Now if this meteoric dust be continually precipitated, it is obvious that it will be always present, and falling,—the supply coming from above. I am confident that if this sodium line fail or become extremely weak at such times, that I must look for its origin elsewhere: and if I get it at all times, even when exposed plates of glass fail to catch, by their prepared surfaces particles of matter of earthly origin, (and easily analyzed as such by a series of such plates prepared at different times.) I can, determine closely the origin of that sodium, and further consideration will show you that I can pretty closely determine with the gas flame and spark whether or not the sodium line belongs to electricity.

That Wondnrful Niagara Meteor. Often in popular works on astronomy, and far too frequently in astronomical text books, we find stated as a fact that during the great star-shower of Nov. 13. 1833, a meteor hung over Niagra Falls for half an hour and emitted radiant streams of light. A greater absurdity than this never found its way into publication. The originator of the tale probably thought that celestial visitants, as well as mundane inhabitants, ought to feel the entrancement of the wonderful beauty of the cataract, and that, therefore, this one determined to halt and devote a half an hour to its inspection. But though the sensational writer was thus particular in relating the time of its lingering over the Falls, he unfortunately omitted to tell us how near it approached them and whither it betook itself. It is difficult to treat with seriousness a story so at variance with our knowledge of the behavior of meteoroids when they enter the atmosphere. Those only which emanate exactly from the radiant appear to stand still, and these are visible for only about a single second, instead of a half-hour, and during that brief interval they are estimated to move with a speed equal to the sum of the velocities of both the earth and the meteor, which rate of motion must be so enormusly increased by the earth's attraction as to cause it to approach the earth from 75 to 100 miles per second.

It chanced that I was an observer of the unexampled meteoric display of 1833, at a point sufficiently near the Falls to have witnessed such a sight had it existed, but nothing of the kind was seen by any one of a group of a half dozen of people who observed it with me. Evidently this story should be relegated to that large class of astronomical myths which too many times pass current as facts.

A large meteor may have exploded over the locality, and the *debris* have been seen for the time named, a phenomenon occasionally witnessed as I myself saw at the return of the shower in 1867. LEWIS SWIFT.

Warner Obs'y, Rochester, N. Y., July 16, 1891.

Solar Disturbances and Terrestrial Magnetism. In THE SIDEREAL MESSENGER for November, 1889, I called attention to a periodicity of the aurora at intervals of "twenty-six or twenty-seven days." By the aid of longer lists of auroras and an improved method of tabulation this period has been amended by successive approximations until twenty-seven days, six hours and forty minutes has been secured as the final result, which corresponds precisely to the most generally accepted value for a synodic revolution of the sun as determined from the average rate of movement of sun-spots. Tables showing the numbers of stations reporting auroras each day in all accessible lists have been constructed at this interval for nearly two hundred years and the periodicity described is evident more or less throughout. Cumulative evidence has been secured also to the effect that it is when disturbed areas are at or near the eastern limb appearing by rotation that they have the power of producing magnetic phenomena chiefly if not exclusively. Certainly the recurring outbursts of auroras are of such brief durations as to demonstrate clearly that the originating solar disturbances have this power during a very limited portion only of each transit. Some months since Professor C. A. Young wrote to me stating in substance that in view of these results it becomes necessary to admit that the sun has more coherence than has been supposed, and that it may even contain a solid nucleus. He stated further that a few years since he would have said that it makes no difference whether a solar disturbance is on the earth-ward side of the sun or not so far as magnetic effect is concerned, but that now it becomes necessary to admit that this power of solar disturbances is related to their visibility. He also, asked whether I had any objection to his refering to this point in an article which he was writing at the time. Presented in this way, and with this qualification, I had no objection to offer. Unfortunately I have not seen Professor Young's article. but I presume that a note in THE SIDEREAL MESSENGER for May, at page 250, refers to it, stating as it does, that "Professor Young has recently called attention to the rediscovery in the United States that there is a connection between visibility from the earth of solar disturbances and terrestrial magnetism." As it seems to me a statement so indefinite as this in regard to the nature of the connection referred to is liable to have various meanings read into it and to be misconstrued. It is evident from what has been said above that the magnetic effect of solar disturbance is not dependent simply upon their visibility, otherwise this effect would continue as long as they are in sight on the earth-ward side of the sun, which is most decidedly not the case. In deed there is positive proof in the tables referred to that we must look elsewhere than to light radiations for the means of conveyance of magnetic impulses from sun to earth. It would be premature perhaps to enter upon the detailed discussion of this proof which is in process of investigation rather than at the stage at which the announcement of conclusions is warranted. It will be found ere long, I think, that the subject is a very live one and I should be well pleased to have the benefit of any contributions which Mr. Sherman, whom you mention in the note above quoted, or any one else, may be prepared to make to it.

May 4, 1891.

Since sending the letter of May 4th I have seen the article of Professor Young's mentioned in it. I find that he is of the opinion that my results in regard to a periodicity of the aurora corresponding to the time of a revolution of the sun, as viewed from the earth, are consistent with certain discoveries of Herz in regard to magneto-electric properties of light. After very careful study of the various pecularities of this periodicity I am very decidedly of the opinion that the solar impulses originating terrestrial magnetic phenomena are *not* conveyed either as light or heat in any form whatever. My reasons will become apparent soon, I hope, when a portion, at least, of the tables upon which they are based shall have been published, together with the necessary comments and explanations. I am very much pre-occupied and the necessary clerical work of arranging the data, etc., is slow. I trust, however, to have the results in such shape that they may be verified by anyone who cares to look into the matter ere long. I am becoming more and more convinced that these results are destined to have a very important bearing upon meteorology. M. A. VEEDER.

May 15, 1891.

Observatory of the University of Mississippi. It may interest the readers of your very valuable "MESSENGER" to know that the University of Mississippi has arranged with the establisment of Sir Howard Grubb for the construction of an instrument that will be capable of doing good work. It is to be of the "twin equatorial" type after the style of the instrument planned by Janssen at Meudon, and will consist of a 15-inch visual telescope and a 9-inch photographic telescope, side by side, on the same support and controlled by the same mechanism. The instrument will be provided with every useful device that Grubb has used successfully with his larger instruments. Work upon it has been progressing satisfactorily for two months, and it is expected to be in place about May 1st, 1892. It will occupy the pier built for the 18½-inch equatorial now at Dearborn Observatory, which was constructed by Alvan Clarke & Sons for the University of Mississippi under the direction of Dr. F. A. P. Barnard. Upon its completion in 1862, Dr. Barnard very properly advised the makers to dispose of it as they thought best, as nothing had been paid them, and the war rendered its final acceptance by the University of Mississippi doubtful. While we will not have now what we would have had in 1862,—the leading telescope in America,—it is expected that the purchase of the new instrument will mark the beginning again of astronomical work that has been interrupted many years by war and consequent financial inability. We need further equipment, but men of wealth, and liberal men of wealth, are not numerous in this section, so we are by degrees working up to the expectations of thirty years ago. R. B. FULTON.

University Mississippi, July 6, 1891.

Small Telescopes Bought and Sold. We have had so much correspondence about small telescopes during the last year that we have decided to devote one or more of our advertising pages to information of this kind, especially in regard to second-hand telescopes, in the interest of those who wish to buy or to sell such instruments. Naturally enough persons who wish to buy such telescopes are timid lest they be cheated in the operation. We cannot recommend a telescope that we have not seen and so we have been unable, in many instances, to help persons in this way who really need aid.

Now, we make this suggestion: That any person having a good, second-hand telescope who wishes to sell it, may try to do so through our agency, for new and second-hand instruments. The telescope should be sent to "Goodsell Observatory of Carleton College, Northfield, Minn.," transportation prepaid, and we will give it a careful examination and publish an account of its condition and the owner's terms of sale.

In case of sale we will charge ten per cent. for all values under $500. For values over $500 special arrangements will be made. If an instrument is not sold within four months it will be returned at owner's expense and no charge will be made for examination and advertising. If the owner still wishes to keep his instrument in the agency for sale, special arrangements to that effect may be made. Correspondence is therefore solicited from all persons wishing either to sell or to buy second-hand astronomical instruments.

Professor Geo. E. Hale has recently been elected Professor of Physics at Beloit College, Wis., and also lecturer on the same subject at the Northwestern University. Professor Hale's present plan is to furnish a course of lectures on physics for the coming year at Beloit College, and to give a shorter course to Professor Hough's students in the Northwestern University.

School of Pure Mathematics and Practical Astronomy.—In this number will be found a provisonal Course of Study for another department of work undertaken at the Goodsell Observatory of Carleton College. One class of two members has already been pursuing this course during the last year. Another class will form at the opening of College in September next. We do not know of an Observatory in this country where a student can pursue a course of post-graduate study in Mathematics and Astronomy more favorably or more systematically than at Goodsell Observatory. Correspondence is solicited with persons who are Bachelors of Arts or Bachelors of Science from Colleges of good standing, wishing further study in these branches.

BOOK NOTICES.

Lessons in Astronomy Including Uranography. A brief introductory course without mathematics, for use in schools and seminaries. By Charles A. Young, Ph. D., LL. D. Publishers, Messrs. Ginn & Company, 1891. pp. 357.

This new book was written to meet the want of certain classes of schools which find the author's "Elements of Astronomy" rather too hard for their courses and pupils. From a full examination of the book, it is evident that the whole matter has been carefully worked over, simplified and re-written, to adapt it to wants of that grade of pupils for which it is intended. In this work we feel sure Professor Young has done better for these pupils than he himself believes, judging from the semi-apology he makes for the book in the preface.

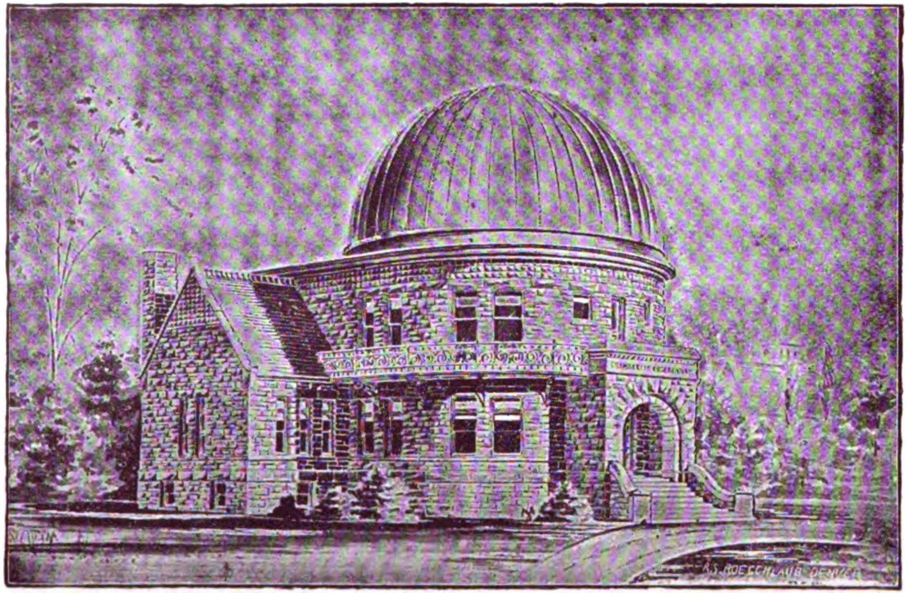
It is so easy for the experienced scholars, writers and teachers in higher branches to forget the many difficulties that the student meets in his first attempts at elementary work, that they are in danger of requiring constantly too much of the beginner. They expect such to know too much, or to acquire new things too easily. Now we have had the impression that our distinguished author has been just a little at fault in this direction, and that his standard in all three of his books on Astronomy is a little severe for the grade of scholarship for which they are respectively written. This, we know, is a good fault, and one greatly to be preferred to weakness of subject-matter in a text-book. A tendency, even, to such an extreme rightly would disgust a good teacher, and a change of book would soon be the remedy.

The first chapter is devoted to fundamental notions and definitions, and then follows a very useful chapter on Uranagraphy, in which is given a brief description of sixty-six constellations, with four double page maps, showing how they are related and all the stars properly designated, down to, and including, the fifth magnitude. At the close of this chapter is a table containing the names of the constellations, the right ascension and declination of each and the number of stars in each, also. Any student with this little book in hand, may locate most of these constellations and a larger part of the 1688 stars to be found in them on these maps. That chapter alone is worth many times the book to any one who wants to make a naked eye study of the heavens.

The other features of the book are those common to a good elementary text, except that the latest information from all lines of active study in the various branches of astronomy, is found in its proper place. It seems to us that teachers of almost any grade of class in Astronomy will find this book a very useful one for reference.

A Higher Algebra, by G. A. Wentworth, Professor of Mathematics in Philip Exeter Academy, Boston, Mass., half morocco, 528 pages. Mailing price $1.55, for introduction, $1.40.

This new book is designed to prepare for colleges and scientific schools, and to furnish in addition what is needed for the *general student* in such institutions. It is equivalent to the author's Complete Algebra, and goes farther in some things, and in some other respects is better. It is, of course, more complete than the School Algebra. It provides in a single book a course parallel to both the School and College Algebra. It is an Algebra that teachers will do well to examine, for its author is one of the most popular writers in the line of school and college text-books in mathematics that our country can boast of.



THE CHAMBERLIN OBSERVATORY,

UNIVERSITY PARK, COLORADO.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

VOL. 10, NO. 8. OCTOBER, 1891. WHOLE NO. 98

STANDARDIZING PHOTOGRAPHIC FILMS WITHOUT THE USE OF A STANDARD LIGHT.*

PROFESSOR FRANK H. BIGELOW.

The employment of photographic effects as the means of measuring photometrically the intensity of the light emitted by an object, has for a number of years engaged the attention of many experimenters. On the whole, with the accumulation of practical experience, the problem does not look to be so easy of solution as was originally supposed. This is due to the obscurity surrounding the nature of the action of light, when it impinges upon the molecules of the substance to be chemically affected, to our ignorance of the fundamental law that governs the density deposit as a function of the time or of the quality of the light, and to an uncontrollable variation in the effects that are presumably derived from uniform conditions.

In May, 1890, I published Bulletin No. 16 of U. S. Scientific expedition to West Africa, wherein I express a view regarding this subject which I should like to see worked out to a practical conclusion. Since that time no little evidence has been produced which strengthens my original solution, and I propose in this paper to bring the main points together in a general statement of the case.

The first point to be taken up is the general nature of the operation by which light is able to produce a deposit of atoms, or a change in certain sensitive chemical substances. The view which seems to give the greatest satisfaction to students may be summarized briefly as follows: A certain substance is what it is, because the atoms which compose it by unknown causes, are constrained to circulate or oscillate about each other in paths or orbits having definite ampli-

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* Read before the American Association for the Advancement of Science at the Washington Meeting Aug. 20, 1891.

tudes and periods; the first grouping of the atoms forming molecules and further groupings constituting the substance. This periodic motion would go on forever, unless energy were conveyed to it from the outside by some process, and if this energy is of the right kind it will disturb the periodic nature of the action. When the energy arrives in the form of the light waves of the ether, we apply a very restricted class of forces out of all that the ether may contain, but to some of the spectrum waves the atomic period becomes sensitive by an accumulation of the impacts of the right type, while to others it is wholly indifferent. Thus it is that certain chemicals respond to given waves but are not influenced by others, and hence arises the method of selective responses in the action of light. If the right waves beat upon the right atomic period, they tend to change the path by expansion or contraction, till at last its original force is overcome and it takes on an orbit of another type; and the molecule being shattered, sets free or deposits an atom, at least so far as the original elements are concerned.

The question arises here as to the nature of the law of the decomposition in its relation to time. We exclude from our discussion that source of variation which arises from a change in the light, or from using at one time certain wave lengths, and at another time other wave lengths. It is clear that the results of different waves acting upon the same atoms, must vary by a complex system of laws, of which we cannot hope to gain a conception until we understand the true laws of natural substance. Let us fix our ideas. Suppose we have 100 atoms forming twenty-five groups or molecules, circulating by the law of the substance. If waves of H length infringe upon them, how will they be deposited or broken up. Some have said that the rule is "the deposit is proportional to the time;" in the first second of time one molecule will be broken up, in the next second one more, and so on, so that at the end of twenty-five seconds all will be broken up. I do not think that this is the correct view, although it is the prevailing one, and has on its side learned men as its advocates.

There is another mode of looking at the law connecting the cause and the effect in this case. If in the first second one molecule is broken up, the energy of the light wave has been able to shatter one twenty-fifth of the total group.

During the next second the light remains the same, but there are only twenty-four molecules to work on, and we shall get not one molecule but $\frac{24}{25}$ of a molecule; or in other words, it requires a little more than one second to pull to pieces the next molecule. This is, we may suppose, due to the fact that in the first second the easiest to break up gives way first; the remaining substance now differs from its original condition by this loss and by the strain introduced into the system by it. Hence the work is becoming more difficult all the time, in this *pari passu* proportion.

Now resorting to mathematics:

Let F_1 = the initial energy in the system,
Let F = the energy remaining after the interval of time t,
m = the modulus of the decay of the system.

$$\frac{dF}{dt} = -mF\text{, at any instant of time.}$$

$$\frac{dF}{F} = -mdt.$$

$$\log F = -mt + C.$$

$$\text{If } t = 0,\ C = \log F_1.$$

$$\log F = \log F_1 - mt.$$

$$\log \frac{F}{F_1} = -mt.$$

$$\frac{F}{F_1} = e^{-mt}$$

$$F = F_1 e^{-mt}$$

The energy at the end of an interval t equals the original energy multiplied by the Naperian base raised to the negative power mt.

This is the law that expresses the change in several well known physical processes, as for example the dissipation of heat by radiation, the decay of an electric current by the resistance of the conductor in which it resides.

In a paper on the "determination of the relation between the exposure-time and the consequent blackening of a photographic film," in No. 6 Publication A. S. P., Mr. Leuschner quotes Captain Abney as having said, at the meeting of the British Association 1889 (p. 493 Report), that his experiments showed "that the intensity was proportional to the time without limitation." This must be an error on Mr. Leuschner's part, for I find that the report says, "the de-

posit of silver made by different intensities of light varies directly as the intensity of the light acting." This is a wholly different statement. The density may be proportional to the intensity of the light, but it is not proportional to the exposure-time, using the same light. Indeed Captain Abney used a formula similar to the one I propose, namely: $T' = T\epsilon^{-\mu x^2}$, $T =$ total transparency,
$T' =$ transparency after time x,
$x =$ some power of 2.

My statement of the law is different from Captain Abney's, but this is only a question of analysis, and we both differ from those who assume that the intensity is proportional to the time.

In his paper Mr. Leuschner describes his experiments for testing the question, and concludes, "the law that the blackening of the film is proportional to the exposure time is confirmed within the limits of *two* seconds and eight seconds (within the limits of accidental errors)." The range is too narrow to uphold the law, and the accidental errors are really quite large, so that the case is wholly made out against the commonly accepted view of the subject.

In passing I will call attention to the unsatisfactory condition of the subject as developed by the observers at Mt. Hamilton. Mr. Leuschner shows that great variations exist on the surface of the same photographic film; that is to say, if the plate is subdivided into squares, there is no assurance that any two squares will give the same density when treated as nearly alike as possible during the operations. Some squares were found to be from two to three times as dark as others exposed for the same length of time. This difference of density was due to changes in the sensitiveness of the film in different parts, as well as to changes in the brightness of the standard flame. In a word the experimenter is by no means sure of knowing the conditions under which he is working. The quality of the plate is not uniform and the light is not constant. To show the general hopelessness of standardizing plates on the old plan, I will quote the result of the experience of the Cayenne eclipse party of Dec. 22, 1889. The following table exhibits the treatment to which ten Seed plates, sensitometer No. 26, were subjected, being standardized by squares exposed to a standard light in the usual manner:

Standard Squares Sept. 24, 1889.

1	2	3	4	5
A	Sent to Cayenne and returned to Lick O.	Developed on Dec. 24, at Cayenne.	5	A = 0.94 J
B			6	B = 0.92 J
C		Developed on Mar. 17, at Lick Observatory.	7	C = 0.55 J
D			8	D = 0.79 J
E	Remained at the Lick O.	Developed on Dec. 22, at Lick Observatory.	3	E = 1.28 J
F			4	F = 1.01 J
G		Developed on Mar. 17 at Lick Observatory.	9	G = 0.38 J
H			10	H = 1.10 J
I	Developed on Sept. 24, immediately after standardizing.		1	I = 1.00 J
J			2	

Additional Squares March 16, 1890.

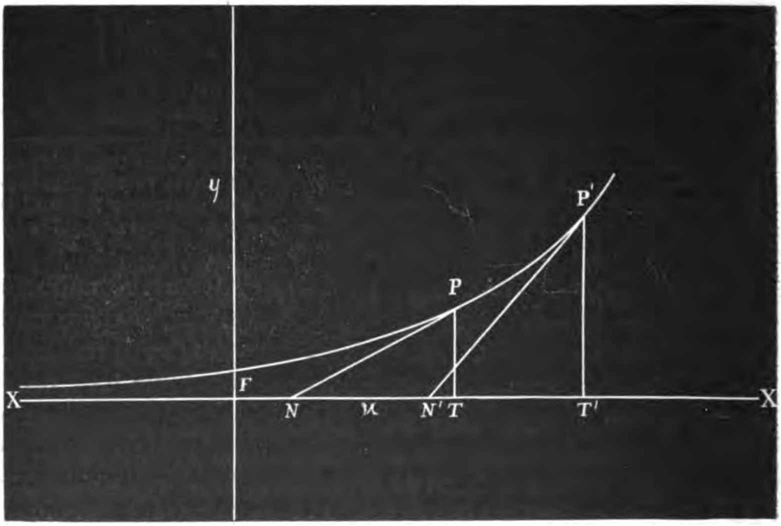
6	7	8	9
	Second Series.	*First Series.*	
C′	C′ = 0.61 H′	C = 0.63 H	C′ = 0.27 J
D′	D′ = 0.67 H′	D = 0.55 H	D′ = 0.37 J
G′	G′ = 0.36 H′	G = 1.35 H	G′ = 0.61 J
H′			H′ = 0.45 J

Columns 1 and 6 are the plate marks; column 2 indicates the places at which the plates were retained; column 3 gives the dates of the development of the plates; column 4 the order of development; columns 7, 8 and 9 the equations which represent the relative densities in terms of J, H and H′ as units by which comparisons can be made.

If the plates had behaved in conformity with the uniform conditions which it was intended to produce, if there had been no change in the standard light between the dates Sept. 24, 1889, and March 16, 1890, and if the films had been homogeneous throughout and had remained so, then the coefficients would have been the same in the whole set of equations. We are greatly indebted to Professor Holden for exhibiting so clearly the utter fruitlessness of such photometric work, when an effort is made to secure absolute measures of actinic brightness. Professor W. H. Pickering first applied the method to the eclipse of 1886, and gave a series of measures of the brightness of the corona in its various parts, and several other related measures of sky light, moon light, and such quantities. These measures would be of great value if they were really absolute, inasmuch as the varying brightness of the corona could be compared from time to time. As it is the range in the measures obtained is enormous, and no confidence can be placed in the accuracy of the work. We are now in possession of the argument sufficiently to proceed to the solution we propose for the problem. Resuming the formula, we have at the end of the intervals t' and t'' respectively.

$$\log F' = \log F_1 - mt',$$
$$\log F'' = \log F_1 - mt'',$$
$$m = \frac{\log F' - \log F''}{t'' - t'}.$$

The equation $F = F_1\, e^{-mt}$ is that of a logarithmic curve. If we put $t = \frac{x}{n}$ and $F = y$, we have $y = F e^{-\frac{x}{n}}$, that is $m = \frac{1}{n}$. Now n is the constant subtangent which is characteristic of the curve, its reciprocal being the modulus of the system.



F = the intercept of the curve on y.
n = the constant subtangent, NT, $N'T'$.
$\frac{x}{n}$ = the time of exposures.
y = the corresponding density products.
After two exposures

$$m = \frac{\log F' - \log F''}{t'' - t} = \frac{1}{n}$$

If we have a plate with a certain density coefficient $\frac{1}{n}$, it is seen that two exposures from the same light will produce two different density products relative in this manner. Now it is seen by an inspection of the formula for m, that we have eliminated the original density F_1, that there is no assumption regarding the light used, and that the elements of uncertainty are reduced to a minimum. If different lights were to be used on the same film, they would, at the end of the intervals t' and t'', pick out two pairs of points P, P', related to each other in such a way as to produce the same modulus to the curve.

We therefore are reduced to two comparatively simple conditions, first, the accurate estimate of the interval of time $t'' - t'$, and second, the determination of the quantities F′ and F″. The first we can pass over as obviously without difficulty. The values of F' and F'' are relative densities, and we may suppose them closely relative to the average number of molecules thrown down.

If we take 100 as representing the color or the plate before exposure, and 0 the density color at its maximum, or when the light action begins to reverse the density product, we can suppose that a visual scale from 100 to 0 will give all the intermediate density shades perceptible to the eye.

If an exposure of 10 seconds gives a density which matches 50 on the scale, and exposure of 15 seconds one that matches 40, we get:

$$m = \frac{1.69897 - 1.60206}{15 - 10} = \frac{0.09691}{5} = 0.01338$$

$$n = \frac{1}{m} = 9.98662 = .96966,$$

which will characterize this film. The serious task is to secure the standard scale. It will need to be a work of art and will require much skill to produce it, for it is well known that nothing is more vexatious than to produce evenly graduated shadings of black and white. The behavior of all the parts concerned is often inexplicable.

After duly considering the case, I am inclined to think that the simplest way to get at a scale will be to make a large number of bits of buck with varying shade, and then by trial place them along side of each other in the right order. This problem is so promising that we may hope some photographer will attempt to produce a prototype scale that can be used in this connection. For it would seem, at least theoretically, that this will afford a means of escape from the very unsatisfactory condition of affairs which now exists either regarding the standardizing of plates, or as regards the application of photography to any kind of photometric use.

SIR G. B. AIRY.

THE ninetieth birthday of Sir G. B. Airy (1891, July 27) is an event of such general interest that we feel sure a brief reference to its celebration by his family and friends will not be deemed an impertinence. Saturday, July 25, was fixed for the reception in honor of the event, and Sir George received in person the congratulations and good wishes of a large and distinguished company.

Astronomy was represented by many familiar faces, including those of the Astronomer Royal, the President of the R. A. S., and the Hydrographer to the Navy. It was delightful also to see Mr. Perigal, who walked up the hill with almost a jaunty step. Trinity College, Cambridge, of which Sir George is both the oldest ex-Fellow and the oldest Honorary Fellow, was represented by its master, Dr. Butler. There were many other guests whose presence was significant, as, for instance, Mr. Biddell, who was forty years ago charged by Messrs. Ransomes and May with the construction of the present Transit Circle. He described to a small knot of most interested guests the dismay of the workmen and their employers at the demands of Sir G. B. Airy, especially those relating to the pivots. These were to be of chilled iron, 6 inches in diameter, and perfect cylinders to within $\frac{1}{80000}$ inch! No error of this magnitude was to be discernible with a delicate spirit-level; and after trying all the most delicate methods of turning then known, the requisite accuracy was obtained by sheer labour—rubbing down bit by bit all the places which this same spirit-level indicated as too high. Each of the pivots cost six weeks of such labour!

Monday, July 27, the actual anniversary, was marked by the performance of a singularly appropriate ceremony. Sir George turned on, for the first time, the gas which is to illuminate the Parish Church clock of Greenwich, and which will now be automatically and regularly turned on by the clock during the evening hours. The very hour (9 o'clock) at which he was thus once more concerned with Greenwich time was curiously in keeping with the occasion, and the excellent speech with which he concluded the ceremony bore evidence to his marvellous vigor. We sincerely hope to be present at an even more important celebration ten years hence.—*Observatory, August, 1891.*

SOME TELESCOPES IN THE UNITED STATES.

WM. H. KNIGHT.

FOR THE MESSENGER.

The following partial list of telescopes in the United States is epitomised from materials I have been collecting during the past two years with a view to publishing a catalogue of the observatories of the world, together with their equipment and personel. In the present list I have included only those instruments of which the aperture is 4 inches or upwards.

It will be seen that the twelve largest refracting telescopes are those of the Lick Observatory with an aperture of 36 inches, Yale University 28, U. S. Naval 26, Leander McCormick 26, Princeton 23, Denver 20, Smithsonian 20, Dearborn 18.5, Carleton College 16.2, Warner 16, Washburn, 15.5 and Harvard 15.

The largest reflecting telescopes are those of Harvard College, 28 inches, and Rev. Dr. John Peate 22. Dr. Peate, who is an amateur maker, is now finishing up a 30½ inch silver-on-glass mirror, which will be presented to the Allegheny College at Meadville: When mounted it will be the largest reflecting telescope in this country. There are numerous reflectors made by Brashear from 9 to 12 inches in diameter.

The Clarks are now grinding an object glass of 40 inches for a telescope to be mounted in an Observatory yet to be built upon Mount Wilson in Southern California.

Though the Lick Observatory possesses the largest telescope at present, Harvard College has the best equipped Observatory for general astronomical work in America, and one of the best in the world.

In foreign countries the largest refractors are those at Pulkowa, near St. Petersburg, 30 inches, Nice 29.75, Vienna 26.75, Gateshead near London 25, and Paris 23.6.

The largest reflectors are those of Lord Rosse in Ireland 72 inches, Melbourne 48, Paris 47, Mr. Common's in England 37.5, another of Lord Rosse 36, Toulouse 32.4, Marseilles 31.5, Greenwich 28, and Cambridge 24.

Location.	*Owner.*	*Description.*
Akron, O.	Buchtel College Observatory	4.5-in.
Albany, N. Y.	Dudley Observatory	13-in. Refractor 6-in. Mer. Circle.
Alfred Center, N. Y.	Alfred Observatory	9-in. Refractor
Allegheny, Pa.	Allegheny Observatory	13-in. Refractor 10-in. Reflector
Amherst, Mass.	Amherst College Observatory.	7.25-in. Refractor 6.37-in. Tran. Cir.
Annapolis, Md.	Annapolis Observatory	7.75-in. Refractor 4-in. Mer. Circle
Ann Arbor, Mich.	Detroit Obs. of the Univ. of Mich.	12.4-in. Refractor 6-in. Mer. Circle
Appleton, Wis.	Underwood Obs. of Lawrence University.	10-in. Refractor 4-in. Transit Circle
Augusta, Me.	Melville Smith	8.5-in. Reflector
Baltimore, Md.	Johns Hopkins University	9.5-in. Refractor
Baltimore, Md.	Geo. Gildersleve	6.1-in. Refractor
Baltimore, Md.	Normal School	6-in.
Baltimore, Md.	John R. Hooper, M. D.	5-in. Refractor 4.1-in. Refractor
Baltimore, Md.	Denmore Observatory	4-in. Refractor
Baltimore, Md.	Justice Stahn	6-in. Refractor
Beloit, Wis.	Smith Obs. of Beloit College	9.5-in. Refractor
Berkeley, Cal.	Students Obs. of the Univ. of Cal.	6-in. Refractor
Boston. Mass.	Boston University	7-in. Refractor
Brighton, Mass.	Edwin F. Sawyer	4.37-in. Refractor
Brooklyn, N. Y.	Henry M. Parkhurst	9-in. Refractor
Brunswick, Me.	Bowdoin College Observatory	6-in. Refractor
Cambridge, Mass.	Harvard College Observatory	28-in. Reflector 24-in. Bruce Photo. 15-in. Refractor 15-in. Reflector 13-in. Rev. Photo. 12-in. Horizontal 11-in. Photo. 8-in. Transit Circle 8-in. Photo. Doub. 4.25-in.Com. Seeker
Camden, N. J.	Camden Observatory	5.5-in. Refractor
Camden, N. J.	A. B. Depuy	9.5-in. Reflector
Charlottsville, Va.	Leander McCormick Observatory of the University of Virginia.	26-in. Refractor 4-in. Refractor
Chicago, Ill.	Kenwood Physical Observatory	12.2-in. Refractor
Chicago, Ill.	Samuel Harris	4.25-in. Refractor
Cincinnati, O.	Cincinnati Observatory of the University of Cincinnati	11-in. Refractor 5.12-in. Mer. Circle 4-in. Refractor
Clinton, N. Y.	Litchfield Observatory of Hamilton College	13.5-in. Refractor 5-in. Refractor 4-in. Refractor
Columbia, Mo.	Observatory of the Univ. of Mo.	7.5-in. Refractor
Columbus, O.	Ohio State University	4-in. Refractor
Crete, Neb.	Boswell Observatory	8-in. Refractor
Dansville, N. Y.	Patterson Observatory	5-in. Refractor
Denver, Col.	Chamberlin Observatory of the University of Denver.	20-in. Refractor 6-in. Refractor
Evanston, Ill.	Dearborn Obs. of N. W. University	18.5-in. Refractor
Fall River, Mass.	Durfee High School	8-in. Refractor

Maker and Date.	*Astronomers.*	*Special Work.*
Pike	H. V. Egbert, Director	Educational
Fitz	Lewis Boss, Director	Comets
Fitz	F. S. Place, Director	
Fitz, 1861	James E. Keeler, Director; Frank W. Very, Observer	Solar Physics, Spectroscopy
Brashear		
Clark	David P. Todd, Director	Jupiter's Satellites, Sun Spots
Pistor & Martins		
Clark		
Repsold		
Fitz	Mark W. Harrington, Director; W. J. Hussey, Observer	Star Positions
Pistor & Martins		
Clark, 1891	L. W. Underwood, Director	Educational
Clark		
Brashear		
1887	Chas. A. Borst, Director	
Hastings, 1884	Geo. Giddersleve, Observer	Solar Observations
Clark, 1866	John R. Hooper, Director	Sun Spot Records, Comets
Hastings, 1879		
Cooke	W. H. Numsen, Observer	
1889	M. B. Stahn, Observer	
Clark, 1882	Charles A. Bacon, Director	Solar Prominences
Byrne	Frank Soulé, Director	Planetary Studies
Clacey	Judson B. Coit, Director	Educational
Clacey, 1882	Edwin F. Sawyer, Director	Variable Stars
Fitz, 1877	Henry M. Parkhurst, Director	Asteroid Photometry.
Wray, 1886		Educational
Draper	Edward C. Pickering, Director; Arthur Searle, S. C. Chandler, Jr., O. C. Wendell, Wm. Maxwell Reed, Wm. H. Pickering, John Ritchie, Jr., Observers	Photometry, Photography, and Meridian Circle Observations
1890		
Merz, 1846		
Draper		
Clark, 1887		
Clark, 1888		
Clark		
Clark, 1870		
Clark, 1885		
Queen, 1888	Edmund E. Read, Jr., Director	Solar Prominences
	A. B. Depuy, Observer	
Clark	Ormond Stone, Director; N. W. Parrish, Frank Muller, Observers	Nebulæ
Kahler		
Brashear, 1891	Geo. E. Hale, Director	Spectroscopy
Merz & Mahler, 1843	Jermain G. Porter, Director	Sidereal Motion
Fauth		
Clark		
Spencer		Star Charts, Variable Stars, Minor Planets
Schrœder		
Steinhold		
Merz & Mahler, 1850	Milton Updegraff, Director	Star Positions
Clark, 1883	Goodwin D. Swezey, Director	Student Work
Clark, 1881	Rowley Patterson, Observer	
Clark, 1890	Herbert A. Howe, Director	Work not yet begun
Brashear		
Clark, 1862	G. W. Hough, Director	Jupt, Double stars
1888		Educational

Location.	*Owner.*	*Description.*
Galesburg, Ill.	Knox College Observatory	6-in. Refractor
Geneva, N. Y.	Hobart College Observatory	8.75-in. Refractor
Geneva, N. Y.	Smith Observatory	10.12-in. Refractor
		9-in. Reflector
		5-in. Reflector
		4-in. Mer. Circle
Glasgow, Mo.	Morrison Observatory	12.25-in. Refractor
		6-in. Mer. Circle
Greencastle, Ind.	McKim Observatory of the De Pauw University.	9.5-Refractor
		4-in. Almucantar
Greenville, Pa.	Rev. John Peate, D. D.	22-in. Reflector
		12.37-in. Silver-on-Glass Reflector
Grinnell, Ia.	Iowa College Observatory	8-in. Refractor
Hamburgh, N. Y.	B. M. Fish	7.33-in. Refractor
Hanover, N. H.	Shattuck Observatory of Dartmouth College	9.25-in. Refractor
		4-in. Mer. Circle
Hartford, Conn.	High School	9.4-in. Refractor
Haverford College, Pa.	Haverford College Observatory	10-in. Refractor
		8.25-in. Refractor
		8.25-in. Newt. Refl.
		4-in. Mer. Circle
Hockessin, Del.	John G. Jackson	6-in. Reflector
Hudson, O.	Western Reserve College	4-in. Refractor
Jackson, Mich.	U. W. Lawton	4-in. Refractor
Joliet, Ill.	Joliet High School	4.5-in. Refractor
Lancaster, Pa.	Daniel Scholl Observatory of Franklin and Marshall College	11-in. Refractor
Lewisburg, Pa.	Bucknell College Observatory	10-in. Refractor
Lewiston, Me.	Bates College	6.25-in. Refractor
Little Rock, Ark.	T. E. Murrell, M. D.	6.5-in. Silver-on-Glass Reflector
Lyons, N. Y.	M. A. Veeder	6-in. Refractor
Madison, Wis.	Washburn Observatory University of Wisconsin	15.5-in. Refractor
		6-in. Refractor
		4.8-in. Mer. Circle
Middletown, Conn.	Wesleyan University	12-in. Refractor
Mount Hamilton, Cal.	Lick Observatory of the University of California	36-in. Refractor
		12-in. Refractor
		6.5-in. Refractor
		6.5-in. Mer. Circle
		4-in. Comet Seeker
		4-in. Transit
		4-in. Photoheliograph
Newburgh, N. Y.	Darwin W. Esmond	4 in. Refractor
New Haven, Conn.	Winchester Observatory of Yale University	28-in. Refractor
		8-in. Refractor
		6-in. Heliometer
New York, N. Y.	Columbia College Observatory	13-in. Refractor
Northfield, Minn.	Goodsell Observatory of Carleton College	16.2-in. Refractor
		8.25-in. Refractor
		4.8-in. Mer. Circle
		4.3-in. Refractor
Oakland, Cal.	Chabot Observatory	8.5-in. Refractor
		4.12-in. Tran. Circle
Oakland, Cal.	Chas. Burckhalter	10.5-in. Reflector

Maker and Date.	*Astronomers.*	*Special Work.*
Clark, 1879	Edgar L. Larkin, Director	Educational
Fitz	H. L. Smith, Director	Educational
Clacey	Wm. R. Brooks, Director; Anna G. Brooks, Observer	Comet Seeking, Planets
Warner & Swasey		
Clark	Carr W. Pritchett, Director	Planets
Sims		Double Stars
Clark, 1885	Wilbur V. Brown, Director	Educational
Clacey, 1883		
Peate, 1890		
Peate	John Peate, Director	
Clark	S. J. Buck	Educational
Clark, 1872	B. M. Fish, Observer	Comet Seeking
Clark		Educational
Clark, 1883		Educational
Clark, 1883	Francis P. Leavenworth, Director; H. V. Gummere, Observer	Double Stars
Fitz, 1852		
Calver		
Sims		
Clark	U. W. Lawton, Observer	
Clark	A. H. Wagner, Director	
Clark		Educational
Clark	Wm. C. Bartol, Director; Wm. G. Owner, Observer	Educational
Fitz		
Brashear		
Fitz	M. A. Veeder, Director	Solar Observations
Clark, 1878	Geo. C. Comstock, Director; A. S. Flint, Observer	Star Places, Constants of Refraction
Clark		
Repsold		
Clark		Educational
Clark, 1886	Edward S. Holden, Director; S. W. Burnham, J. M. Schæberle, E. E. Barnard, Charles B. Hill, W. W. Campbell, Observers	Star Motions, Double Stars, Nebulæ, Spectroscopy, Comets
Clark, 1881		
Clark		
Repsold, 1884		
Clark		
Fauth, 1881		
Clark		
Clark	Leonard Waldo, Director; Wm. L. Elkin, H. A. Newton, C. S. Hastings, Observers	Stellar Parallax, Meteorites
Grubb		
Repsold		
	John K. Rees, Director; C. H. Jacoby, Observer	Educational
Brashear, 1891	Wm. W. Payne, Director; Herbert C. Wilson, Miss C. R. Willard, Observers	Star Positions, Celestial Ph[illegible]raphy
Clark, 1876		
Repsold		
Byrne		
Clark	Chas. Burckhalter, Director	Educational
Fauth		
Brashear	Chas. Burckhalter, Director	

Location.	*Owner.*	*Description.*
Oakland, Cal.	Dr. J. H. Wythe	8.5-in. Reflector
Oakland, Cal.	F. G. Blinn	5-in. Refractor
Oakland, Cal.	Mills College	5-in. Refractor
Omaha, Neb.	Creighton College Observatory	5-in. Refractor
Pasadena, Cal.	Pasadena Hotel	4-in. Refractor
Philadelphia, Pa.	Central High School	6-in. Refractor 4.5-in. Mer. Circle
Poughkeepsie, N. Y.	Vassar College Observatory	12.25-in. Refractor 5-in. Refr. Portable
Princeton, N. J.	Halsted Observatory of Princeton University	23 in. Refractor 9.5-in. Refractor 4-in. Mer. Circle
Providence, R. I.	Ladd Observatory of Brown University	12-in. Refractor 4-in. Refractor
Providence, R. I.	Seagrave Observatory	8.25-in. Refractor
Rochester, N. Y.	Warner Observatory	16-in. Refractor 4.5-in. Com. Seeker
Salem, O.	I. W. Thompson	4-in.
San Francisco, Cal.	Davidson Observatory	6.4-in. Refractor
San Francisco, Cal.	Charles Goodall	5-in. Refractor
San Francisco, Cal.	James Murphy	4-in. Refractor
San Francisco, Cal.	Wm. M. Pierson	8.5-in. Refl. 1890
San José, Cal.	University of the Pacific	6-in. Refractor
San Mateo, Cal.	St. Mathews Hall College	8.5-in. Reflector
Saratoga Springs, N. Y.	Hathorn Observatory	6-in. Refractor
South Bergen, N. J.	Henry Harrison	5.5-in. Refractor
South Hadley, Mass.	Williston Observatory of Mount Holyoke Seminary	8-in. Refractor
Stanford, Fla.	J. E. Ingraham	4.5-in. Refractor
St. Charles, Mo.	Capt. Petitdedier	12-in. Reflector
St. Louis, Mo.	Observatory of Washington University	6.5-Refractor
St. Louis, Mo.	Dr. J. G. W. Steedman	8-in. Reflector
Swarthmore, Pa.	Swarthmore College Observatory	6-in. Refractor
Syracuse, N. Y.	Holden Memorial Observatory	8-in. Refractor
Syracuse, N. Y.	H. P. Stark	5.3-in. Refractor
Tarrytown, N. Y.	Chas. H. Rockwell	6.4-in. 4-in.
Washington, D. C.	U. S. Naval Observatory	26-in. Refractor 9.6-in. Refractor 8.5-in. Tran. Circle 5.3-in. Prime Vert. Transit 5-in. Transit 4-in. Mural Circle
Washington, D. C.	Georgetown College Observatory	4.8-in. Refractor 4.5-in. Transit 4-in. Mer. Circle
Washington, D. C.	Smithsonian Physical Obs.	20-in. Refractor
Waterville, Me.	Shannon Obs. of Colby University	
West Point, N. Y.	Observatory of the U. S. Military Academy	12-in. Refractor 8-in. Tran. Circle
Williamstown, Mass.	Williams College Observatory	4.8-in. Mer. Circle
Wilmington, Del.	Alfred G. DuPont	12-in. Reflector 4.5-in. Refractor
Wilmington, Del.	Elwood Garrett	8.5-in. Reflector
Wilmington, Del.	Geo. W. Humphrey	6.5-Reflector

Maker and Date.	*Astronomers.*	*Special Work.*
Brashear		
Clark		
Stewart	Joseph Rigge. Director	Educational
Merz		Educational
Ertel		
Clark.	Mary W. Whitney, Director	Educational
Clark		
Clark	Charles A. Young, Director; Malcolm McNeill, Observer	Solar Physics, Comets
Clark		
Brashear, 1891	Winslow Upton, Director	
	Frank E. Seagrave, Director	Double Stars
Clark, 1881	Lewis Swift, Director; Edward D. T. Swift, Observer	Nebulæ, Comet Seeking
Clark, 1885	George Davidson, Director; Geo. F. Davidson, Thos. D. Davidson, Observers	Planets, Eclipses, Occultations
Clark		
Clark	T. C. George, Director	Educational
Brashear		
Clark, 1883	F. J. del Corral, Observer	Planets
Byrne	Henry Harrison, Director; M. Paddock, Observer	Double Stars
Clark, 1881	Miss Elizabeth M. Bardwell, Dir.	Educational
Clark, 1885	H. S. Pritchett, Director; Alfred Ramel, Observer	Comets, Planets
Brashear, 1888	J. G. W. Steedman, Director	
	S. J. Cunningham, Director	Educational
Clark, 1887	H. A. Peck, Director	Educational
Spencer		
Hastings	Chas. H. Rockwell, Director	Lunar Wave in Earth's Crust
Clacey		
Clark, 1873	Capt. F. V. McNair, Supt.; Asaph Hall, W. Harkness, J. R. Eastman, Edgar Frisby, L. J. Brown, A. N. Skinner, H. M. Paul, Asaph Hall, Jr., W. M. Brown, Geo. A. Hill, C. S. McCoy, Observers.	Planets, Satellites. Comets, Double Stars, Parallax
Merz & Mahler, 1845		
Pistor & Martins, '65		
Pistor & Martins, '45		
Ertel, 1844		
Simms, 1844		
Simms	John G. Hagen, Director; James F. Dawson, Observer	Variable Stars, Star Occultations
Ertel		
Simms		
Grubb	S. P. Langley, Director	
	Wm. A. Rogers, Director	
Clark, 1884	Lt. Wallace Mott, Director	
Repsold, 1885		
Repsold	Truman H. Safford, Director	
Brashear		
Clark		
Brashear		
Brashear, 1882		

THE CHAMBERLIN OBSERVATORY.

FOR THE MESSENGER.

The Chamberlin Observatory owes its existence to the munificence of Hon. H. B. Chamberlin, of Denver, who has erected the building at a cost of about $25,000, and has made contracts for the instrumental equipment. The site embraces nearly fourteen acres, situated at a distance of five miles from the business centre of Denver, at University Park, the seat of the University of Denver, of which it forms a department.

The building is constructed of a very hard sandstone taken from the Archalow quarries at Lyons, Colo. The facing of the walls, from the watertable up, is a soft, rich red sandstone from the same quarries. The pier which is to support the twenty-inch equatorial is built of dimension stone, and is sixteen feet square at the base, and twelve feet square at the top; its height is twenty-five feet, half of which is below the grade line. There are two other piers; one for the four-inch meridian-circle, and the other for the photographic measuring engine.

The basement has a special entrance in the rear and contains a work-shop, store-room, janitor's quarters, photographic room with dark closet and porcelain sinks, and boiler room. The floor is of cement, except close to the piers, where a three inch space is left, filled with loose sand.

The director's office, on the main floor, in the west wing, contains shelves for the working library, and a case of twenty-four drawers for miscellaneous pamphlets; it is adorned by a grate and mantel. The transit-room in the east wing contains a sandstone pier of unusual form; two heavy blocks of stone are surmounted by a cap connecting them. The roof-shutters are of iron, and each is opened in 5 seconds by a simple gearing. Adjoining the transit-room is the chronograph-room, the two being connected by a window through which the chronograph can be watched.

In the clock-room provision has been made for two clocks, which are to be suspended on small oak beams which have been built into the equatorial pier, and project through the partition surrounding it. Around each beam, where it comes through the partition, is a space filled with mineral wool. Clock closets will be built around the clocks. On the main floor are also the reference library, a computing room, an instrument room and a lavatory.

The second story contains a computing room, a bed-room, three large closets, and the dome room, which is thirty-four feet in diameter, and is surmounted by an iron dome built upon the Hough system, by Mr. William Scherzer, of Chicago. It is equipped with the Cooke shutter, which is a vertical semicircle, one extremity of which rests on a pivot, while the other rides on a track tangent to the base-ring of the dome. This shutter is surmounted by a Globe ventilator, and is eminently satisfactory. The entire slit, which is five feet wide and extends from the horizon to a point thirty inches beyond the zenith, is uncovered at once.

The building faces southward, and measures sixty-five feet by fifty; it is heated by steam and wired for electric lighting.

The Students' Observatory, likewise presented by Mr. Chamberlin, is twenty-four feet by fourteen feet, and shelters the six-inch Saegmuller-Brashear equatorial, and the two-inch Saegmuller transit. The dome is of wood, covered with tin, and was built by Mr. F. A. Walter, of University Park. The instruments have been fairly tested, and have proven themselves to be excellent. The design of the equatorial is noteworthy for simplicity, beauty, and serviceability.

HOW TO MAKE GOOD MERIDIAN OBSERVATIONS.

T. H. SAFFORD.[*]

FOR THE MESSENGER.

DIFFERENTIAL OR ZONE OBSERVATIONS.

The ordinary instrumental corrections are somewhat variable. The correction for level and azimuth can be readily transformed, by using Bessel's formulæ, into equatorial (m) and polar (n); and the variations of n measured by observing known polars at the beginning and end of an evening's work. Those of m can be readily obtained from the formula

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[*] Williams College, Williamstown, Mass.

$$m = i \sec \varphi - n \tan \varphi$$

when i is the inclination, measured by the spirit level or by a combination of known collimation and nadir observations or, what is in many cases equally convenient, can be joined with those of the clock-correction. In fact most Observatory clocks are subject to variations from their average rate from day to day quite comparable with those of the quantity m, so that the values of $dt + m$ are obtained at the beginning and end of an evening's work by quick moving stars, and are not separated in their application. This was in fact the practice of both Bessel and Struve, and of many other first rate observers.

The hourly variations, unaccounted for by clock-rate, of $dt + m$, and those of n, may amount to several hundredths of a second hourly during an evening's (or morning's) work and it is not safe, therefore, to neglect them; but always best to determine clock and instrumental error at intervals of two or three hours.

The great zones, observed between 1869 and the present time, under the direction of the Astronomische Gesellschaft by a co-operative effort on the part of astronomers in many European countries and in the United States, were so arranged by Argelander. The northern heavens were divided into zones usually of 5° breadth; each Observatory taking part was to observe all stars down to the magnitude 9.0 and all fainter which had been previously determined by certain meridian observers—Lalande, Bessel and others. The participants were in freedom to subdivide their zones or not as their convenience dictated. The zones were to be divided into portions of about an hour and a half in length; each to be preceded and followed by zero stars in the same average declination as the zone itself; and not more than 10° from it on either side. And the instrumental correction (n) was to be obtained by polar stars both before and after the zone if thought necessary. As, however, its influence was slight because the zones were narrow and the average declination of both determined and determining stars the same, this point was not very important.

Here is a sample zone: No. 13, Christiania, May 6, 1870. A. R. 12^{h} 51^{m} — 14^{h} 25^{m}, Dec. 65° — 70° not subdivided:

ZERO STARS.

76 Ursæ Majoris	12^{h} 36^{m}	63.4°
Gr. 2001	13 23	73.1
α Draconis	14 1	65.0
Gr. 2125	14 28	60.8

Polaris sub polo for value of *n*.

or No. 162 1873, Dec. 10. A. R. 0^{h} 11^{m} — 1^{h} 25^{m}, Dec. 65° — 69°.

ZERO STARS.

β Cassiopeiæ	0^{h} 2^{m}	58.5°
Groomb 29	0 9	76.2
Bradley 82	0 43	63.6
40 Cassiopeiæ	1 28	72.4
43 Cassiopeiæ	1 32	67.4

Polaris above for value of *n*.

The declinations, as well as the right ascensions, are reduced by the zero-stars, so that the nadir, if used at all, is only employed to indicate changes in the zero-points; and in general the observations are differential, the zero-stars being observed under nearly the same circumstances as the zone-stars themselves.

The result of this method is to eliminate very completely the peculiarities of the instrument.

Chr..	H	Chr.		H		H — Chr.	
		s	″	s	″	s	″
13	51	24.36	52.0	24.42	52.8	+ 0.06	+ 0.8
23	96	32.65	22.3	32.84	21.8	+ 0.19	— 0.5
25	100	51.62	58.3	51.37	57.8	— 0.25	— 0.5
30	117	5.99	8.8	4.96	7.0	— 0.03	— 1.8
38	163	37.71	36.9	37.91	38.3	+ 0.20	+ 1.4
39	164	46.01	50.5	46.10	51.1	+ 0.09	+ 0.6
56	233	48.26	54.6	48.36	54.1	+ 0.10	— 0.5
62	284	45.58	49.5	45.50	50.3	+ 0.02	+ 0.8
78	331	14.13	17.7	13.94	18.2	— 0.19	+ 0.5
88	402	21.59	52.1	21.50	52.8	— 0.19	+ 0.7
							″
				Mean.		0.000	+ 0.15
						s	″
				P. E. 1 Diffr.		± 0.118	± 0.70

I have given here a comparison between the first ten stars common to the Helsingfors and Christiania zones, as a sample taken quite at random. It will be seen that there is no constant difference which cannot be explained by casual errors; yet the Christiania zone (65° — 70°) was taken with a meridian circle, with an aperture of 4.3 inches, and the circle about 2.6 inches diameter was read by two verniers, while the Helsingfors zone was observed with a transit instrument fitted with a divided arc of 24 degrees with a radius of 15 inches read by a single microscope. The flexure of the telescope of the latter instrument was very large, and the services of the former gave much trouble; but the outstanding errors seem to have been perfectly corrected by the differential method.

The probable difference in right-ascension is about the same as we should expect. Both observers used the eye-and-ear method, and observed these stars 2 or 3 times on 3 or 4 wires each; so that, after reduction from the parallel of 65° to the equator, we find the declination and right ascension to be observed with a probable error of not far from half a second of arc in either case.

Future zone observations are likely to be made in less quantity. There are not far from 150,000 stars included in the project now nearly completed; each star has been observed at least twice. The project extends from 80° north to 23° south declination; the region around the north pole was observed by Carrington, and has been more or less worked up by others, with a somewhat greater degree of completeness, all told; the required zero-points of the photographic survey will be less in number, as 6 stars to a plate 2° square means less than 70,000 stars in the whole sphere, or about a third as many for the same area. The future zone-observations will be made for photographic zero-points; hence probably greater accuracy (7 to 15 wires for each star and 2 microscopes in all cases) will be aimed at in the single observations. But on the other hand the quantity of work required is so large and the advantages of the differential method are so considerable, that it will doubtless be employed with the slight modification that few stars to a zone will be taken, but on more wires and with two microscopes.

Those observers on the Astronomische Gesellschaft's plan who were able to work most rapidly employed one microscope only. But in this case the bisection was made twice, on two successive division lines of the limb, and the repetition of the observation made on a different part of the circle. At Helsingfors, as before stated, the instrument had but one microscope; but the errors of all the divisions on the limb of 24° were carefully determined by an ingenious process invented by Professor Krüger. Moreover the zero-point was always shifted from zone to zone by unclamping the divided arc and moving it to another position. My own participation in this great work was interrupted by the consequences of the great Chicago fire, after about two and a half years had been employed upon it. The Chicago meridian circle (now at Evanston) has an aperture of 6.4 inches. According to the formula which I employ for this purpose

$5^{m}.0$. + 5 log aperture in English inches

it is adequate to the observation (with full illumination) of stars down to the magnitude 9.0; with modified illumination of the field, stars of the magnitude 9.7 (called 9.4 or 9.5 in the Durchmusterung) can be taken with almost as much accuracy, if special pains be taken. But at Christiania, where the aperture was only 4.3 inches, the limit of the most accurate observation under average circumstances would be 8.9; 8.2 with full illumination; so that the astronomers there must have taken especial pains to pick up the faint stars on unusually transparent nights.

With wire-illumination of course much fainter stars can be taken; while the glass-scales which have been a good deal employed in this country seem to cut off about half a magnitude from the ordinary range of field illumination. That is to say, they reduce the effectiveness of the aperture nearly 37 per cent; or a 6-inch telescope with glass scales is no better than a 4¾-inch with field-illumination and spider lines.

In fact with the 8-inch Harvard College meridian circle and glass scales there seems to be difficulties in getting the fainter stars of the programme which are quite of the same order as those noticed by Argelander with 4.8 inches and spider-lines, with field-illumination. The next improvement to be made in zone-observations will be, I think, the use of 7th and perhaps 8th magnitude stars as zero-points; such stars to be carefully determined at several Observatories in considerable number. I shall have more to say about this in my next article; in which I shall also give a detailed account of Professor Boss's admirable zone, +1° to +5°, takat Albany.

ON THE EFFICIENCY OF A SMALL INSTRUMENT.

GEORGE C. COMSTOCK.*

FOR THE MESSENGER.

In the *Description de l'Observatoire Astronomique Central de Poulkova* by F. G. W. Struve occurs the following passage prefixed to the description of the great vertical circle: "Many astronomers have found in their experience that small instruments furnish results which, comparatively speaking, are much more precise than those given by large ones, and this is especially true in the case of zenith distances. The two classes of instruments, being equally subject to the effect of atmospheric disturbances ,have their efficiency in some measure equalized by this circumstance. Nevertheless under the most favorable external conditions, where the large instruments possess all the advantage of greater magnifying power, and where the precision of the graduation is not nullified by the uncertainty of the pointings, small instruments have shown themselves comparatively superior to large ones."

Struve is not here considering the relative optical efficiency of small and large telescopes, which has been so frequently discussed in recent years, but their ability to furnish accurate numerical results in the determination of latitude, time, azimuth, etc., and my purpose in the present article is to add something by way of confirmation to the opinion above expressed. The Washburn Observatory has recently acquired a small universal instrument by Bamberg, of Berlin, which is used principally in the instruction of students in practical astronomy, and in connection with this use I have had occasion to study the instrument with some care to determine what measure of precision is attainable with it, and the numerical results cited below are the result of this study. The instrument consists essentially of a horizontal and vertical circle, each 175 ^{mm} in diameter, divided to 10′ and read by two micrometer microscopes to 5″, or by estimation to 0″.5. The telescope is a broken one of 36 ^{mm} aperture and 378 ^{mm} focal length, and is provided with an eye-piece giving a magnifying power of 36 diameters. As or-

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* Director, Washburn Observatory, Madison, Wis.

iginally constructed the instrument was provided with a system of spider threads which I have removed and substituted for them a glass plate with ruled lines blackened by filling them with powdered graphite. The lines thus obtained are much finer than any spider threads I have ever seen, and are in every way preferable to them.

Taking up now the question of attainable precision we note that Foerster, who has made a careful investigation of a somewhat smaller instrument by the same maker, states that "the probable error of a single determination of altitude with the five-inch instrument can be reduced to one second of an arc," a statement which agrees very well with the results of my own experience, for I find from latitude observations made with the instrument above described that the probable error of a single zenith distance, the mean of a reading Circle Right and Circle Left, is $\pm 0''.8$, certainly a surprising degree of accuracy for an instrument which is small enough to be picked up and carried about in one's hands.

It is, however, in connection with time determinations that I possess the largest amount of data in regard to the efficiency of the instrument. For these determinations I have used exclusively the method of transits over the vertical of the pole star, Doellen's method with the formulæ slightly modified; employing a sidereal chronometer beating half seconds and observing the transits of the stars by eye and ear over five threads. Albrecht's formula for the probable error of an observed transit of a star over a single thread, which is in substantial agreement with the experience of the observers of the U. S. Coast Survey, is

$$v = \sqrt{a^2 + \left(\frac{b}{u}\right)^2 \sec^2\delta} \qquad a = 0.07^s \qquad b = 3.18^s$$

where v is the magnifying power employed. This gives for an observation of an equatorial star with this instrument $v = \pm 0^s.113$, while from actual observation with the instrument I find the following values of this probable error, each value being derived without reduction to the equator from all the observations of a single night, and every night on which four or more stars were observed being included in the summary.

Date.	No. of Stars.	P. E. of a Transit over a Single Thread.
1891, April 3	4	$\pm 0.07^s$
June 8	4	.08
July 18	4	.07
" 30	5	.04
Aug. 4	6	.06
" 7	4	.08
" 13	4	.07
" 15	4	.06
Sept. 4	4	.06

The mean of these results $\pm 0.066^s$ indicates a precision more than three times as great as that assigned by the formula, which is based upon observations made with larger instruments and greater magnifying power. A partial explanation of this difference may perhaps be found in the appearance of a bright star in a large telescope, a flaming body of light whose exact position cannot be determined as precisely as can that of a fainter star or the same star seen in a smaller telescope. It is also probable that the actual relation of magnifying power to precision of observation is not represented by the formula.

Perhaps the most striking illustration of the precision attainable with the instrument under consideration is furnished by the individual values of the chronometer correction furnished by the several stars observed on each night. These are given in the following table, which is not a selection of the most consistent results out of a series, but contains the chronometer correction given by every star observed by me with this instrument between June 8 and Sept. 4, 1891. An equal number of stars is observed in each position of the clamp and the collimation has been derived from the observations.

June 8.	July 18.	July 30.	Aug. 4.	Aug. 7.	Aug. 13.	Aug. 15.	Sept. 4.
-5.15^s	-10.33^s	-11.79^s	-14.20^s	-13.52^s	-8.50^s	-8.24^s	-14.09^s
5.00	10.40	11.79	14.17	13.52	8.48	8.20	14.16
5.10	10.29	11.74	14.18	13.64	8.49	8.29	14.12
5.03	10.44	11.73	14.20	13.62	8.51	8.23	14.18
		11.81	14.14				
			14.22				
−5.07	−10.36	−11.77	−14.18	−13.58	−8.50	−8.24	−14.14

From the 35 residuals furnished by the above observations I find for the probable error of a chronometer correction from a single star $\pm 0.038^s$, while for the meridian circle of the Washburn Observatory, used in connection with a chronograph, the corresponding probable error is ±0.030. In comparing the precision of the results furnished by these two instruments it should be borne in mind that the accuracy of the meridian circle time determinations depends upon the perfect determination of the collimation by instrumental means, while in the case of the smaller instrument the collimation is eliminated by reversal; and that wherever the time is required with great precision, as in the determination of longitude, this difference between the instruments gives a marked advantage to the reversible one.

The chronometer corrections contained in the above table will compare favorably with the corresponding quantities in any published longitude determination with which I am acquainted, and put in evidence not only the quality of the instrument but also the excellence of the method of determining time by means of an instrument mounted in the vertical of the pole star. It is to be regretted that American astronomers make but little use of so excellent a method concerning which we are tempted to say with Doellen that, under all circumstances where time is to be determined with a portable transit instrument, it is more advantageous to mount that instrument in the vertical of the pole star than to mount it in the meridian.

Washburn Observatory, September, 1891.

A NOTE ON THE DISTRIBUTION OF THE STARS.

W. H. S. MONCK.

FOR THE MESSENGER.

In former numbers of THE SIDEREAL MESSENGER I pointed out that, adopting the photometric scale and assuming the distribution of the stars to be uniform, the stars comprised in any half-magnitude ought to be (in round numbers) double that comprised in the preceding half-magnitude and equal to the entire number of brighter stars. Taking the Harvard and Oxford Photometries it appeared that this ratio was not realized anywhere except for the half-magnitude 2.0 to 2.5, but that for all magnitudes below 5.5 these Catalogues could not be regarded as complete. Taking, however, Dr. Seeliger's count of the stars in the ***Durschmusterung*** and Schönfeld's southern extension of it, the theoretical ratio again appeared to be exceeded for the half-magnitudes 8.0 to 8.5 and 8.5 to 9.0. The half-magnitude 9.0 to 9.5 I omitted, because it was known that Argelander had classed many 10th magnitude stars as 9.5, that being the highest figure used by him. The number of stars from 5.5 to 6.0 did not appear in Seeliger's table, and the position of that half-magnitude was consequently left in doubt.

The recently published Harvard tables enable us to a certain extent to test Argelander's and Schönfeld's figures by the photometric scale. They are not indeed convenient for this purpose, because larger stretches were examined for the brighter stars in the D. M. than for the fainter ones. I recently, however, made a count of the stars in question confined to the stretches of the sky in which all stars rated up to 9.0 in the D. M. were photometrically measured; and though the following figures may not be strictly accurate I have no doubt that they are so substantially:

Magnitudes.	No. of Stars Measured at Harvard.
Brighter than 5.0	= 57
5.0 to 5.5	= 49
5.5 to 6.0	= 98
6.0 to 6.5	= 200
6.5 to 7.0	= 334
7.0 to 7.5	= 565
7.5 to 8.0	= 973
8.0 to 8.5	= 1654
8.5 to 9.0	= 2871

The first four divisions here approach the theoretic ratio very closely, thus apparently indicating a relative thickening of the stars between 5.5 and 6.5 similar to that between 2.0 and 2.5 but less marked. But from this point onwards the theoretical ratio is not realized, and the conclusion drawn from the D. M., as to its being exceeded between 8.0 and 8.5, seems contradicted. As regards the interval 8.5 to 9.0 the question is more doubtful, for the present Harvard table is no doubt incomplete. All stars up to 9.0 in the D. M. in these stretches were measured, but there are probably many stars rated above 9.0 in the D. M. which would rate below 9.0 if measured photometrically.

In order to see whether there was any considerable difference in the star-distribution in different parts of the sky I compared the stretches from 0° to 20° N. (inclusive) with those from 0° to 20° S. inclusive. The northern stretches seem to have embraced a slightly larger portion of the sky, which I believe accounts for its apparent greater richness in stars. The figures are as follow:

Magnitudes.	No. of Stars N.	No. of Stars S
Over 5.0	17	20
5.0 to 5.5	11	12
5.5 to 6.0	29	16
6.0 to 6.5	62	54
6.5 to 7.0	109	74
7.0 to 7.5	146	143
7.5 to 8.0	278	222
8.0 to 8.5	474	419
8.5 to 9.0	846	758

These figures do not present any differences which seem inexplicable on the doctrine of chances when only a small portion of the sky is examined. The greater richness of the southern region in the stars brighter than 5.0, however, appears to be borne out as we go farther north. Thus for the stretches from 64° N. to the pole, where the effect of the Galaxy is trifling, I find

Magnitudes.	No. of Stars.	Magnitudes.	No. of Stars.
Brighter than 5.0	2	7.0 to 7.5	76
5.0 to 5.5	8	7.5 tp 8.0	127
5.5 to 6.0	11	8.0 to 8.5	206
6.0 to 6.5	28	8.5 to 9.0	331
6.5 to 7.0	47		

These figures seem rather opposed to the theory, which is current in many quarters, that the brighter stars are distributed pretty equably everywhere, while the fainter ones are congregated in and around the Galaxy. But we shall not be able to reach any decisive conclusion so long as our measurements are confined to selected stretches instead of embracing the entire sky. Laborious as the latter process will be it must, I think, ultimately be undertaken; but in the meantime less laborious photometric measurements (whether in connection with photography or with Professor Menchin's photo-electric discoveries) may be substituted for those of Professor Pickering.

In conclusion it may be desirable to explain briefly what the theoretic ratio means. It does not imply that the stars are uniformly distributed in all directions. Suppose, for instance, that all space is divided into a number of cones, each having its vertex at the spectator, the theoretic ratio would be realized if the distribution in each cone was uniform, although one cone might be much more thickly packed with stars than another. It would also be realized if, as we move outward from the spectator, the changes of density in these cones were of a compensating character. But the theoretic ratio might not be realized if space was divided into a rich region and a poor region, although the distribution of the stars was sensibly uniform within each region. If the shape of the rich region was such that when we drew a number of spheres round the earth as centre with ever-increasing radii a constantly decreasing proportion of the spherical surface lay within the rich region, the theoretical number of stars would never be realized—at least unless we chanced on an unusual number of rich clusters at a particular stage. And I think few persons will assign to the Galaxy a spreading shape which would occupy an equal proportion of the surface of each successive sphere. The first question which we have to solve, however, seems to me to be this: Are we *in* the Galaxy—the sun being one of the Galactic stars situated in a comparative vacuity—and if not, at what distance do our successive spheres first encounter it? If we are outside of the Galaxy there ought apparently to be an increase in the number of stars beyond the theoretic ratio at the distance where the first serious encounter of the Galaxy with one of our successive spheres takes place. But circumstances might modify this result. If, for instance, as some astronomers believe, the stars in the Galaxy are considerably smaller (on the average) than those elsewhere, the reverse effect might first take place. Suppose that at the average distance of a 7th magnitude star we cut for the first time pretty deeply into the Galaxy, and that the stars from their smaller size were (on the average) of the 8th magnitude, we would seem to have cut not into a rich region but into a vacuity; and the stars of the 7th magnitude, instead of exceeding the theoretical number, would fall short of it. The figures which I have given do not, however, seem to afford decisive indications of our cutting into the Galaxy at *any* distance, and therefore the conclusion seems to be either that the sun is in the Galaxy or that the distance of the Galaxy from the sun is greater than that of an average star of the 9th magnitude. An absorption of light, however, either by the ether or by meteors would modify the phenomena; and if meteors exist in space in anything like the numbers which the Meteoritic Hypothesis supposes the loss of light from this cause must be very considerable.

RELATIVE MOTIONS OF THE SPOTS AND MARKINGS ON THE SURFACE OF JUPITER, FROM MICROMETRICAL OBSERVATIONS MADE AT THE LICK OBSERVATORY.

E. E. BARNARD.

FOR THE MESSENGER.

In the August number of THE MESSENGER Professor Hough has an interesting note about some of the markings on Jupiter. In speaking of the southern white spots he says "These spots . . . give a rotation period approximately the same as the great red spot." I have made quite a number of observations of several of these objects with the 12-inch equatorial, and find that their rotation period is considerably shorter than that of the great red spot. Their longitudes diminish 0°.57 (56^s) daily, or 23^s at each rotation of Jupiter, while the red spot is approximately stationary. One of these white spots is now passing the red spot closely south of it.

Following are its longitudes on two of the dates of observation:

1891 Aug. 12 $\lambda = 8°.6$
Aug. 27 $\lambda = 357°.4$

Following are two observations of the great red spot for comparison:

1891 June 5 $\lambda = 3°.1$
Sept. 3 $\lambda = 3°.3$

I have also followed another of these white spots for some time. It is about 1½″ in diameter, and is surrounded by a dark circular shade. It has continued permanent for over a month without any special change. Following are two observations of it:

1891 July 27 $\lambda = 125°.9$
Aug. 25 $\lambda = 110°.0$

I have observed the new red spot, mentioned by Professor Hough, since its formation last year. It was first dark and then turned red. Following are its longitudes at two of the observations:

1891 July 25 $\lambda = 177°.2$
Sept. 7 $\lambda = 151°.5$

Its period is quite different from that of the old red spot, being shorter, and does not materially differ from that of the southern white spots, one of which has been attached to its preceding end since last year. The present motion will bring it around in conjunction again with the great red spot in May next, when it will pass close south of that object.

It is now the most conspicuous marking on the planet. There is a similar spot—a little longer and not so definite—preceding the great red spot a short distance.

These two objects, with the bright spots, are situated on a belt which passes just free of the southern edge of the great red spot. There are, however, some small bright spots south of this belt.

Quite a number of small black spots appeared, at the close of the observations last year, on the first narrow belt about 9″ north. They were exceedingly small and black—like a row of needle points strung along the belt. Some of them have enlarged greatly and are now becoming quite noticeable.

The small dark spots on the north edge of the equatorial belt, mentioned by Professor Hough, were first seen by me on April 26, 1890, and have been carefully followed ever since. They were at first as black and round as the shadows of the satellites, but later became red. Their periods, though shorter than that of the great red spot, are somewhat longer than those of the southern white spots. A series of micrometer measures was begun last year upon two of these which were then about on the same meridian with the red spot. They have been gradually approaching each other, the distance between them having diminished about 3″ since last year. They are now about 6″ apart. There were six, in all, of these small spots and their latitudes were exactly the same.

Following are observatians of the first of the two mentioned:

1890 April 26 $\lambda = 348°.4$
1891 Aug. 9 $\lambda = 253°,9$
Sept. 7 $\lambda = 248°.1$

The longitudes are derived with the aid of Dr. Marth's invaluable Ephemeris (System II.) in *Monthly Notices.*

There has been quite a change in the equatorial regions since last year. A broad white band now occupies the space between the northern and southern equatorial belts.

I have already called attention to the increased intensity of the great red spot, in a communication to the *Monthly Notices* of the R. A. S.

A remarkable feature connected with the red spot is the persistence of the bay formed north following it by the southern equatorial belt. This has been a prominent feature for quite a number of years and is intimately associated with the history of the spot. It was entirely absent in 1880, though present in 1879.

On Sept. 4, 1891, the first satellite was observed in transit, overlapping its shadow on the south following side. The shadow appeared as a crescent. With the great telescope, *the satellite itself appeared perfectly round, with no mark upon it.*

Mt. Hamilton, Sept. 9th, 1891.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at superior conjunction with the sun on Oct. 27. During the first two weeks of this month the planet will be in good position for daylight observations in the early part of the day. The phase will be gibbous, seven-tenths of the disk being illuminated on Oct. 3, and the whole on Oct. 27.

Venus is now "evening planet" but will for this month be too close to the solar rays to be easily seen. Daylight observations in the afternoon may be of value in the study of the markings on the planet and its rotation period. With our 16-inch telescope we have, on several occasions, examined the planet in full sunlight, with excellent definition, and, although there were very faint dusky shadings, they were so indefinite and illusory that it seemed hopeless to identify them.

Mars is behind the sun and will not be observable during this year.

Jupiter is now a splendid object in large or small telescopes. Crossing the meridian between ten and eleven in the evening, he is the most conspicuous object in the sky, excepting, of course, the moon. With a small telescope the four moons and three or four principal belts can be seen. With a large telescope the belts become more numerous, from six to ten, their color is more pronounced and vastly more of detail is seen in them. The great red spot is quite conspicuous now, its color decidedly pink, the central area changing from white to pink. The belt just south of the spot (above it in an inverting telescope) is considerably darker than the spot and seems now to crowd upon it. Whether one overlaps the other it seems impossible to decide. A portion of this belt preceding the red spot by a distance equal to about one quarter of Jupiter's diameter, is very deep red and now more conspicuous than the great spot. Several observers have called attention to this new red spot. A number of small spots along the edge of the second principal belt north of Jupiter's equator, which, with low powers, appear almost round and black, become, with higher powers, elongated patches of deep red. Six of these were counted on the edge of one belt and three on another on the night of Sept. 3, 1891, by Professor Payne and Dr. Wilson.

The attention of observers is called to a very narrow belt midway between the two principal belts of Jupiter, almost exactly on the equator of the planet, which is not shown in drawings made in other years. It was sketched at Goodsell Observatory Aug. 31 at 12:30 and Sept. 3, 12:15.

Saturn is "morning star," rising an hour and a half before the sun. The rings are now invisible, the sun shining on the south side of the rings, while we look upon the north side. On Oct. 30 the sun will begin to illuminate the north side of the rings so that they should then become visible. The planet will be in such an unfavorable position for observations that probably little can be seen of the phenomena attending the gradual illumination and opening of the rings.

Uranus will be at conjunction with the sun Oct. 24, so that he is out of view.

Neptune may be seen after nine o'clock, the best hours being from midnight to four in the morning. He is almost exactly north of the bright red star Aldebaran at a distance of a little less than four degrees, in the constellation of Taurus.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Oct. 25	13 54.5	− 10 58	6 20 A. M.	11 39.2 A. M.	4 59 P. M.
Nov. 5	15 02.8	− 17 46	7 14 "	12 04.1 P. M.	4 55 "
15	16 06.2	− 22 25	7 59 "	12 27.9 P. M.	4 56 "
			VENUS.		
Oct. 25	14 37.9	− 14 53	7 19 A. M.	12 22.1 P. M.	5 25 P. M.
Nov. 5	15 32.7	− 19 05	7 50 "	12 33.9 "	5 18 "
15	16 24.8	− 21 59	8 16 "	12 46.6 "	5 17 "
			MARS.		
Oct. 25	12 10.4	+ 0 06	3 52 A. M.	9 55.5 A. M.	3 59 P. M.
Nov. 5	12 35.8	− 2 41	3 45 "	9 37.7 "	3 31 "
15	12 59.3	− 5 10	3 39 "	9 21.6 "	3 05 "
			JUPITER.		
Oct. 25	22 41.7	− 9 47	3 00 P. M.	8 25.0 P. M.	1 50 A. M.
Nov. 5	22 41.3	− 9 47	2 17 "	7 41.3 "	1 06 "
15	22 42.2	− 9 39	1 38 "	7 02.8 "	12 28 "

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			SATURN.		
Oct. 25	11 46.6	+ 3 37	3 14 A. M.	9 31.6 A. M.	3 49 P. M.
Nov. 5	11 50.8	+ 3 11	2 37 "	8 52.6 "	3 09 "
15	11 54.3	+ 2 50	2 02 "	8 16.8 "	2 31 "
			URANUS.		
Oct. 25	13 59.0	− 11 38	6 27 A. M.	11 43.8 A. M.	5 00 P. M.
Nov. 5	14 01.8	− 11 53	5 48 "	11 03.3 "	4 19 "
15	14 04.1	− 12 05	5 11 "	10 26.2 "	3 41 "
			NEPTUNE.		
Oct. 25	4 28.7	+ 20 08	6 42 P. M.	2 10.6 A. M.	9 39 A. M.
Nov. 5	4 27.3	+ 20 05	5 58 "	1 26.3 "	8 54 "
15	4 26.2	+ 20 03	5 18 "	12 45.9 "	8 14 "
			THE SUN.		
Oct. 25	13 59.5	− 12 12	6 29 A. M.	11 44.1 A. M.	5 00 P. M.
Nov. 5	14 42.4	− 15 46	6 44 "	11 43.7 "	4 44 "
15	15 22.9	− 18 34	6 57 "	11 44.7 "	4 32 "

Jupiter's Satellites.

	Central Time. h m	
Oct. 16	12 19 A. M.	II Ec. Re.
17	5 32 P. M.	II Tr. Eg.
	7 28 "	II Sh. Eg.
19	8 01 "	III Oc. Dis.
	11 26 "	III Oc. Re.
20	12 13 A. M.	III Ec. Dis.
	12 58 "	I Oc. Dis.
	10 07 P. M.	I Tr. In.
	11 09 "	I Sh. In.
21	12 26 A. M.	I Tr. Eg.
	1 27 "	I Sh. Eg.
	7 26 P. M.	I Oc. Dis.
	10 44 "	I Ec. Re.
22	5 37 "	I Sh. In.
	6 53 "	I Tr. Eg.
	7 55 "	I Sh. Eg.
	10 01 "	II Oc. Dis.
23	5 13 "	I Ec. Re.
	5 31 "	III Sh. Eg.
	7 08 "	IV Sh. In.
	10 54 "	IV Sh. Eg.
24	5 04 "	II Tr. In.
	7 14 "	II Sh. In.
	7 57 "	II Tr. Eg.
	10 05 "	II Sh. Eg.
26	11 37 "	III Oc. Dis.
27	11 56 "	I Tr. In.
28	1 04 A. M.	I Sh. In.
	9 15 P. M.	I Oc. Dis.
29	12 40 A. M.	I Ec. Re.
	6 24 P. M.	I Tr. In.
	7 33 "	I Sh. In.
	8 43 "	I Tr. Eg.
	9 51 "	I Sh. Eg.
Oct. 30	12 25 A. M.	II Oc. Dis.
	6 13 P. M.	III Sh. In.
	7 09 "	I Ec. Re.
	9 33 "	III Sh. Eg.
31	7 25 "	IV Oc. Re.
	7 31 "	II Tr. In.
	9 52 "	II Sh. In.
	10 24 "	II Tr. Eg.
Nov. 1	12 43 A. M.	II Sh. Eg.
2	6 51 P. M.	II Ec. Re.
4	11 06 "	I Oc. Dis.
5	8 14 "	I Tr. In.
	9 28 "	I Sh. In.
	10 33 "	I Tr. Eg.
	11 46 "	I Sh. Eg.
6	5 11 "	III Tr. In.
	5 34 "	I Oc. Dis.
	8 38 "	III Tr. Eg.
	9 04 "	I Ec. Re.
	10 15 "	III Sh. In.
7	5 01 "	I Tr. Eg.
	6 15 "	I Sh. Eg.
	10 00 "	II Tr. In.
9	5 06 "	IV Sh. Eg.
	9 28 "	II Ec. Re.
11	4 40 "	II Sh. Eg.
12	10 06 "	I Tr. In.
	11 24 "	I Sh. In.
13	7 26 "	I Oc. Dis.
	9 00 "	III Tr. In.
	11 00 "	I Ec. Re.
14	4 34 "	I Tr. In.
	5 53 "	I Sh. In.
	6 53 "	I Tr. Eg.
	8 11 "	I Sh. Eg.
15	5 29 "	I Ec. Re.

Configuration of Jupiter's Satellites at 10 p. m., for an Inverting Telescope.

Oct. 16	3	○	1 2 4	Nov. 1	3 2	○	1 4	Nov. 16	3 4 1	○	●
17	3 1 2	○	4	2	1 3	○	2 4	17		○	3412
18	3 2	○	1 4	3		○	1234	18	1 2	○	4 3
19	1	○	2 4 ●	4	2 1	○	3 4	19	2	○	1 3 4
20		○	1234	5	2	○	3 4 2	20	1	○	3 2 4
21	2	○	3 4 ●	6	●	○	2 4 2	21	3	○	2 4 2
22	1 2	○	3 4	7	3 1	○	2 4	22	3 2	○	1 4
23	3 4	○	1 2	8	3 2	○	4 1	23	3 1 2	○	4
24	3 4 1 2	○		9	4 3 1	○	2	24		○	3142
25	4 3 2	○	1	10	4	○	1 3 2	25	1 2	○	3 2
26	4 1 3	○	2	11	4 1 2	○	3	26	4 2	○	1 3
27	4	○	1 2 3	12	4 2	○	1 3	27	4 1	○	2 3
28	4 2 1	○	3	13	4 1	○	3 2	28	4 3	○	1 2
29	4 2	○	3 4	14	4 3 1	○	2	29	4 3 2	○	●
30	4 3	○	1 2	15	3 4 2	○	1	30	4 3 2 1	○	
31	3 1	○	4 4								

Approximate Central Times when the Great Red Spot passes the Central Meridian of Jupiter.

	h	m			h	m			h	m	
Oct. 5	9	09	P. M.	Oct. 19	10	41	P. M.	Nov. 3	12	11	A. M.
6	5	00	"	20	6	32	"	3	8	02	P. M.
7	10	47	"	22	12	19	A. M.	4	3	53	"
8	6	38	"	22	8	10	P. M.	5	9	10	"
9	12	26	A. M.	24	1	51	A. M.	6	5	31	"
10	8	17	P. M.	24	9	48	P. M.	7	11	18	"
11	4	08	"	25	5	39	"	8	7	10	"
12	9	55	"	26	11	26	"	9	3	01	"
13	5	46	"	27	7	17	"	10	8	48	"
14	11	33	"	29	1	04	"	11	4	39	"
15	7	26	"	29	8	55	"	12	10	26	"
17	1	12	A. M.	30	4	46	"	13	6	17	"
17	9	03	P. M.	31	10	33	"	15	12	04	A. M.
18	4	54	"	Nov. 1	6	24	"	15	7	55	P. M.

Occultations Visible at Washington.

			IMMERSION.		EMERSION.		
Date.	Star's Name.	Magnitude.	Wash. Mean T. h m	Angle f'm N. P't. °	Wash. Mean T. h m	Angle f'm N.P't. °	Duration. h m
Oct. 5	...α^2 Libræ	2.9	4 10	119	5 30.1	291	1 20
10	...B. A. C. 6666	5.8	8 50	165	Star 0.1′ S. of moon's limb.		
12	...35 Capricorni	6.2	7 11	54	8 29.6	255	1 19
12	...37 Capricorni	6.0	12 02	18	12 45.0	288	0 43
19	...56 Tauri	6.0	16 58	159	17 05.6	172	0 07
20	...103 Tauri	6.0	10 05	50	11 02.9	270	0 58
Nov. 14	...σ Arietis	5.5	15 49	51	16 43.5	269	0 55
15	...13 Tauri	5.7	12 23	333	Star 0.6′ N. of moon's limb.		

Phases and Aspects of the Moon.

	Central Time.	d	h	m	
Perigee	Oct.	16	11	24	A. M.
Full Moon	"	17	7	45	A. M.
Last Quarter	"	24	7	56	A. M.
Apogee	"	28	10	42	P. M.
New Moon	Nov.	1	12	33	P. M.
First Quarter	"	9	2	46	A. M.
Perigee	"	13	7	12	P. M.
Full Moon	"	15	6	16	P. M.

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A..............$0^h\ 52^m\ 32^s$
Decl.............. $+81°\ 17'$
Period..........$2d\ 11^h 50^m$

Oct. 17	7 P. M.
22	7 "
27	7 "
Nov. 1	6 "
6	6 "
11	6 "

ALGOL.

R. A.............$3^h\ 01^m\ 01^s$
Decl..............$+40°\ 32'$
Period..........$2d\ 20^h 49^m$

Oct. 25	3 A. M.
27	midn.
30	9 P. M.
Nov. 2	6 P. M.
14	5 A. M.

λ TAURI.

R.A...............$3^h\ 54^m\ 35^s$
Decl..............$+12°\ 11'$
Period.........$3d\ 22^h\ 52^m$

Oct. 11	11 P. M.
21	9 "

λ TAURI, CONT.

Oct. 25	8 P. M.
29	7 "
Nov. 2	6 "
6	5 "

R CANIS MAJ.

R. A........... $7^h\ 14^m\ 30^s$
Decl............... $-16°\ 11'$
Period $1d\ 03^h 16^m$

Oct. 17	5 A. M.
23	midn.
24	3 A. M.
25	6 "
Nov. 2	2 "
3	5 "
10	1 "
11	4 "

S ANTLIAE.

R. A........... $9^h\ 27^m\ 30^s$
Decl............ $-\ 28°\ 9'$
Period........$0d\ 07^h\ 47^m$

Oct. 16	6 A. M.
17	5 "
18	5 "
19	4 "

S. ANTLIÆ, CONT.

Oct. 20	3 A. M.
28	6 "
29	6 "
30	5 "
31	5 "
Nov. 1	4 "
2	4 "
3	3 "
9	6 "
10	5 "
11	4 "
12	4 "
13	3 "

Y. CYGNI.

R. A...........$20^h\ 47^m\ 40^s$
Decl...............$+34°\ 15'$
Period........$1d\ 11^h\ 57^m$

Oct. 11	midn.
19	"
22	"
25	"
28	"
31	"
Nov. 3	11 P. M.
6	11 "
9	11 "
12	11 "
15	11 "

COMET NOTES.

Ephemeris of the Temple-Swift Periodic Comet.

(Continued from page 367.)

1891	App. R. A.			App. Decl.		log Δ	Ab. T.		$\frac{1}{r^2\Delta^2}$
	h	m	s	°	′		m	s	
Oct. 16	21	10	48	+ 6	6.4				
18	21	12	49	+ 6	43.9	9.4512	2	21	9.54
20	21	15	13	+ 7	23.4				
22	21	18	00	+ 8	04.8	9.4353	2	16	10.54
24	21	21	12	+ 8	43.3				
26	21	24	50	+ 9	34.0	9.4189	2	11	11.64
28	21	28	56	+ 10	22.2				
30	21	33	30	+ 11	12.8	9.4021	2	06	12.83
Nov. 1	21	38	35	+ 12	05.8				
3	21	44	11	+ 13	01.6	9.3851	2	01	14.09
5	21	50	21	+ 13	59.9				
7	21	57	07	+ 15	00.9	9.3683	1	56	15.41
9	22	04	31	+ 16	04.2				
11	22	12	34	+ 17	10.1	9.3520	1	52	16.71
13	22	21	20	+ 18	18.0				
15	22	30	48	+ 19	27.7	9.3370	1	48	17.93

Ephemeris of Encke's Comet for 1891.

(Continued from page 368.)

		App. R. A. h m s	App. Decl. ° ′	log *r*	log *Δ*	Ab. T.
Oct.	6	11 20 36	+ 9 42.0	9.6659	0.0159	8 36
	7	11 27 55	+ 8 27.2	9.6503	0.0223	
	8	11 35 12	+ 7 11.8	9.6347	0.0289	8 52
	9	11 42 29	+ 5 56.0	9.6191	0.0357	
	10	11 49 45	+ 4 39.8	9.6042	0.0427	9 09
	11	11 57 02	+ 3 23.2	9.5897	0.0498	
	12	12 04 20	+ 2 6.4	9.5762	0.0570	9 27
	13	12 11 40	+ 0 49.4	9.5627	0.0642	
	14	12 19 03	− 0 27.6	9.5531	0.0713	9 47
	15	12 26 30	− 1 44.4	9.5444	0.0783	
	16	12 34 00	− 3 0.9	9.5377	0.0853	10 06
	17	12 41 34	− 4 16.9	9.5336	0.0921	
	18	12 49 13	− 5 32.2	9.5321	0.0987	10 25
	19	12 56 53	− 6 46.1	9.5336	0.1050	
	20	13 04 34	− 7 58.3	9.5374	0.1111	10 43
	21	13 12 16	− 9 8.9	9.5439	0.1169	
	22	13 19 59	− 10 17.7	9.5527	0.1225	11 00
	23	13 27 41	− 11 24.3	9.5634	0.1278	
	24	13 35 21	− 12 28.7	9.5757	0.1329	11 16
	25	13 42 59	− 13 30.5	9.5893	0.1378	
	26	13 50 34	− 14 29.9	9.6036	0.1426	11 31
	27	13 58 06	− 15 26.8	9.6187	0.1472	
	28	14 05 33	− 16 21.2	9.6341	0.1516	11 46
	29	14 12 56	− 17 13.1	9.6497	0.1560	
	30	14 20 14	− 18 2.4	9.6654	0.1604	12 00
	31	14 27 27	− 18 49.3	9.6809	0.1646	
Nov.	1	14 34 36	− 19 33.9	9.6963	0.1687	12 14

Ephemeris of Comet 1891 (Wolf's Periodic Comet).

(Continued from page 367.)

		App. R. A. h m s	App. Decl. °	log *r*	log *Δ*	Br.
Oct.	5	4 31 23	+ 11 48.3	0.2110	9.9249	
	6	32 20	+ 11 17.6			
	7	33 15	+ 10 46.7	0.2121	9.9211	
	8	34 07	+ 10 15.4			
	9	34 55	+ 9 44.0	0.2133	9.9175	
	10	35 41	+ 9 12.2			
	11	36 25	+ 8 40.3	0.2145	9.9143	
	12	37 05	+ 8 08.1			
	13	37 43	+ 7 35.8	0.2158	9.9115	12.0
	14	38 17	+ 7 03.3			
	15	38 49	+ 6 30.8	0.2171	9.9089	
	16	39 18	+ 5 58.1			
	17	39 44	+ 5 25.3	0.2185	9.9068	
	18	40 07	+ 4 52.5			
	19	40 28	+ 4 19.6	0.2199	9.9050	12.1
	20	40 46	+ 3 46.8			
	21	41 01	+ 3 14.0	0.2214	9.9036	
	22	41 13	+ 2 41.2			
	23	41 22	+ 2 08.6	0.2230	9.9026	
	24	41 29	+ 1 36.0			
	25	41 33	+ 1 03.6	0.2246	9.9021	12.0
	26	41 35	+ 0 31.3			
	27	41 34	− 0 00.8	0.2262	9.9020	

Gr. M. T.	App. R. A.	App. Decl.	Log r	Log Δ	Light.
	h m s	° ′			
28	4 41 30	− 0 32.5			
29	41 24	− 1 04.0	0.2279	9.9023	
30	41 16	− 1 35.2			
31	41 05	− 2 06.1	0.2296	9.9030	
Nov. 1	40 52	− 2 36.7			
2	40 37	− 3 06.9	0.2313	9.9042	
3	40 20	− 3 36.6			
4	40 01	− 4 05.9	0.2331	9.9059	
5	39 40	− 4 34.8			
6	39 17	− 5 03.1	0.2350	9.9080	11.2
7	38 52	− 5 31.0			
8	38·25	− 5 58.2	0.2369	9.9105	
9	37 57	− 6 25.0			
10	37 27	− 6 51.1	0.2388	9.9135	
11	36 56	− 7 16.6			
12	4 36 24	− 7 41.6	0.2407	9.9169	10.4

Total Eclipse of the Moon Nov. 15, 1891. This will be visible generally throughout North and South America, Europe, Asia and Africa. In the eastern and central parts of the United States, the whole of the eclipse will be visible. In the western parts the moon will rise eclipsed. The following are the elements of the eclipse as given in the *American Ephemeris:*

Greenwich mean time of conjunction in right ascension, Nov. 15, 12^h 08^m 44.8^s.

Sun's R. A.	$15^h\ 23^m\ 54.99^s$	Hourly motion	10.29^s.
Moon's R. A.	3 23 54.99	Hourly motion.	145.10
Sun's Decl.	18° 37′ 41.1″ S.	Hourly motion	0′ 37.9″ S.
Moon's Decl.	18 21 05.5 N.	Hourly motion	12 23.6 N.
Sun's Equa. hor. parallax	8.7	Sun's true semi-diam.	16 10.9
Moon's Equa. "	60 03.2	Moon's true semi-diam.	16 21.1

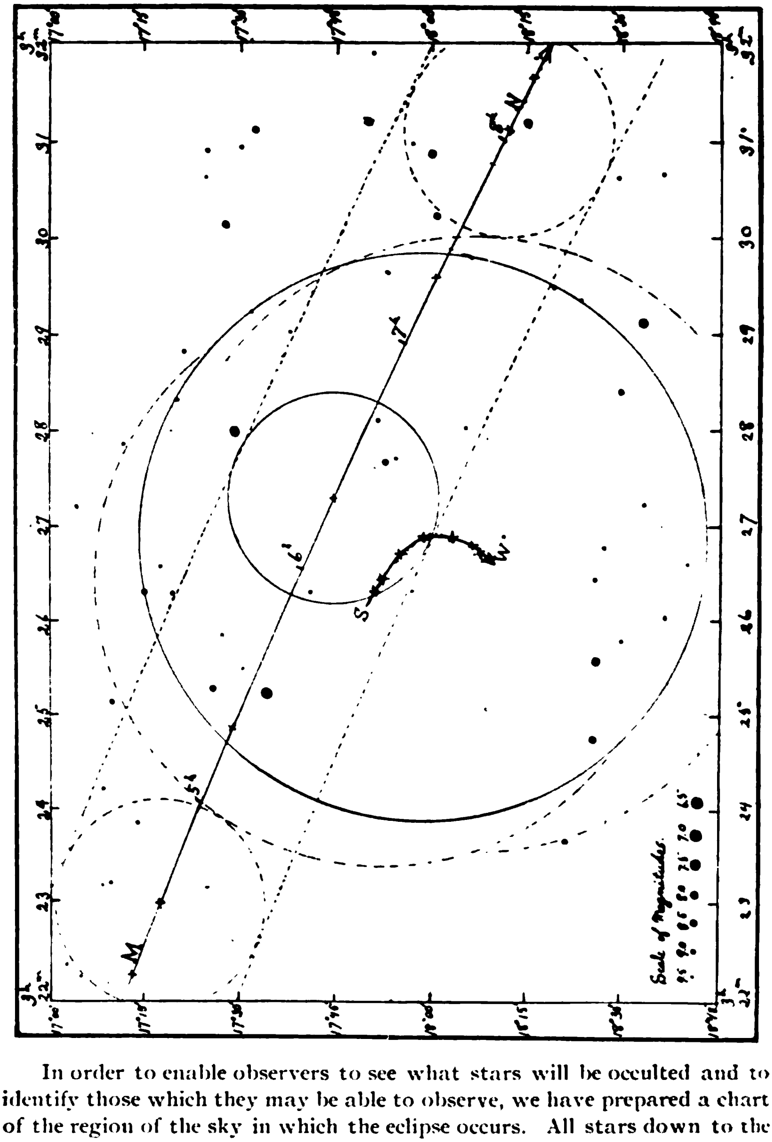
Times of the Phases.

	Gr. Mean Time.		Gr. Mean Time.
Moon enters penumbra	Nov. 15 9h 35.9m	Total eclipse ends	13h 00.7m
Moon enters shadow	10 35.0	Moon leaves shadow	14 03.0
Total eclipse begins	11 37.0	Moon leaves penumbra	15 02.6
Middle of eclipse	12 18.8		

To obtain the standard times of these phases for any given place, subtract the longitude of the meridian which is employed as a standard for time at that place. Thus for a place using Eastern time, subtract 5^h; for one using Central time substract 6^h, etc., from the Greenwich times.

At Northfield the moon will be a little below the eastern horizon at 4^h 35^m central time, when it begins to enter the dark part of the earth's shadow.

During the eclipse the moon will occult a number of faint stars. Ordinarily the brightness of the moon's light effectually prevents us from seeing occultations of stars fainter than the seventh magnitude, but during a total eclipse the ruddy light is so mild that much fainter stars can be observed as they pass behind the moon's limb. All observations of the occultations of such stars are of value as data for determining the diameter of the moon and for deciding the question of the lunar atmosphere. The points to be noted are the exact times of disappearance and reappearance of the star, and any change in the physical appearance of the star as it approaches or recedes from the edge of the moon. The observer must determine accurately the error of his time-piece and the latitude and longitude of the place of observation.



In order to enable observers to see what stars will be occulted and to identify those which they may be able to observe, we have prepared a chart of the region of the sky in which the eclipse occurs. All stars down to the 9.5 magnitude are shown, the places being taken from Argelander's catalogue, known as the Durchmusterung. The apparent path of the moon and of the earth's shadow, as affected by parallax at Northfield, are also laid down on the chart. The line *MN* is the path of the moon's center. The small circles represent the moon at the beginning, middle and end of eclipse. The large circle represents a cross-section of the earth's shadow at the distance of the moon. The line *SW* is the apparent path of the center of the cross-section of the shadow as seen from Northfield. The figures on the line *MN* are the hours of central time when the moon's center will be at the points marked. The figures on the margin of the cut give the right ascensions and declinations of the portions of sky represented.

It will be easy for observers in the vicinity of Northfield to determine approximately the time of immersion and emersion of each star, by simply drawing circles of the size given for the moon with their centers along the line *MN* and circumferences passing through the star in question, then measuring the proportional parts of hours along the line *MN*. For a place very distant from Northfield it will be necessary for the observer to calculate for his own station the path of the moon and plat it upon the chart.

For the convenience of observers, also Professor John A. Parkhurst has computed for a number of observatories in the United States, the times of immersion and emersion, and the angles from the north point and vertex of the moon where these will occur, for all of the stars likely to be occulted. We have added to the table which he has prepared, the corresponding data for Northfield, calculated by one of our own computers.

List of Stars in and near the Earth's Shadow.

Star.	Mag.	R. A. 1892.0	Decl. 1892.0.	Star.	Mag.	R. A. 1892.0	Decl. 1892.0.
DM. +		h. m. s.	° ′	DM. +		h. m. s.	° ′
17, 558	9.4	3 22 00	+ 18 06.5	17, 574	9.5	3 27 52	+ 17 11.5
16, 440	9.5	22 14	17 04.9	17, 575	7.0?	28 00	17 29.3
16, 447	9.5	22 20	17 02.9	17, 576	9.5*	28 02	18 05,7
17, 559	9.5	23 10	17 25.0	17, 577	9.5*	28 07	17 51.5
17, 560	9.5	23 12	17 09.6	17, 578	9.0	28 20	17 20.5
18, 489	8.6	23 38	18 21.3	18, 505	9.3	28 24	18 29.9
17, 561	9.5	23 50	17 14.0	17, 579	9.3	28 49	17 21.1
17, 562	9.3	24 14	17 08.3	17, 580	9.5?	29 02	17 37.5
18, 492	8.3	24 44	18 25.5	18, 507	7.0	29 07	18 33.4
18, 493	9.5	25 04	18 09.1	17, 581	9.5	29 14	17 31.6
17, 563	9.1	25 08	17 09.8	18, 508	9.5	29 21	18 23.8
17, 564	6.5*	25 14	17 34.6	17, 582	9.3*	29 39	17 52.8
17, 565	8.5*	25 17	17 26.0	17, 583	9.5*	29 48	18 06.4
17, 566	9.5	25 29	17 30.8	17, 584	8.3	30 09	17 27.8
18, 494	8.3	25 34	18 26.1	17, 585	8.5*	30 13	18 00.7
18, 496	9.5	25 47	18 30.1	17, 586	9.5	30 37	17 24.6
18, 497	9.5	26 02	18 36.9	18, 511	9.5	30 38	18 29.6
17, 567	9.3?	26 17	17 19.4	18, 512	9.4	30 41	18 36.3
17, 568	8.8	26 18	17 15.1	17, 587	8.0*	30 52	18 00.0
17, 569	9.5*	26 18	17 41.1	17, 588	9.3	30 55	17 24.7
17, 570	9.5?	26 20	17 57.0	17, 589	9.3	30 57	17 30.4
18, 498	9.5	26 26	18 26.1	17, 590	9.5	30 58	17 56.7
17, 571	9.4	26 35	17 17.9	17, 591	8.5	31 07	17 32.7
18, 499	9.5	26 36	18 39.9	18, 514	8.3*	31 11	18 15.2
18, 501	9.5	26 46	18 27.2	17, 592	8.5	31 13	17 49.9
18, 502	9.3	26 53	18 11.4	18, 516	9.5	31 52	18 16.3
17, 572	9.2*	26 55	17 58.6	17, 593	9.0	31 54	18 06.1
16, 460	9.5	27 12	17 04.4	17, 594	9.5	31 55	17 50.8
18, 504	9.5	27 13	18 33.3	17, 595	8.2	32 19	17 15.0
17, 573	8.3*	27 40	17 53.1				

The places of the stars are taken from Argelander's Beobachtungen zu Bonn. Band III, and have been reduced to 1892.0.

The stars marked with an * will be occulted at Northfield. Those marked ? will perhaps be occulted at Northfield.

Those marked *, having greater R. A. than $3^h 30^m$ will be occulted after the moon passes partially out of the shadow.

Approximate Times of Occultations during the Lunar Eclipse, Nov. 15, 1891.

CALCULATED BY J. A. PARKHURST.

STAR.	ALBANY. Eastern Time.		ROCHESTER. Eastern Time.		EVANSTON. Central Time.		MARENGO. Central Time.		MADISON. Central Time.		NORTHFIELD. Central Time.	
	Im. h m s	Em. h m s	Im. h m s	Em. h m s	Im. h m s	Em. h m s	Im. h m s	Em. h m s	Im. h m s	Em. h m s	Im. h m	Em. h m
DM. + 17°, 559.												
T	5 9 36	6 0 54						5 2 0		5 4 35		
Angle from N	57	254						276		265		
" " V	105	303						324		313		
DM. + 17°, 561.												
T	5 23 0	5 58 54						5 6 30		5 7 4		
Angle from N	112	198						245		215		
" " V	160	248						293		262		
DM. + 17°, 562.												
T									4 47 5	4 54 26		
Angle from N									146	167		
" " V									196	217		
DM. + 17°, 564.												
T	5 57 52	6 52 9		6 52 36	4 59 48	5 51 0	5 0 21	5 50 54	5 1 31	5 52 36	5 5.0	5 54.0
Angle from N	70	238		243	72	250	60	251	60	253	56	256
" " V	118	288		293	120	300	108	301	107	302		
DM. + 17°, 565.												
T	5 57 49	6 41 26		6 43 27	5 2 11	5 43 53	4 57 45	5 44 23	4 59 5	5 46 44	5 1.3	5 49.0
Angle from N	100	208		215	57	222	91	223	88	266	84	229
" " V	148	258		265	105	272	138	272	134	314		
DM. + 17°, 566.												
T	6 2 36	6 52 51		6 53 7	5 9 5	5 53 0	5 3 30	5 53 40	5 4 49	5 54 57	5 6.3	5 56.1
Angle from N	88	220.		226	84	233	78	234	76	236	74	238
" " V	138	271		276	132	283	125	284	122	285		
DM. + 17°, 569.												
T	6 24 54	7 21 1	6 25 32	7 20 55	5 25 6	6 17 45	5 25 35	6 17 48	5 27 3	6 19 17	5 29.3	6 20.7
Angle from N	72	235	67	240	62	248	63	248	59	251	64	248
" " V	123	285	116	290	111	299	112	298	107	301		
DM. + 17°, 570.												
T	6 37 42	7 28 5	6 48 5	7 23 40	5 52 42	6 13 12	5 54 3	6 12 5				
Angle from N	35	271	13	294	357	812	354	315				
" " V	87	323	63	344	49	3	44	5				

DM. + 17°, 572.												
T	6 57 48	7 45 6	7 0 47	7 41 39	6 3 13	6 31 35	6 3 55	6 30 47	6 7 1	6 30 34	6 15.8	6 25.2
Angle from N.	26	279	19	286	6	302	4	304	1	308	346	325
" " V.	76	330	69	336	56	353	54	355	50	358		
DM. + 17°, 573.												
T	7 3 18	8 2 51	7 3 30	8 2 40	6 1 46	6 55 44	6 2 22	6 55 2	6 3 23	6 56 24	6 8.8	6 56.8
Angle from N.	65	239	60	249	53	255	67	257	49	258	41	268
" " V.	116	289	110	299	103	306	118	308	98	308		
DM. + 17°, 576.												
T	7 25 30	8 19 6	7 26 45	8 15 45	6 27 39	7 4 46			6 30 45	7 4 14	6 13.2	7 7.2
Angle from N.	33	270	27	256	52	292			10	297	59	249
" " V.	84	319	77	306	103	342			60	347		
DM. + 17°, 577.												
T	7 13 24	8 10 36	7 12 45	8 9 55	6 9 31	7 5 7	6 9 37	7 5 26	6 10 57	7 6 13	6 37.4	7 4.0
Angle from N.	81	224	75	229	61	240	67	241	66	243	3	304
" " V.	131	274	125	279	112	291	117	292	105	293		
DM. + 17°, 582.												
T	8 3 19	8 34 0			6 45 1		6 47 38	7 35 51	6 48 43	7 39 54	6 44.5	7 44.3
Angle from N.	123	180			88		97	276	95	210	88	219
" " V.	173	229			139		148	325	145	260		
DM. + 17°, 583.												
T	8 3 31	9 6 12	8 2 29		6 56 57		6 57 35		6 58 17	7 56 49	6 52.2	7 48.6
Angle from N.	74	228	66		57		56		54	251	48	259
" " V.	124	274	116		108		106		104	301		
DM. + 17°, 585.												
T	8 16 24	9 2 42	7 59 42		7 3 37		7 4 35		7 4 37		7 10.7	8 4.6
Angle from N.	105	287	91		85		84		81		51	256
" " V.	155	333	141		136		135		131			
DM. + 18°, 511.												
T	8 52 18	9 43 24										
Angle from N.	21	282										
" " V.	67	322										
DM. + 17°, 587.												
T			8 38 9		7 23 53		7 23 30		7 22 32		7 30.1	8 17.1
Angle from N.			358		108		103		101		101	204
" " V.			46		160		152		151			
DM. + 17°, 590.												
T					7 31 18				7 28 52			
Angle from N.					126				121			
" " V.					178				171			

ASTRONOMY FOR AMATEURS.

Drifting Meteor Trains.

E. E. BARNARD.

The observations of meteors and meteor trains by the naked eye is common, but the study of these interesting objects by the aid of the telescope, so far as we know, is almost wholly neglected, although such work might yield valuable results.

Whenever a train is visible to the unaided eye for several seconds of time, it can often be seen with the telescope for as many minutes; since this is so, such observations might throw light on the question regarding the existence of a constantly eastward current or currents in the upper atmosphere. We have kept a record of all the trains of meteors observed for nearly a year past, and give the following as the more important part of it:

In 1881, Nov. 16, near 7^h (full account given in *Science*, No. 75, Vol. 2, and *Science Observer* No. 35), magnificent meteor near Capella, many times brighter than *Venus*; traversed a path of about 10° in about two or three seconds toward the north-east; the train remaining plainly visible to the naked eye for six minutes, and in the telescope for over fifteen minutes, its width about one-fourth of a degree, its length the full extent of the meteor's path. The luminous train was knotted with cloudy tufts and crooked in a most curious manner, constantly changing, and of a bright pinkish color. It moved north-east four degrees in fifteen minutes of time.

August 5, near 9^h, 1882; Brighter than a first magnitude star, of a whitish color, rapid in motion, passing a little east of over head. Its flight was from *Cassiopeia* to *Scorpio*. This meteor left a streak nearly 60° long, visible to the naked eye for a few seconds only, but watched in the telescope for fully ten minutes, where it appeared first, very bright and unbroken, straight as a shaft, clean and sharp in outline, and brighter along the axis, but in two seconds it became crooked and sinuous, drifting south-east at the rate of about one degree in two minutes (at this time there was a faint breeze *from* the south-east). The brightness of the train remained very prominent, though it became more and more distorted and crooked each moment. Near the point of disappearance of the meteor there was a very bright irregular mass of glowing vapor which retained its brightness longest, and had the irregularity of the great nebula of *Orion*, which it somewhat resembled at times. The gaseous train was more or less distinct, though getting faint when observation ceased. The color of this train was that of lightish smoke tinged with a warm glow especially in the southern part of the train near *Scorpio*. A few seconds after the appearance of this meteor, a similar one shot rapidly across the heavens from *Cassiopeia* to the east of south; a train from it was visible for several seconds, but there was no time to examine it with the telescope.

August 10, near 10^h, two bright meteors, white in color, of the first magnitude were seen within a few minutes; both had short paths and came from *Cassiopeia*; very quick in flight, following nearly the same path toward the west. The track of each meteor was examined—almost whil the meteors were in flight—that part of the sky being watched in the hope of catching a meteor in motion. The trains were seen and were similar in every respect, a narrow streak 3° or 4° long melting away in about two or three seconds, affording merely a glimpse: both were straight, their duration was too short to detect any motion; color, light warm.

August 11, near 15^h, nearly of first magnitude, whitish, appeared just north of β of *Auriga*, and traversed a path of about 20° very quickly toward the south: luminous train full length of path, visible to the eye only for a second or two, but watched in the telescope for nearly five seconds in which it appeared long and perfectly straight, much brighter along the axis, but in a few seconds it began to crook and bend, moving rapidly south-east. A bright knot became visible in it which moved much more rapidly, seeming to pull the rest of the luminous streak after it. The motion toward the south east was one degree in one minute and ten seconds, the train, a pale warm color.

August 18, near $10^h\ 30^m$. Fine meteor equal to a first magnitude star. Very rapid flight towards the south-west, passing a little east of α of *Capricornus*. Luminous train seen with the naked eye only a few seconds, but visible in the telescope for fully ten minutes; at first, as a thin straight line which in a few seconds began to bend and crook itself into serpentine curves, moving the meanwhile slowly toward the north-east, about one degree in three and a quarter minutes. In places along the train were brighter cloudy masses. These had a motion greater than the general train.

August 19, near $13^h\ 30^m$, a fine bright meteor of the first magnitude, of a whitish color, shot very rapidly across *Cetus* just south-east of *Mira*; motion towards the south, slightly west. Duration of flight over one and one-half seconds, train visible to the eye for about two seconds; with the telescope the train was not continuous, there being little or none of the luminous smoke where the meteor disappeared, while near the point of appearance lay a very bright strip some 30′ long and about 1′ broad; between this and the south end of the train were numerous bright cloudy masses. The train became quickly distorted, one bright portion moved more rapidly, the rest following in its wake. The bright mass was visible for nearly three minutes, moving at the rate of one degree in thirty-two seconds. This gradually faded from sight without diffusion seeming to melt from view. During the watch it had expanded slightly in size. This train had the most rapid motion of any before observed. The brightest parts would be but a little less than the nebula of *Orion*.

From the above observations many interesting thoughts are suggested. It is apparent that the opportunity for continued observation of the luminous smoke left by the meteor in its retarded flight through our atmosphere, is not so very rare and its existence not so transient as might be supposed, not infrequently offering ten or fifteen minutes of observation and possibly, in some rare instances, remaining visible in good telescopes for several hours, thus affording sufficient time for examination into their chemical composition by the aid of the spectroscope. The idea suggests itself to us that observations of the motions of these trains would be invaluable in determining atmospheric currents at great altitudes, there being now no possible means of knowing anything relative to the existence and direction of currents in the upper strata of our atmosphere.

We can ascend but a few miles at most in balloons, and the highest clouds reach very little above that, and at such low altitudes the atmospheric currents are likely to be disturbed and greatly changed by local causes, such as mountain chains, etc. But at such great altitudes where the meteor first enters our atmosphere, there are no local causes to disturb the general direction of the currents, and if we were only able to observe their motion a much better knowledge of the physical construction of our globe's envelope of air might be had.

It is utterly impossible to detect, by artificial means, the motion of air currents at great distances above the earth. Were it possible to place any object in the upper part of the atmosphere to drift with the currents then we could determine by observation of its movements the direction of motion, velocity etc., of the currents; or were it possible for clouds to form in the rarer strata, we could by observing them determine the currents along which they drift. As these are manifestly impossibilities we can have recourse to but one agency for bettering our knowledge of the upper currents, and that is, to take advantage of the opportunity afforded by the luminous train left by the occasional meteor.

The meteor strikes our atmosphere with a great velocity—forty or fifty miles a second. Passing our hand through the air we feel but little or no resistance, and certainly no sensible increase of heat, but when that motion is increased a hundred thousand fold, as in the case of the meteor, the resistance encountered is great so that the moving body is at once converted into an incandescent mass of light. Thus the meteor, hurrying swiftly through space, suddenly rushes into our atmosphere which acts like an almost impenetrable shield, checking its velocity which is quickly converted into intense heat, many times greater than that of the hottest furnace. As the meteor is being consumed, it leaves a train of luminous gas or smoke which can but float along with the current of air in the same manner that the smoke from our chimneys moves through the atmosphere and, like it, indicating the direction of the wind or air currents. By frequent observations of these drifting gas trains a general idea could be formed as to the existence and direction of those upper currents. So far, my observations indicate the existence of an easterly current, or currents, of possibly long duration. All the trains observed were drifting easterly, either directly east, or north, or south-east; some in a direction opposite to the meteors' flight. If there were no currents where the meteor passed, we would naturally expect the train from inertia to move slowly in the direction the meteor went; but it is seen that the train overcomes that and assumes a motion that depends undoubtedly on that of a regular current in our atmosphere.

The peculiarity of bending and twisting in meteor trains is produced by denser portions of the gaseous matter. It may be suggested that these are heavier particles sinking more rapidly earth-ward, though these particles will doubtless sink thus towards the earth, yet they are seen, sometimes, to move in a direction different to that we would expect if such were the case. They seem to be more at the will of the air currents, along which the train drifts and are followed by the less dense portions of smoke. These are possibly small fragments thrown off from the meteor by minor explosions. Another remarkable thing is the quantity of luminous gas constituting these trains; in nearly every case it has exceeded three or four cubic miles. This is a great quanity of gas to be evolved by the combustion of such an insignificant thing as the meteor is. It is singular that the train should remain luminous so long. It must be burning to be seen; but why burn so long, as fifteen minutes?

This kind of observation is particularly suited to amateurs. The regular observer with a dome over his head can not do much of this kind of work. But any one with a telescope properly mounted, with a knowledge of the diameter of the field of his eye-piece, and with a desire to do something, can do valuable work by keeping a sharp lookout for bright meteors, quickly examining their paths and recording what he sees. This work is especially adapted to comet sweepers, as they are generally in the open air, and have instruments capable of quick change of position.

To those beginning such observations it may be well to say: Note the direction of flight of the meteor; turn the telescope at once to its path, sweep rapidly back and forth over the place where the meteor passed. If there is a train left you will likely strike it the first sweep. If bright and persistent, sweep the full length of it examining any peculiarities; then let your telescope stand at rest and allow the train to pass across the field, note the time it requires to pass through from edge to edge of field, taking into account the motion of the sky, note the direction of motion, the width of the train, the time of observation within a few minutes, note the point of observation in the sky, etc. When the train begins to bend or become irregular, which it is sure to do if it remains visible any length of time, see if the forward positions (in the direction of motion) are brighter than the general train. It would be well to watch the stars it passes over, also to note if there is any change in steadiness and brightness as the luminous mass passes over them; write out your observations and send them to the SIDEREAL MESSENGER or some other scientific journal where they will receive proper attention. If several observers some distance apart could attend to this kind of work and carefully record the paths of the meteors seen, it is likely that the same object might be examined by two or more and its height above the earth could be determined, and therefore the actual velocity with which its train moves and the quantity of gaseous matter it contains. [*Reprint from Vol. I by request.*—ED.]

NASHVILLE, Tenn., Sept. 20, 1882.

Astronomical Society of the Pacific.

CHARLES BURCKHALTER, SECRETARY.

Meeting of the Astronomical Society of the Pacific held at Lick Observatory Sept. 5th.

The Directors Meeting was held from 5:30 to 6 o'clock, President Pierson presiding. The minutes of last meeting were approved, and twenty five members were elected as follows:

Robert Stanton Avery, 302 A Street, Washington, D. C.; R. L. Bischoffsheim, 3 Rue Taitbout, Paris, France; Dr. Charles M. Blake, 1840 Howard Street, S. F., Cal.; Mrs. E. E. Cook, 220 Main Street, Davenport, Iowa; Alfred L. Edwards, 12 W. 33d Street, New York City; T. A. Hagerty, 537 Belden Ave., Chicago, Ill.; John P. Hely, C. E., 418 Claremont Ave, Chicago Ill.; Kirk Himrod, 150 Lincoln Ave., Chicago, Ill.; Williams Hoskins, Lagrange, Cook Co., Ill.; Mrs. M. M Johnson, Circleville, Piute Co., Utah; Professor J. H. Kedzie, Evanston, Ill.; Professor Malcolm McNeill, Lake Forest, Ill.; Beverly K. Moore, 56 Bedford Street, Boston, Mass.; Miss Pendleton, 1522 Locust Street, Philadelphia, Pa.; Mrs. William Gibbons Preston, The Berkeley, Boston, Mass.; Miss M. J. Turner, 11 Faxon Ave., Quincy, Mass.; Professor J. M. Taylor, State University, Seattle, Wash.; J. M. Van Slyke, 29 S. Pinckney St., Madison, Wis.; David Hewes, Miss Anna Lathrop Hewes, and Frank McMullen, San Francisco; Frederick H. Whitworth and Professor J. M. Taylor, Seattle ,Washington; Miss Mary E. Wilson, Oakland, California; J. Henry Turner, Woodville, Virginia. The membership of the Society is now 420, of whom forty four are life members.

The meeting of the Society was held in the Library of the Observatory, President Pierson in the chair. The minutes of last meeting were approved.

The Secretary read a list of thirty-eight presents received since last meeting and the thanks of the Society were voted to the donors.

The following papers were presented:

a. Measurement of Jupiter's Satellites by interference methods, by Professor Michelson, of Clark University, Massachusetts.

b. Enlarged Drawings from the Moon-Negatives of the Lick Observatory, by Professor Weinek, Director of the Observatory of Prague.

c. Catalogue of the Library of the Society, prepared by Otto Von Geldern.

d. Observations of Jupiter and of his Satellites with the 36-inch Equatorial of the Lick Observatory [1888-1890].

e. The Observatory of the United States Military Academy at West Point, by Lieut. Harlow, in charge.

Only *a* was read by Professor Campbell and the meeting adjourned.

After adjournment the members were admitted to the domes of the twelve and thirty-six-inch telescopes and made the most of the superb seeing until a late hour.

NEWS AND NOTES.

Foreign subscribers will please draw post orders or notes on St. Paul instead of Northfield, in payment of subscriptions to the MESSENGER, as the latter place has no foreign money order post office.

The Chicago Evening Journal, September 8, reports an interview with Professor Hough, Director of the Observatory of the Northwestern University at Evanston, concerning the 40-inch lens which is now being made by Alvan Clark, Cambridge, Mass., for the Observatory to be located on Wilson's Peak, California. In this interview Professor Hough is reported as saying "that the great objective will cost $60,000, that the telescope, in cluding objective, mounting and machinery, will probably cost $120,000. The Observatory and dome will cost, as near as can be judged, about $30,000.

From this report it appears that plans are being made to have this great telescope completed in time to exhibit it at the Columbian Exposition in Chicago in 1893.

New Spectroscope for Allegheny Observatory. From a letter under date of Sept. 21, we learn that Professor J. E. Keeler has been provided with funds to secure a new spectroscope of the most efficient kind, to carry on his special studies. Mrs. Wm. Thaw, of Pittsburgh, is the generous donor of the money and J. A. Brashear, of Allegheny City, will make the spectroscope.

Wm. F. Rigge, S. J., has been appointed successor to C. M. Charroppin in the department of Mathematics and Astronomy in the St. Louis University. Professor Rigge will soon have a 3¼-inch equatorial telescope and undertake astronomical work in the Observatory of the University.

The Photochronograph. We have been greatly interested in a paper recently sent us by J. G. Hagen, S. J., Director of Georgetown College Observatory, entitled *The Photochronograph and its Applications.* A considerable part of the work for this paper was done some time ago. We had not seen the account of the experiments that was published in the Woodstock College Print, Woodstock, Md. Vol. 18, No. 3, p. 402, for October, 1889. By these experiments important advancement seems to be made in photographing the transit of a star. Professor Hagen has prepared a valuable paper.

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The Distribution of the Moon's Heat and its Variation with the Phase- is the title of a prize essay prepared by Frank W. Very, of the Allegheny Observatory. The essay was presented to the Utrecht Society of Arts and Sciences, in response to the proposition

"On demande de déterminer la chaleur donnée par la Lune dans des phases diverses."

It obtained the prize of the General Assembly of the Society held at Utrecht on the 2d of July, 1890.

A full abstract of this paper, with illustrations, will be published in a future number of THE MESSENGER, for it is certainly an essay of very high merit.

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Transit of Jupiter's III Satellite. I beg leave to report the following observations of the transit of Jupiter's third satellite and its shadow last evening:

At 7h 30m, when the observations began, the satellite was near the central line of the planet and the shadow near the eastern limb. The shadow appeared jet black, round and larger by about one third than III, which appeared at the time round and of a dark chocolate or reddish brown hue. Both shadow and satellite were very distinct and sharply defined on the disc of the planet and the "seeing" was remarkably good and steady.

After the satellite passed the central line of the planet it appeared to grow smaller and its outlines became very irregular and, when about half way between the central line and western limb of the planet, it was very small and, in shape, nearly a half moon, but very irregular in outline. This appearance continued until the satellite reached a point on the disc about 3 or 4 diameters of the satellite from the western limb, or about where the belts begin to shade down (so to speak), when it gradually became a brilliant white, well-defined, much larger than the former dusky appearance and *perfectly round.* It so remained plainly visible on the planet during the rest of the transit and came off the limb white and brilliant against the dark sky. At egress, the limb of the planet, at the point of contact, appeared to flatten down, and shrink away from the satellite (an optical illusion, of course) the limb being sharply defined and the whole planet exquisitely distinct.

The instrument used was a 5 in. refractor (just received from Messrs. Alvan Clark & Sons) with powers of 105 and 200. E. S. MARTIN.

Wilmington, N. C., Sept. 18, 1891.

August Meteors. There was a remarkably fine display of August Meteors here last night. The air was clear and still and, notwithstanding the moonlight, the meteors flashed forth in great numbers and brilliancy. From 8^h 30^m P. M. to 11^h 30^m P. M. (when I retired) there was an almost constant discharge of meteors, all apparently radiating from the same point or region, the Constellation Perseus, and the numbers increased as that Constellation rose higher.

The meteors were mostly small—lasting only a moment—though some of them were very fine and left behind them a stream of light, or vapor, like the tail of a comet, which lasted, in some instances, a considerable time after the meteor had disappeared.

I observed a remarkably brilliant and handsome meteor at 9^h 30^m which travelled slowly, from a point between N. and N. E., across the meridian between Polaris and Vega, down towards the S. W., vanishing about the Constellation Libra. It appeared larger and brighter than Jupiter now appears to the naked eye, and had a haze or coma around it like the nucleus of a comet and left behind it a stream of light, or vapor, some 30° in length, which slowly faded away.

The number of meteors may be safely put at an average of at least five per minute for the three hours that I observed, though at times, more than that number were visible at once flashing across the sky in the different directions, but all radiating from one source. They seemed to come in groups or shoals and not in a a continuous stream.

It is the finest meteoric display I have observed since that of the November meteors in 1867. E. S. MARTIN.

Wilmington, N. C., August 11, 1891.

Spectroscopic Astronomy. Dr. William Huggins has kindly favored THE MESSENGER with a copy of his address, as President, recently given before the British Association for the Advancement of Science. The address presents a full and very complete outline of the history of the spectroscope in Astronomy, and American astronomers will read it with great interest. It is published by the Association and the London daily papers.

An Astronomer's Work in a Modern Observatory is the title of a paper by David Gill, Astronomer at the Cape of Good Hope, read before the meeting of the Royal Institution of Great Britain, May 29, 1891. The author says that the work of Astronomical Observatories has been divided into two classes, viz.: Astrometry and Astrophysics. The first of these relates to astronomy of precision, that is, to the determination of the position of celestial objects; the second relates to the study of their physical features and chemical constitution. Some years ago these two classes were considered as perfectly distinct; but latterly they have become so interlaced that they cannot be divided advantageously, and a fully equipped modern Observatory will include the work of *Astrometry* and *Astrophysics.*

The discussion of this theme is a very profitable one, extending through fifteen printed pages of the size of this one. One full-page plate, a fine engraving, shows the spectrum of Sirius as compared with iron; that of α Aurigæ and that of β Aurigæ.

THE SIDEREAL MESSENGER.

CONDUCTED BY WM. W. PAYNE.

GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

VOL. 10, NO. 9. NOVEMBER, 1891. WHOLE NO. 99

ELEMENTARY PRINCIPLES GOVERNING THE EFFICIENCY OF SPECTROSCOPES FOR ASTRONOMICAL PURPOSES.

JAMES E. KEELER.

FOR THE MESSENGER.

The exact determination, by analytical methods, of the size and disposition of the parts of a spectroscope which shall best adapt it to any one of the numerous purposes for which this instrument is used in astronomy, is not generally possible, since practical considerations, not amenable to mathematical treatment, materially modify the results of theory. As in many other instruments, the adopted form is frequently a compromise between conflicting requirements. Nevertheless, sufficiently broad principles may be stated, which will serve as guides in estimating the efficiency of any form of spectroscope for its intended purpose. The effect of the practical considerations which have been alluded to can best be studied by seeing how they effect the several requirements deduced from purely theoretical considerations. The object of the present article is to state the principles of efficiency in an elementary manner, and illustrate their application, for the benefit of students who are beginning work in astronomical spectroscopy. It may seem as if they are too obvious, from well-known laws of optics, to require explanation, but examination of printed descriptions of spectroscopic observations will show that they have not been entirely understood, or, at least, not always borne in mind by many practiced observers.* Little apology seems necessary, therefore, for setting forth these principles for the benefit of beginners.

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* See Professor Hastings' review of the spectroscopic observations printed in *Vol. XLI, Memoirs of the R. A. S.*, in the *Report of the Eclipse Expedition to Caroline Island, May, 1883.* I may perhaps be also allowed to instance certain criticisms of my own spectroscopic work, at the meeting of the Royal Astronomical Society on May 8, 1891, as reported in the June *Observatory*.

In considering such matters relating to instruments as are not theoretically determinate, I have had to rely largely on individual experience, which may be at variance with that of other observers. Statements to which this explanation applies will generally be easily recognized.

With a few exceptions, which will be considered later, the spectroscope for astronomical purposes is always used in connection with a telescope. The simplest possible combination is a prism placed in front of the object-glass of a telescope. This form of instrument has great advantages for certain kinds of work, as everyone who is familiar with the wonderful results obtained at Harvard College Observatory will recognize, but it is limited in its application, and it is expensive, since the prism, if no light is lost, must be large enough to cover the full aperture of the telescope objective. Its greatest disadvantage is that it does not allow the use of a comparison spectrum. As it is not likely that the student will have occasion to use a spectroscope of this kind, it will not be considered further here.

The most common, and most generally useful form of spectroscope for astronomical purposes, is the compound spectroscope, consisting essentially of slit, collimating lens, prism or other dispersive member, and observing telescope. It is seen in its simplest construction in the small spectroscopes used in chemical laboratories for the analysis of minerals.

The functions of the different parts of the compound spectroscope may be briefly explained as follows: The collimating lens serves to form a virtual, erect image of the slit at an infinite distance, and this image, the brightness of which determines the brightness of the spectrum, may be viewed directly with the observing telescope in the same way as a distant object. If the image is monochromatic (that is, if the slit is illuminated with monochromatic light), the action of a prism placed, in the position of minimum deviation, so as to intercept the rays from the collimator, is simply to displace the image through a certain angle, without changing in any way its magnitude, shape, or (neglecting loss of light by reflection and absorption) its brightness. If the image emits light of different but determinate wave-lengths, each set of parallel rays is displaced through a different angle, forming a series of monochromatic images of the slit, or bright-line spectrum. As long as these images are separated in the field of the observing telescope, the brightness of the spectrum will depend solely on the brightness of the primary image, any change in the width of the slit making a corresponding change in the width of the lines without changing their brightness.[*] The case is different if the images overlap so as to form a continuous spectrum. The brightness is then proportional not only to the brightness of the primary image, but also to the width of the slit. The *purity* of the spectrum, or exactness with which the rays of slightly different wave-length are separated, also depends, down to a very small limit, upon the width of the slit, to which it is *inversely* proportional. To get a bright spectrum, the slit must be wide; to get a pure spectrum the slit must be narrow. In any practical case, experiment shows what compromise is most advantageous.

When different spectroscopes are compared, the width of the slit mnst be taken to be its width in angular measure, as seen from the optical center of the collimating lens.

The laws which govern the brightness of the spectrum as seen in the observing telescope under different magnifying powers are the ordinary laws of the brightness of telescopic images. The highest power P which will give the maximum brightness is obtained by dividing the aperture of the observing telescope by the aperture of the pupil of the eye. If the latter is taken to be one-fifth of an inch, the value of P will be five times the aperture of the observing telescope in inches. In practice a better result will be obtained with a power of seven or eight for each inch of aperture. For any magnifying power p greater than P the brightness is proportional to $\frac{P^2}{p^2}$.

When the compound spectroscope, the principles of which have been briefly considered above, is used in connection with an equatorially mounted telescope, two different telescopes form parts of the apparatus; namely, the great telescope of the equatorial and the telescope of the spectro-

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[*] Provided the angular width of the slit is greater than the angle subtended by one wave-length of light at a distance equal to the collimator aperture.

scope. To avoid confusion they will be distinguished by the terms telescope and observing telescope, respectively.

The spectroscope is mounted in such a way that the axis of the collimator is coincident with the axis of the telescope, and the slit is brought into the focal plane of the great objective. An image of any distant object to which the telescope is pointed is therefore formed upon the slit-plate. Certain limitations are then imposed upon the dimensions of parts of the spectroscope.

The first condition to be fulfilled is that the angular aperture, or ratio of linear aperture to focal length, shall have the same value for both telescope and collimator; otherwise, there will be a marginal ring on one lens or the other which will never be used. If the great telescope is of one foot aperture and fifteen feet focal length, the collimator, if of one inch aperture, should have a focal length of fifteen inches. For reasons which will appear further on, it will be advantageous to have the aperture of the collimator lens a little greater than that given by the rule, but in that case we must distinguish between actual aperture and effective aperture. The latter, which is determined by the rule, is the diameter of the emergent beam from the collimator when the telescope is directed to a star, and a marginal ring on the lens receives no light from the telescope objective. A cap may be provided to cover this ring, so that the actual and effective apertures can be made the same if desired. In the following discussion it will be assumed that they are the same.

If no light is to be lost, the prisms and observing telescope must be capable of transmitting the cylindrical beam from the collimator. Greater dimensions than those necessary for this purpose would be useless. The effective aperture of the collimator may then also be called the aperture of the spectroscope.

The lens which is placed in front of the spectroscope to form an image of the source of light on the slit-plate (*i. e.*, in the case we are considering, the telescope objective), is ordinarily called the "condensing lens." This name is inappropriate, as it fails to define correctly the function of the lens, and Professor Hastings* has proposed to substitute for it

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* *Caroline Island Report*, p. 108.

the term "image lens." As the intrinsic brightness of the image of a surface, the moon for example, in the focal plane of an image lens of constant linear aperture, is inversely proportional to the square of the focal length of the lens, it might seem at first sight as if the spectrum of the surface, when a short-focus lens is used, ought to be brighter than with a long-focus lens of the same aperture. Nevertheless, it is easy to show that the brightness of the spectrum is independent of the angular aperture of the image lens.

To do this let A, F, S, represent respectively the aperture, focal length, and area of the image lens, a, f, s, the corresponding dimensions of the collimating lens. Then as has already been shown, $\frac{A}{F}=\frac{a}{f}$.

Let the source of light be a small uniformly bright surface, and let the unit of light be that quantity which falls upon an area equal to that of the collimating lens. Then the quantity of light which falls upon the image lens is

$$\frac{S}{s}=\frac{A^2}{a^2}=\frac{F^2}{f^2}.$$

All this light falls upon the collimating lens, and is therefore found in the virtual image formed by the latter at an infinite distance; but the angular magnitude of this image is $\frac{F}{f}$ times, its angular surface $\frac{F^2}{f^2}$ times that of the object.* Hence we have $\frac{F^2}{f^2}$ times the light distributed over a surface $\frac{F^2}{f^2}$ times as great, and therefore the brightness of the image is the same as that of the object.

The brightness of the virtual image determines the brightness of the spectrum. We conclude, therefore, from this discussion that the brightness of the spectrum of the distant object is independent of the angular aperture of the image lens. A long-focus telescope is as advantageous for observations of the spectra of the sun, moon and extended nebulæ as a short-focus telescope. The efficiency, so far as brightness is concerned, is determined solely by the effective aperture of the spectroscope.

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* It will easily be seen that this is true. The collimator lens may be regarded as the eyepiece of a telescope, the magnifying power of which is $\frac{F}{f}$.

To illustrate this result, let us suppose that we have a spectroscope of one inch aperture, with collimator twenty inches long, used in connection with a telescope of one foot aperture and twenty feet focal length. The diameter of the solar image on the slit plate, when the telescope is directed to the sun, will be about 2.2 inches. Let us suppose that the slit-width is adjusted until the spectrum is of satisfactory purity and brightness.

If the spectroscope is now removed and placed upon a telescope of the same aperture but only half the focal length, the image of the sun on the slit-plate will be only 1.1 inches in diameter, and it will consequently be four times as bright; but only one-fourth of the rays passing through the slit fall upon the collimator lens. The spectrum will therefore have the same brightness, and as the slit-width has been unchanged, the same purity as before.

If the collimator is now shortened one-half, all other dimensions being as before, all the rays passing through the slit will fall upon the collimating lens, which must now have a focal length of ten inches; but the slit is now twice too wide, and if narrowed until the original purity is restored, the spectrum will be just as bright as before.

If instead of shortening the collimator to make its angular aperture equal to that of the second telescope, we increase its aperture to two inches (the dimensions of the other parts of the spectroscope being correspondingly increased), the brightness of the spectrum will be increased four times, with the same degree of purity as at first.

Another interesting conclusion, which is a well-known fact in optics, may be drawn from the preceding discussion. Since in determining the brightness of the virtual image F and f may have any values, and since the virtual image formed by one set of lenses may become the object for another set, it follows that by no combination of lenses can we obtain an image of an object which shall be brighter than the object itself.

If an image of the sun is formed by a convex lens, the con ditions of temperature and brightness at any point within the image are (neglecting loss of light due to absorption and reflection) the same as if the point were brought to within such a distance of the sun that its disc would sub-tend the same angle as the lens. The same statement holds good for any other extended surface. We may base upon this a conventional way of regarding the distant source of light which is sometimes useful in determining the brightness of the image upon the slit-plate, namely: we may regard the object-glass as replaced by the luminous surface itself, stretched across the open end of the telescope tube; or we may consider the luminous surface to be just outside the objective, in which case the absorption of the glass is taken into account. This convention leads to the same conclusions as the discussion already given. It can be applied to a consideration of the brightness of the spectrum only when the image is sufficiently large to fill the slit of the spectroscope.

We have shown that for certain objects a small telescope gives as bright spectra as a large one; indeed, the small one has the advantage, since its object-glass is thinner and absorbs less light. The beginner might then naturally ask why a large telescope is desirable for spectroscopic work. The answer is that for such objects there is no advantage in a large telescope, but all objects which we have to examine are not extended surfaces like the sun and moon.

The case which is furthest removed from that which we have hitherto considered, is that of a star. The image lens may then properly be called a condensing lens, since the brightness of the spectrum, as well as that of the image, will depend on the aperture of the lens. In a stellar image we cannot discriminate between quantity of light and brightness. The spectroscope slit is in all cases so narrow as just to include the image, and all the light of the star goes into the spectrum. Hence increasing the aperture and focal length of the collimator does not increase the brightness, although, as the same slit-width then subtends a smaller angle, it increases the purity of the spectrum.

The other extreme in the character of the source of light is when the angular magnitude of the object is as great as the angular aperture of the telescope. Seen from the slit, such an object would completely fill the opening occupied by the object-glass, and the removal of the object-glass would increase its apparent brightness. The brightness of the sky spectrum, for instance, is greater when the object-glass of a telescope is removed. It is obvious that for such objects better results can be obtained without a telescope.

A practical case of this kind occurs in astronomy. For observing the spectrum of the aurora, or of the zodiacal light, no telescope should be used. The aperture of the spectroscope should be as large as possible, and (from considerations of convenience and portability) the collimator and observing telescope should be short.

The same construction may be extended to meet the case of bodies of no larger angular magnitude than the sun and moon. If the angular aperture of the collimator is ½°, *i. e.* if the focal length is 115 times the aperture, the solar spectrum obtained with a given spectroscope when the collimator is pointed to the sun is the brighest possible. The telescope or image lens is here dispensed with. Considerable advantage may sometimes be gained by applying this principle, particularly in laboratory work where a heliostat is used, and where the use of a long collimator is attended with no inconvenience. In measures of the heating effect in different parts of the spectrum, for which rock-salt lenses and prisms are used, the saving of an additional lens is a matter of some importance.

It will be noted that a spectroscope of this construction is necessarily an *integrating* spectroscope, and it cannot be used to study the spectrum of any particular part of the luminous source. An attempt to apply the same principle to the other heavenly bodies presenting sensible discs would be rendered futile by the excessive length of collimator required.

We have still to consider the case of bodies of small angular magnitude, like the planets.

In this case the image of the object does not cover the entire length of the slit. To form a clear idea of the conditions of efficiency which depend upon the size of the telescope, let us suppose that we have a spectroscope attached to a telescope of considerable size, and have adjusted the slit so as to obtain a satisfactory degree of brightness and purity in the spectrum.

If we now imagine the telescope to become smaller, preserving the same angular aperture, the brightness and purity of the spectrum will remain unchanged, but the width of the spectrum, which is determined by the diameter of the image on the slit, will diminish. Now the visibility of an object depends upon its size, as well as upon its brightness, and a long line is easier to see than a short one, when the length of either is inconsiderable. The breadth of the smaller image can be increased by means of a cylindrical lens, but only by a proportional sacrifice of brightness. Hence we conclude that for spectroscopic observations of small bodies, such as the planets and their satellites, the head of a comet, and small planetary nebulæ, a large telescope is desirable.

We come now to the consideration of more complex sources of light. One of the most interesting cases is that of the solar prominences, in which we have luminous bodies emitting light of definite wave-lengths, ordinarily invisible on account of the glare from the brilliant white light of the sky. The most obvious method for making the prominences visible in the spectroscope is to weaken the continuous sky spectrum by employing a high dispersion. If the object were simply to see the bright lines of a prominence, the same end might theoretically be attained by using a narrow slit, for narrowing the slit diminishes the brightness of the continuous spectrum without altering that of the bright lines. The slit might then, however, be so narrow that the bright lines would be invisible on account of insufficient breadth. By using a spectroscope of greater aperture and a higher magnifying power the slit would not have to be so narrow, and the lines might be seen, but it is evident that the size of the spectroscope to fulfil these conditions, when the bright lines are relatively faint, might transcend all practicable limits. Moreover, we desire to see the whole prominence, and hence must use a wide slit. The only available method, then, is to use a very high dispersion.

On account of the smaller image of the prominence when a short telescope is employed, and consequently smaller slit-width required, a telescope of moderate dimensions is more suitable for observing prominences than a large one.

Another case of extreme interest is that of the corona. The conditions of efficiency for an instrument to be used in observations of the corona during a total eclipse have been determined by Professor Hastings,* who has shown that for such observations a spectroscope with large aperture is required.

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* *Caroline Island Report*, p. 110.

The necessity of a large aperture will appear from the following considerations. The spectroscope must be capable of showing dark lines in a continuous spectrum, as well as bright lines on the same background. We have just seen that sufficient contrast between the light of the bright lines and that of the continuous spectrum can be obtained by using a high dispersion with wide slit, or by using a spectroscope of large aperture (and correspondingly high magnifying power) and a narrow slit. Now dark lines cannot be seen with a wide slit, *i. e.*, a slit whose angular width exceeds a few minutes of arc; hence to show dark lines as well as bright lines in a continuous spectrum we must use the second of the two methods just mentioned. From a review of numerous reports of observations of total eclipses, Professor Hastings concluded that an aperture of less than half an inch was ill suited for observations of the corona, while anything over three-quarters of an inch, if properly designed in other respects, would make an effective instrument.

I have found the bright lines in the spectra of some stars to become invisible if more than a very moderate dispersion is used, probably because they are really somewhat diffuse bands, which widen with increase of dispersion.

The conclusions which we have so far reached, relating to the efficiency of the telespectroscope, may now be summed up, as below. It should be noted that they are based upon the principles of common geometrical optics, it being assumed that they are not carried to the limit at which a consideration of the finite length of a light wave is necessary.

A. 1. In all cases the collimator should have the same angular aperture as the telescope.

B. When the object observed is a luminous surface of considerable angular magnitude, such as the sun, moon or a large nebula:

2. The brightness of the spectrum is independent of the angular aperture of the telescope.

3. The brightness is independent of the linear aperture of the telescope.

4. The efficiency of the spectroscope as regards brightness is determined by its aperture, *i. e.*, by the effective aperture of the collimator, the other parts of the instrument being of

such dimensions as to transmit a beam of the same diameter.

C. When the object is of very large angular magnitude, as the sky illuminated by sunlight, the aurora, or the zodiacal light:

5. The spectra of objects whose angular magnitude is greater than the angular aperture of the telescope are best observed without a telescope.

6. The efficiency of a spectroscope for such objects, so far as brightness is concerned, depends upon the aperture of the spectroscope.

7. The same method may be extended to the sun and moon by using a sufficiently long collimator.

D. When the object is a star:

8. The brightness of a star spectrum is proportional to the area of the telescope objective, and independent of the aperture of the spectroscope.

9. The purity of the spectrum is proportional to the length of the collimator.

E. When the object is a body of but small angular magnitude, such as a planet, head of a comet, satellite, small nebula, sun-spot, etc.:

10. For spectroscopic observations of such small objects a large telescope is desirable.

F. The case of the solar prominences seen in full daylight:

11. A spectroscope of high dispersive power should be used for observing the solar prominences.

12. A telescope of moderate dimensions is more suitable than a very large one.

G. The case of the corona during a total solar eclipse:

13. A spectroscope of large aperture with an observing telescope of correspondingly high magnifying power is most efficient for seeing both bright lines and dark lines in the continuous spectrum of the corona.

As remarked at the beginning of this article, the principles just summarized cannot be applied with mathematical exactness. The conditions of efficiency are different, for instance, for large and for small surfaces; but the dividing line between large and small surfaces cannot be sharply drawn. In this respect the rules which have been given do not differ from many others occurring in physical science, which, notwithstanding their limitations, are correct and useful in their broad application.

We may now consider the practical bearing of these principles on the construction of spectroscopes. The size of the telescope may be left out of the question, as this is usually fixed by other considerations, independent of the use of the spectroscope. An aperture of less than ten inches, however, will hardly be sufficient for studying the spectra of stars.

On referring to the principles which have been established it will be seen that a large aperture is one of the conditions of efficiency for nearly every kind of spectroscope. The same condition will also in a great measure determine the size and weight, and hence also the cost of the instrument. As the prisms must be of such size as to transmit the emergent beam from the collimator, and as their weight varies as the cube of their linear dimensions, the aperture cannot be made very great without making the instrument unmanageable; it is therefore necessary to use a moderate aperture, and a number of small prisms instead of one large one, notwithstanding the theoretical advantage of the latter. An aperture of one inch, which with a telescope of ordinary construction will imply a focal length for the collimator of about fifteen inches, may be taken as suitable for a twelve-inch telescope. For larger telescopes the aperture of the spectroscope may be increased, but for even the largest it is likely that a spectroscope of much over two inches aperture would, if sufficiently rigid, prove to be too heavy a burden. The case of grating spectroscopes is somewhat different, increase in the size of the grating not being attended with increased weight and absorption of light, while the efficiency of the instrument becomes much greater.

Experience seems to show that the most effective form of prism for star spectroscopes is the compound, or Rutherford prism, made up of a heavy flint glass prism with a large refracting angle (usually 90°), and two crown glass prisms cemented one on each face of the flint glass with Canada balsam. Without the two small prisms light could not be made to pass through the large one.

The investigations of Lord Rayleigh throw some doubt on the generally accepted superiority of the compound prism. The greater refracting angle and length of base which may be given to the flint glass seem to be a hardly sufficient compensation for the negative effect of the crown glass. One definite advantage that may be stated is that very heavy flint glass, which is subject to oxidation on exposure to the air, may be used in the construction of the compound prism, as the perishable flint glass is protected by the hard crown. For photographic purposes such very dense flint is highly objectionable, as it has a strong yellow tinge.

A compound prism used on the large star spectroscope of the Lick Observatory has a dispersive power more than three times as great as that of a single 60° prism of white flint glass.

Two compound prisms are used in the Potsdam spectrograph for determining the motions of stars in the line of sight. It is not likely that a greater number could be used advantageously in eye observations.

The half-prism which is sometimes used for astronomical purposes, has a number of disadvantages as compared with the form just described. The purity of the spectrum is not so great as with other prisms giving the same dispersion; the emergent beam is laterally displaced, and if, as usually is the case, the observing telescope is in line with the collimator, the spectrum is formed by eccentric pencils, increasing the difficulty of avoiding errors of parallax and other small displacements; when several prisms are used, the emergent beam becomes very narrow, and only a correspondingly small part of the objective of the observing telescope is used, greatly to the detriment of good definition. The direct view is also a disadvantage in observing objects near the zenith, which are otherwise most favorably situated. On these grounds, and perhaps some others, preference should be given to the Rutherfurd prism.

For faint objects giving a continuous spectrum a high dispersion cannot be used, and the spectroscope should therefore be arranged to carry a single 60° prism.

When only a single prism, either simple or compound, or a grating is used, the observing telescope can be made to point to a center of motion which is in the prolongation of the collimator axis and in the axis of the deviated ray. With more than one compound prism the beam of light is displaced laterally so far that either the center or the position of the observing telescope must be changed. Thus if a great range of dispersive power is required, the construction of the instrument is considerably complicated, but in a first class instrument designed for various kinds of work such an arrangement is necessary. When the train of four compound prisms is used on Professor Young's new spectroscope, the observing telescope is held by a pair of brackets, the necessary rigidity being secured by a brace extending to the upper end of the collimator.

For solar work a diffraction grating will generally be used, the loss of light as compared with a prism train being in this case of no importance. I have recently shown * that a grating can also be used to great advantage in observations of nebulæ giving a bright line spectrum. For observation of stars with a grating a very large telescope aperture is necessary. But for the remarkable brilliancy of the gratings which in the last few years have been ruled by Rowland on surfaces prepared by Brashear, such observations would be quite impossible.

The objectives of the collimator and observing telescope should preferably be made of Jena glass, as such objectives when properly corrected have so little chromatic aberration that all parts of the spectrum except the extreme ends have practically the same focus. No adjustment of the observing telescope is required in passing from one part of the spectrum to another, an advantage which adds greatly to the convenience as well as to the accuracy of the observations. To diminish the loss of light by reflection, the object-glasses if small, (as they always are in a star spectroscope) may be cemented with Canada balsam.

It is usual to make the collimator and the observing telescope of the same focal length. If, however, the collimator is unusually long, say twenty inches or more, the most effective eyepiece for an equally long observing telescope must have an equivalent focal length of several inches, and this, according to my experience, is undesirable, if precise measurements are required, on account of the effect of changes in the accommodation of the eye. I therefore prefer a shorter

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* *Publications of the Astronomical Society of the Pacific, No. 11.*

observing telescope and deeper eye-pieces to obtain the same magnifying power. Ten or twelve inches is a convenient focal length. These remarks obviously apply only to visual observations, and they do not apply to solar spectroscopes, on which much higher magnifying powers are used than that which gives the maximum brightness.

The eyepieces of the observing telescope should be achromatic, in order to have the micrometer wires as nearly as possible in focus for all parts of the spectrum. It is impossible to fulfil this condition exactly, at least without a specially constructed eyepiece, as the eye itself is not perfectly achromatic.

On account of the imperfect achromatism of the nominally achromatic telescope, the collimator must have a sliding motion in the direction of its length, in order to bring the slit into the focal plane of the rays which form the part of the spectrum under examination. About one inch is a proper allowance for a twelve-inch telescope of the ordinary construction, and for telescopes of different sizes the amount of motion required will be in proportion to the focal length. The position of the collimator in its slide is shown by a graduated scale. If the spectroscope is quite small it may be attached to the draw-tube of the telescope, and the whole instrument moved in or out to bring the slit into the required position.

The slit is an important part of the spectroscope, and it deserves careful attention. Very good mechanical work is required in its construction. It is convenient to have both jaws move equally in opposite directions on turning the slit screw, the center of the slit thus remaining always in the same place. This construction is condemned by Dr. Scheiner in his text book on celestial spectroscopy as only fit for small instruments not intended for accurate measurements. All the devices which he describes are certainly open to objection, but the double-motion slit with jaws actuated by a right and left-handed screw, as made by Brashear and other American instrument makers, is practically free from error. Caution must be observed not to rely too implicitly on the principle of the double-motion slit, as it is only in certain positions of the prism or grating that a spectral line widens symmetrically when the slit is opened.

The arrangement of a diagonal eye-piece for viewing the slit from behind, first described (so far as I know) by Dr. Carl Braun in one of the volumes of the Haynald Observatory publications, is a very useful, and when a large telescope is employed, indispensable addition. With this eyepiece a good view of the object to which the telescope is directed can be obtained on widening the slit, and on narrowing the slit the observer can assure himself that the exact part of the image which he wishes to examine spectroscopically is within its jaws. The eyepiece should move between stops, so that when fully in the slit may be in the center of the field, and when withdrawn the rays from the slit may pass without obstruction. An equivalent focal length of about one inch will give a convenient magnifying power.

The positions of unknown lines in the spectrun of a heavenly body are determined by comparing them with known lines, usually furnished by a terrestrial source, such as an electric spark passing between metallic points, a spectrum tube or a flame. In order to make the comparisons reliable there must be no displacement of any kind in the comparison spectrum; that is, a line in the spectrum of light coming through the telescope must fall at precisely the same place as the same line in the spectrum of light which is reflected into the slit from the artificial source. It seems to me that this coincidence is best assured, apart from good workmanship in the instrument, by making the light from both sources traverse the instrument under identically the same conditions. In some of the earlier spectroscopes light from the electric spark was reflected from a plane mirror to a totally reflecting prism directly over the slit and thence into the collimator; but this is a bad arrangement, since the spark, being of very small dimensions and at some distance from the slit, sends light to but a small portion of the collimator lens, while the full aperture of the collimator is filled with light from a heavenly body. An *image* of the spark should be formed on the slit by a lens having a greater angular aperture than the collimator, so that the light from the spark, after being reflected through the slit in the direction of the collimator axis, will completely fill the aperture of the collimator. If the actual aperture of the collimator is greater than the effective aperture, it should be reduced by a stop until equal to the effective aperture, as recommended in the first part of this article. If very accurate comparisons are necessary, as in measures of the motions of stars in the line of sight, all the optical parts of the instrument must be perfect, and all the adjustments must be made with the greatest care. The latter condition, it is, of course, the business of the observer to fulfil. In a paper on the motions of the planetary nebulæ in the line of sight, I have described briefly the arrangement of the slit and comparison apparatus of the large spectroscope of the Lick Observatory, which leaves little to be desired in the way of convenience and accuracy.

In spectroscopes for observing solar prominences the slit plate is frequently movable in a direction at right angles to the slit, as the adjustment of the slit on the limb of the solar image is a delicate one, not easily made with the slow motions of the equatorial. This construction is not to be recommended for other purposes.

When the spectrum of a star is observed, a cylindrical lens is placed in front of the slit to give the spectrum sufficient breadth. The way in which a cylindrical lens is used will appear from the following considerations:

When a convex cylindrical lens is placed in the cone of rays from the object glass two real, linear images are formed by the combined action of the two lenses. The one nearer to the cylindrical lens is called the principal focal line. Its axis is parallel to the axis of the cylindrical surface of the lens, and its length is equal to the diameter which the cone of rays will have at that point if the cylindrical lens were removed. Its distance from the focal plane of the telescope and from the cylindrical lens depends upon the focal length of the latter.

The linear image farther from the cylindrical lens is called the secondary focal line. Its axis is perpendicular to the axis of the cylindrical lens, and its length depends upon the focal length and position of the cylindrical lens. The secondary focal line is always in the focal plane of the objective, and it is therefore the more convenient one to use. It must be made to fall precisely within the jaws of the slit, and in making this adjustment the diagonal eyepiece already described is almost indispensable. The breadth of the spectrum, which is evidently equal to the length of the line, can be varied by simply changing the distance between the lens and the slit.

The focal length of the cylindrical lens is not entirely an indifferent matter. If the rays passing through the slit are widely divergent, they will fall outside the limits of the collimator lens, and some light will be lost. Hence the cylindrical lens should have a considerable focal length, say ten or twelve inches. The emergent beam from the collimator will then be elliptical in section, with the longer axis parallel to the slit, and a stop may be cut so as to just allow the passage of the beam, and placed over the collimator lens when the comparison apparatus is used. It should be noted that the *minor* axis of the emergent beam is equal to the effective aperture of the collimator; hence unless the actual aperture is somewhat greater, some light will be lost.* The advantage of a collimator aperture somewhat in excess of the requirements of the rule given in the summary under *A* has already been mentioned. As prisms are almost invariably higher than necessary to transmit a cylindrical beam, no change in their dimensions need follow the enlargement of the objectives of the collimator and observing telescopes.

For measuring the positions of lines in the spectrum a great many devices are used, such as a graduated circle read by microscopes or verniers, and a micrometer slow-motion screw for moving the observing telescope. The illuminated scale reflected from the first surface of the prism, commonly used on small spectroscopes for analyses of minerals, is one of the roughest devices for recording the position of lines. It is not necessary that the positions should be read in terms of any determinate unit. It is not necessary, for instance, to eliminate eccentricity from the readings of a graduated circle by reading opposite verniers, (unless *deviations* are required for other purposes), since the correction for eccentricity is itself a continuous function of the circle reading. I have no doubt that if an instrument of given weight and cost is to be designed so as to give the greatest accuracy of

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* The same remarks apply to the case when a considerable length of slit is used, as in observing any extended surface, the cylindrical lens being dispensed with.

measurement, the end will best be reached by relying entirely upon the use of the comparison apparatus and eyepiece micrometer, and using a graduated circle, if at all, only as a finder. The cost and weight of all other attachments can then go into the important parts which determine the efficiency of the instrument.

No reference has yet been made to the *resolving power* of a spectroscope, or its power of separating close lines in the spectrum. Lord Rayleigh has shown that for simple prisms the resolving power depends upon the difference between the longest and shortest paths of rays in traversing the prisms. With properly constructed apparatus the extreme difference of paths will be the sum of the bases of the prisms. A single prism is therefore equal in resolving power to two prisms of half the size. Hence we see that the power of a spectroscope is by no means defined by its dispersion, for it is easy to obtain large dispersion with small resolving power. It is customary to state the optical power of an instrument in terms of the number of simple prisms required to give the same dispersion, and although the statement is indefinite, yet, as prisms for astronomical spectroscopes are generally of about the same size, it is accurate enough for conveying a general idea of the efficiency of the apparatus employed.

The relation between thickness of glass and the resolving power of a prism is quite analogous to that between aperture and separating power of a telescope objective.

For compound prisms the rule for resolving power requires modification, a given thickness of the less dispersive medium (crown glass) not counting for so much as the same thickness of flint glass.

The equations of Lord Rayleigh show that a prism of dense flint glass must have a base of at least one centimetre in order to separate the *D* lines. If the student wishes to test this result by actual experiment, let him place a cardboard stop with an aperture of about one-tenth of an inch over the collimator of his spectroscope when the telescope is directed to the sun. If not more than two simple prisms are used, he will find that with no adjustment of the apparatus can he separate the *D* lines, although there may be abundance of light. A long slit one-tenth of an inch wide may be used instead of a circular aperture, provided it is placed parallel with the refracting edge of the prism, and not crosswise.

The resolving power of a grating depends on the number of lines used on the grating and on the order of the spectrum. It is the same in all parts of the spectrum of one order, whereas the resolving power of a prism increases very rapidly toward the violet, where it is seven or eight times as great as in the red.

Professor Schuster takes as the unit of resolving power that power which is necessary to separate lines differing by the thousandth part of their own wave-length. A spectrum in which such lines can just be separated has unit purity. The resolving power of a spectroscope is numerically equal to the greatest purity of spectrum obtainable with it.

The *D* lines are very nearly one one-thousandth part of their own wave-length apart. Hence the spectroscope considered above, with a prism one centimetre on the base, would have a resolving power of unity for sodium light. A grating with one thousand lines, would have unit resolving power in the first spectrum.

The great advantage of a grating over a prism in regard to resolving power is apparent from the figures which have been given. A resolving power of 100, which is easily realized in large gratings of modern construction, would theoretically require a thickness of one metre of glass if obtained by prisms, and doubtless it would actually require much more if enough light were left after passing through the prisms to make the experiment practicable.

When there is paucity of light, the full resolving power of a spectroscope cannot be realized.

For efficiency in regard to resolving power a large aperture of the spectroscope is an important condition, as we have shown it to be in most cases from another standpoint, for brightness.

Almost all our space has been devoted to a consideration of the compound spectroscope, as it is the only form with which exact comparisons of spectra are possible. For merely seeing the spectrum very simple spectroscopes suffice. The McLean star spectroscope, which is much used for looking at the spectra of stars, has no slit, and therefore cannot be used for any other purpose. In all instruments of this kind which I have seen, the spectrum is made unnecessarily wide, and correspondingly weak by using a cylindrical lens of too short focus. A somewhat similar combination of a small direct-vision prism and a cylindrical lens, placed on the eyepiece of a telescope so as to receive the emergent beam, will give good views of stellar spectra.

Such spectroscopes are necessarily of small resolving power, but as the prisms required are very small, but little light is lost by absorbtion, and they give brilliant spectra.

It has been impossible to mention in this article the optical and mechanical features of the great variety of forms which have been given to the spectroscope, but a fair judgment of the efficiency of any particular form for its intended purpose may be based on the general principles which have been explained. The mechanical execution has much to do with the "efficiency" of an instrument, not in the limited sense in which we have used the term, but in its more usual application. Even mechanical defects which are apparently trivial, such as the division of a micrometer head into any number of parts but one hundred, or the marking of a scale by longer lines in any other way than by fives and tens, by causing annoyance and loss of time to the observer, possibly even mistakes, detract from the usefulness of the instrument. The mechanical appliances should be such as to afford the greatest facility for adjustment and accurate measurement, as well as to give proper support to the optical parts.

A FURTHER NOTE ON STAR-DISTRIBUTION.

W. H. S. MONCK [*]

FOR THE MESSENGER.

Some years ago I pointed out a formula by which the relative brilliancy of binary stars whose orbits were known and whose light had been measured by a photometer, could be determined. The relative brilliancy thus computed proceeded on the assumption that the stars were in each case globes of the same density. The formula was only strictly correct where the satellite was very small compared with the principal star, but in every case it afforded an approximation

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which, in dealing with averages, was quite sufficient for the purpose.

Last year Mr. Gore published a complete catalogue of the binary stars whose orbits had hitherto been computed, giving in each instance the brilliancy according to my formula. The result was to confirm a conclusion which I had already drawn as to the extraordinary difference in brilliancy between different binary stars. Adopting the star ξ Ursæ Majoris as the unit (its orbit being well determined and the intensity of its light accurately measured both at Harvard and at Oxford) Mr. Gore's figures ranged from 92.99 down to 0.0015. So far, however, the table did not throw much light on the problem of star-distribution; but to this it has recently been extended by Mr. Maunder of Greenwich, in a paper which appeared in *Knowledge* for June, 1891. Mr. Maunder compared the brilliancy of 21 binary stars of the Sirian type, with that of 29 stars of the solar type, obtaining an average of 12.0 for the former against 2.3 for the latter. Reducing this result to the photometric scale I find that a Sirian star whose mass and distance is equal to that of a solar star will, on the average, appear 1.79 magnitudes brighter. In other words if we suppose the mean range of a telescope to extend to stars of the 12th magnitude, it will give Sirians at a distance corresponding to the 12.9th magnitude, while it will stop with solar stars at a distance corresponding to the 11.1th magnitude. Sirian stars will thus be visible at more than double the distance of solar stars of equal mass.

These consequences are important as regards the number of stars of different classes which we can see either with the naked eye or with the telescope. If 50 per cent. of those which we see are Sirians, it does not follow that one-half of the stars are of the Sirian type. We see Sirian stars at distances where the corresponding solar stars are invisible. On the hypothesis of uniform distribution the stars of the $n + 1$th magnitude should be nearly 4 times as numerous as those of the nth magnitude and 3 times as numerous as all the stars brighter than the $n + 1$th magnitude. I have pointed out that in using photometric measures this proportion is never realized. 3 and 2 will be found to answer better than 4 and 3, and for the present purpose I shall adopt them. As a difference of one magnitude makes the stars three times as numerous, a difference of 1.79 magnitudes will make them about seven times as numerous and the Sirian stars visible, either with the naked eye or in any given telescope, will be about five times as numerous as they would appear to be if our eyes and our telescopes had the same space-penetrating power for solar as for Sirian stars.

How far this result can be carried on to red stars I am not in a position to offer any opinion. But I think there is little doubt that their brilliancy is less than that of solar stars and that the space-penetrating power of telescopes for red stars is consequently less than for solar stars. If we could separate the stars included in any given sphere with the sun as centre from those lying outside that sphere, we should probably find the red stars much more numerous than a mere count of the sky would have led us to expect, the solar stars about as numerous as we expected, and the Sirian stars much reduced in number. It is no objection to this conclusion that some Sirian stars have measurable parallaxes and that some bright red stars have not. Stars, no doubt, differ enormously in mass as well as in brilliancy, and no conclusion in which one of these elements has been neglected can be relied on in individual instances.

Mr. Maunder, it should be stated, holds that solar stars are generally speaking of greater mass than Sirian. We shall hardly be in a position to decide this question until the parallaxes of binary stars have been better determined. Greater mass would, of course, act as an equivalent for great brilliancy and the space-penetrating power of our telescopes for both classes of stars might, on this assumption, be nearly identical. Without denying that there are some grounds for Mr. Maunder's opinion, however, I think the supposed greater mass of the solar stars will not explain the whole of the phenomena. Binary stars which can be separated in the telescope and yet revolve in a measurable period must be among our comparatively near neighbors. Mr. Maunder's comparison of these gives 29 solar stars to 21 Sirian. But probably even within these limits of distance there are solar stars which have escaped observation (at least such continuous observation as would be required for the computation of orbits) owing to their faintness, but which would have been observed and computed if promoted to the Sirian rank. The proportion of 58 solar stars to 42 Sirian is thus likely to be under instead of over the mark, at least as regards the nearer stars; whereas on a general count of the sky these proportions would probably be reversed. There is no reason to think that solar stars have a greater tendency to form binary systems than Sirian: indeed for very close doubles which are detected only in eclipse or by spectroscopic variations the evidence points the other way. The subject is well worth following up. One consequence of my theory that Sirian stars are farther from us than solar stars of the same photometric magnitude is that the solar stars of any magnitude will on the average have a greater proper motion than the Sirian while the red stars will probably surpass both. A classification of fast-moving stars—say those with a proper motion of over 0.5″ per year—according to their spectra would help to solve this problem.

I may remark that this conclusion does not depend on the assumption that the unit of surface is brighter in the case of Sirian than of solar stars. The effect would be the same if Sirian stars were of small density and presented to us a very large extent of illuminated surface relatively to their mass. The phenomena of the Algol type of variables (assuming them all to be Sirian; but I am not aware that the spectra of some of them have been determined) favor this assumption of small density. But small density does not imply small mass, and it seems certain that the mass of some of the nearer Sirian stars exceeds that of the sun. But of course the sun may be a very small solar star. I ought to have noticed that the larger mass of the solar stars assumed by Mr. Maunder might render the computation of orbits more easy by shortening the period of the revolution. Measures of parallax seem here again requisite, though a part of the difficulty might be removed by observations (carried on for some years) of the spectroscopic velocities of the stars in the line of sight. To both parallax-measurers and spectroscopists binary stars offer an interesting field of investigation.

THE HISTORY OF ASTRONOMY.*

G. F. CHAMBERS, F. R. A. S.

Every science has a history, and it will often happen that a due presentation of the facts of that history and a due comprehension of their bearing will greatly aid an intelligent reader in his study of the particular science in its modern aspects. All this is particularly true of Astronomy. A student who has mastered the facts appertaining to its origin in early times, and to its subsequent developement down to the present epoch, should have acquired a considerable general knowledge of the science itself as a whole.

Poetry and romance have always talked about the Chaldean shepherds as the first astronomers. I can neither affirm nor deny the idea. But when one considers how much time men of the shepherd class spend out in the open air, and how accurate their anticipations of the weather generally are, it seems not unreasonable to think that such men as the shepherds of Eastern lands may have been in a certain general sense the earliest astronomers.

This conception naturally suggests the question, "Do we find any allusions to astronomical matters in the Holy Scriptures?" To this the answer must be in the affirmative. Of historical events there are two, the astronomial import of which is very obvious: (1) The standing still of the sun and moon, as so stated, at the command of Joshua;† and (2), the going back of the shadow of the sun for King Hezekiah's sake on the dial of Ahaz.‡

The former of these events has never been adequately explained, and it can only be regarded as having been a miracle in the proper sense of the word. With respect, however, to what happened in the case of Hezekiah there seems reason to believe that the observed facts may be reconcilable with the circumstances of a partial eclipse of the sun, visible as such at Jerusalem on January 11, 689 B. C. This eclipse is known to have happened nearly at noon, and if we may suppose the words "dial of Ahaz" to apply to a large gnomon or sundial formed of masonry, and similar in character to

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* From Pictorial Astronomy for General Readers, June, 1891.

† Joshua x. 13.

‡ II. Kings xx. 11.

such a structure as that which still exists at the ruined Hindù Observatory at Benares, we may understand that a shadow caused by an uneclipsed sun might be brought back on the upper part of the sun's disk suddenly ceasing for an hour or so to be a source of light.*

Passing from Asia into Europe we come to the Greeks, of whom it may be said generally that they were great astronomers as well as physicists. The names of Thales, Pythagoras, Anaximenes, Meton, Eudoxus, Philolaus, Aristotle, Calippus, Archimedes, Aratus, Aristarchus, Eratosthenes, Apollonius and Hipparchus will readily occur to the mind. They were perhaps not all Greeks in the strict literal sense of the word, but may virtually be regarded as such, bearing in mind the school of thought (to use a hideous modern term) to which they belonged. Two or three of those mentioned, such as Thales, Aristotle, and Hipparchus, were giants in science, comparable with the Humboldts and Herschels of the present century. This remark is peculiarly true of Hipparchus. The work which he performed really laid the foundations for the science of exact astronomy as distinguished from mere star-gazing.

The labors of Hipparchus were as varied as they were important. He discovered the Precession of the Equinoxes; was the first to use Right Ascensions and Declinations; probably invented the stereographic projection of the sphere; suspected that inequality in the moon's motion afterwards discovered by Ptolemy and known as the Evection; calculated eclipses; and formed the first regular catalogue of stars in consequence of having observed a temporary star burst forth in 131 B. C.

After the Christian Era the first illustrious name which appears on the pages of Astronomical History is that of Ptolemy of Alexandria, who lived from 100 A. D. to 170 A. D. He was both a writer and an observer. His great work was the celebrated *Μεγάλη Σύνταξις*, better known by its Arabian designation of *The Almagest*. This work contains, among other things, a review of the labors of Hipparchus; a description of the heavens, including the Milky Way; a catalogue of stars; sundry arguments against the motion

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* All the details of this are very well worked out in Mr. J. W. Bosanquet's *Messiah, the Prince*, 8vo, London 1869, p. 176, *et seq.*

of the earth, and notes on the length of the year. To Ptolemy we owe the discovery of the Lunar Evection, of the refractive properties of the atmosphere, and of the theory of the universe which bears his name.

It is a remarkable fact that, great as they were in almost every department of life, the Romans utterly failed as men of science. Perhaps it would be more accurate to say that they never tried their hands at physical science. This is the more remarkable when we remember how great they were in everything else. They were great lawyers, great engineers, great statesmen, great generals, great scholars, great poets, great even in medicine and surgery, but as sailors they obtained but moderate success, whilst for physical science they have left us nothing to show.

During the first half dozen centuries of the Christian Era, Alexandria may be regarded as having been the great center whence astronomical knowledge was disseminated throughout the world. But in 640 A. D., the Alexandrian school was broken up by the Saracens under Omar. In the following century, on the building of Bagdad by the Caliph Al-Mansar, that place became the great center of Astronomy, and continued to be such for 400 or 500 years.

The names which have come down to us in this conection are not numerous, but they are individually weighty. Grouping together various writers and workers under the general name of Arabic or oriental astronomers, we fall in with the following: Albategnius, Alfraganus, Al-Sufi, Ebn Yunis, and Abûl Wefa. Albategnius (*circa* 880 A. D.) may be regarded as the most distinguished astronomer between Hipparchus and Tycho Brahe. He discovered the motion of the solar apogee, corrected the value of precession and of the obliquity of the ecliptic as previously received, formed a catalogue of stars, and was the first to use sines and chords. Al-Sufi (d. 986 A. D.) was a distinguished Persian astronomer, who left behind him a very curious and interesting catalogue of stars, of which a translation into French was published by Schjellerup at St. Petersburg, in 1874. Ebn Yunis and Abûl Wefa both lived about the year 1000 A. D., and greatly developed the use of trigonometry. The latter is thought by some to have discovered the lunar inequality known as the Variation.

In 1079 we find a Persian astronomer of the name of Omar proposing to reform the Calendar by interpolating one day in every fourth year, but postponing to the thirty-third year the interpolation belonging to the thirty-second year. This would have produced an error of only one day in 5000 years, whereas the error arising in the Gregorian Calendar, adopted five centuries later, and which we now use, amounts to one day in 3846 years. The acuteness and research of this Persian philosopher may well excite our surprise and admiration.

The translation of Ptolemy's *Almagest* from Arabic into Latin, and the work done in Spain under the patronage of Alphonso X., King of Castile, indicate a movement of astronomical knowledge in a western direction over Europe. Accordingly the revival of letters, the invention of printing, and the taste for geographical research, cultivated especially by the English, the Portuguese, and the Spaniards, gave a great impulse to the exact sciences, and of course to astronomy amongst them. Hence it follows that work and workers multiply all over Western Europe, Germany taking the lead. The names of several of the famous men of the 16th and following centuries have already occurred in these pages in connection with particular items of work which they did, and with the results which they left behind. It may serve to fix some of these names in the mind of the reader if I enumerate a few of these men, and the centuries in which they died.

During the 16th century we have Regiomontanus, Copernicus, and Jordanus Brunus. The two first were working astronomers in the fullest sense, but Jordanus Brunus was rather a philosophical speculator on astronomical subjects than, strictly speaking, a working astronomer.

In the 17th century we find Tycho Brahe (d. 1601), Fabricius (d. 1616), Kepler (d. 1630), Galileo (d. 1642), Torricelli (d. 1647), Descartes (d. 1650), Gassendi (d. 1655), Hevelius (d. 1687), and C. Huygens (d. 1695). This century produced the first star atlas, by Bayer, a work which constituted a new departure in astronomical records; the refracting telescope; the discovery of spots on the Sun; the discovery of the satellites of Jupiter and of Saturn; observations of transits of Venus and Mercury; pendulum clocks;

the reflecting telescope; the discovery of the progressive transmission of light; and important investigations into the theory of the Moon. In 1666 Flamsteed commenced observations at Greenwich Observatory, and by so doing laid the foundations for that great and prolonged developement of scientific work there which inspired Bessel, half a century ago, to say that if all the books on astronomy in the world, and all the observatories in the world, except Greenwich, were destroyed by some great catastrophe of nature, the whole science could be re-constructed from its foundation by means of the knowledge gathered up and stored at the Greenwich Observatory.

All things considered, the 18th century did not show such an advance over the 17th as the progress of learning and the multiplication of telescopes might have led us to expect. Although Newton lived on till the year 1727, yet he belonged much more to the previous century, his immortal *Principia* having been published as far back as 1687. The first and greatest of the five generations of the Cassini family who have left their mark on French astronomy (Jean Dominique), though he died in 1712, yet performed all his important work (and very important it was) during the second half of the 17th century. The names which should be picked out and attached to the 18th century are only Leibnitz (d. 1716), who was more a mathematician than a scholar, Flamsteed (d. 1719), J. P. Maraldi (d. 1729), Halley (d. 1742), Bradley (d. 1762), La Caille (d. 1762), Ferguson (d. 1776), Pingré (d. 1796), and Le Monnier (d. 1799). A detailed inquiry into the circumstances of the 18th century discloses the general fact that the French came very much to the front as observers and mathematicians; that the Italians to a considerable extent, and the Germans almost entirely, receded into the background; whilst the progress of the English was chiefly in regard to practical matters, such as nautical astronomy and navigation, clocks, chronometers, and time appliances generally, and the construction of astronomical instruments of precision. But we must not pass away from the 18th century without noting two very important points of progress, the invention of the achromatic object-glass by Dollond, and Sir. W. Herschel's success in the manufacture of the reflecting telescopes, and the use of them.

The progress of astronomy during the 19th century has been so absolutely great, that it is quite hopeless to given even a sketch of it. However, nearly all the facts which belong to this century, together with the names of the men, and some of the dates, have already been brought before the reader in previous chapters. The only points which it seems possible to specify are: the great progress in the construction of large astronomical instruments, and the application of photography and of the spectroscope to astronomical purposes. But besides these general points, it is impossible not to be struck with the remarkable growth of the science in England in the hands of amateurs; in Germany in the hands of government establishments; and in America in connection with universities, colleges, and semi-public observatories endowed by deceased benefactors. These are three well-marked national differences of *modi operandi* on which a political astronomer would probably feel inclined to comment at length, and from which to draw moral lessons.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

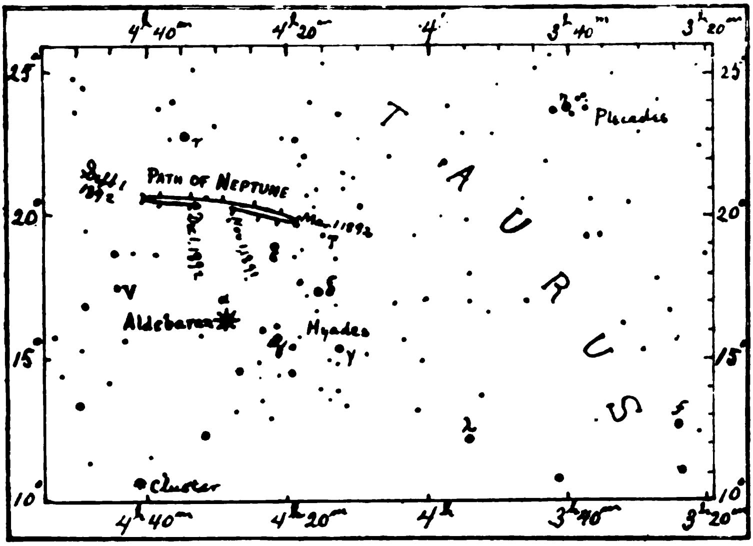
Mercury, having just passed superior conjunction will be for a few days too near the sun to be observed. During the latter half of November daylight observations of the planet may be obtained in the afternoon. During the second week in December, Mercury will be visible to the naked eye about an hour after sunset each evening. The planet will be at greatest elongation east of the sun, 20° 36′, Dec. 11 at 9 A. M.

Venus is moving slowly eastward from the sun, but is at the same time going south so that its position is becoming less favorable to northern observers. Venus and Mercury will be in conjunction, only 1° 15′ apart in declination, Dec. 5 at 9 A. M., central time.

On the afternoon of Oct. 9, the atmosphere being exceedingly transparent and steady, we turned our 16 inch telescope upon Venus, and were able, after half an hour of steady looking, to make out and to sketch some markings on the planet's surface. There was no doubt in the observer's mind that the markings seen were real, but to decide upon their exact form and sketch them correctly was almost impossible. The configuration most easily grasped was that of an irregular wheel, of about two-thirds the diameter of the planet, with four spokes meeting a little south-west of the center of the planet's disk. The magnifying power of the eyepiece used was 400.

Mars is not in position to be observed.

Jupiter is the brilliant star which everyone must notice now toward the south in the early evening. And a grand object he is in the telescope. We have spent several enjoyable hours with this planet during the past month. The new large red spot was on the central meridian of the planet Oct. 8 at 10^h 12^m central standard time. Mr. Denning gives the period of rotation of this spot as 9^h 55^m 18.3^s or about 23 seconds less than that of the great red spot (*Observatory*, Oct. 1891, p. 329). It is in the same latitude with the dark belt just south of the great red spot, and is perhaps just a darker part of that belt. It was first noticed by Mr. A. S. Williams in June, 1889. There are several white spots in this belt which have the same period of rotation. One of these was on Jupiter's central meridian at 8:30 P. M., Oct. 15, following the red spot by a little less than two hours.



MAP SHOWING PATH OF NEPTUNE THROUGH TAURUS.

In the "English Mechanic" for Oct. 2, Mr. Denning has an interesting list of rotation periods derived by different observers from markings in the southern hemisphere, which agree closely together but differ from that of the great spot. We quote them for the benefit of our readers:

h.	m.	s.		
9	55	17.6	Schröter.	A break in a dark streak, lat. 20° S.
9	55	20	Lohse.	Dark streak, lat. 30° S.
9	55	17.2	Schmidt.	A marking S. of the great S. belt.
9	55	23	Trouvelot.	Grey belt S. of red spot.
9	55	15	Trouvelot.	Grey spot in same zone as last.
9	55	21.6	Williams.	White spot in lat. 30° S.
9	55	11.8	Williams.	Dark spot ditto.
9	55	17.8	Williams.	Dark spot ditto.
9	55	17.9	Denning.	Short belt ditto.
9	55	18.2	Denning.	Bright spot ditto.

The mean of all these is 9^h 55^m 18^s.

The fine belt on the equator of the planet mentioned last month has been seen on several occasions since that time. It can be seen only when the definition is good; at times the white belt between it and the great southern dark belt seems full of very faint red markings.

Saturn is not in good position yet for observation, but every opportunity should be used to watch the gradual reappearance of the rings during this month. Saturn may be observed only in the morning from 3ʰ to sunrise.

Uranus is behind the sun.

Neptune comes to opposition, Nov. 29. He may be observed during the whole night, and is to be found, in the early evening, toward the east not far from the bright star Aldebaran in the constellation Taurus. The accompanying map shows the stars which are visible to the naked eye in that region of the heavens. The two groups of bright stars, the Hyades and the Pleiades will be easily recognized on any clear night. The fainter stars can only be seen on very dark nights. An opera glass will enable one easily to see all of these and more.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Nov. 25	17 11.0	− 25 12	8 39 A. M.	12 53.1 P. M.	5 07 P. M.
Dec. 5	18 13.4	− 25 45	9 05 "	1 16.3 "	5 27 "
15	18 58.6	− 24 03	9 02 "	1 21.9 "	5 42 "
			VENUS.		
Nov. 25	17 18.6	− 23 51	8 40 A. M.	1 00.9 P. M.	5 22 P. M.
Dec. 5	18 13.4	− 24 31	8 58 "	1 16.2 "	5 34 "
15	19 08.2	− 23 56	9 11 "	1 31.6 "	5 52 "
			MARS.		
Nov. 25	13 22.8	− 7 36	3 32 A. M.	9 05.7 A. M.	2 39 P. M.
Dec. 5	13 46.7	− 9 57	3 26 "	8 50.2 "	2 14 "
15	14 10.9	− 12 12	3 20 "	8 34.9 "	1 49 "
			JUPITER.		
Nov. 25	22 44.3	− 9 24	1 00 P. M.	6 25.6 P. M.	11 52 P. M.
Dec. 5	22 47.6	− 9 02	12 22 "	5 49.7 "	11 17 "
15	22 52.0	− 8 33	11 45 A. M.	5 14.7 "	10 44 "
			SATURN.		
Nov. 25	11 57.3	+ 2 33	1 27 A. M.	7 40.5 A. M.	1 54 P. M.
Dec. 5	11 59.9	+ 2 19	12 [illegible] "	7 03.8 "	1 16 "
15	12 01.9	+ 2 09	12 15 "	6 26.5 "	12 38 "
			URANUS.		
Nov. 25	14 06.3	− 12 17	4 35 A. M.	9 49.1 A. M.	3 03 P. M.
Dec. 5	14 08.4	− 12 28	3 59 "	9 11.9 "	2 25 "
15	14 10.3	− 12 38	3 22 "	8 34.5 "	1 47 "
			NEPTUNE.		
Nov. 25	4 25.0	+ 20 00	4 38 P. M.	12 05.4 A. M.	7 33 A. M.
Dec. 5	4 23.8	+ 19 57	3 58 "	11 25.0 P. M.	6 52 "
15	4 22.7	+ 19 55	3 17 "	10 44.4 "	6 12 "
			THE SUN.		
Nov. 25	16 04.7	− 20 49	7 10 A. M.	11 47.2 A. M.	4 24 P. M.
Dec. 5	16 47.8	− 22 25	7 21 "	11 50.8 "	4 20 "
15	17 31.8	− 23 18	7 30 "	11 55.4 "	4 20 "

Jupiter's Satellites.

	Central Time. h m				Central Time. h m		
Nov. 16	6 38	P. M.	II Oc. Dis.	Dec. 1	6 49	P. M.	III Oc. Dis.
17	7 30	"	III Ec. Re.		10 17	"	III Oc. Re.
	9 05	"	IV Ec. Dis.	2	6 58	"	II Tr. In.
18	4 27	"	II Sh. In.		9 43	"	II Sh. In.
	4 40	"	II Tr. Eg.		9 51	"	II Tr. Eg.
	7 18	"	II Sh. Eg.	4	6 32	"	IV Ec. Re.
20	9 20	"	I Oc. Dis.		6 38	"	II Ec. Re.
21	6 28	"	I Tr. In.	5	5 41	"	III Sh. Eg.
	7 49	"	I Sh. In.		10 19	"	I Tr. In.
	8 47	"	I Tr. Eg.	6	7 40	"	I Oc. Dis.
	10 07	"	I Sh. Eg.	7	4 48	"	I Tr. In.
22	7 25	"	I Ec. Re.		6 09	"	I Sh. In.
23	4 36	"	I Sh. Eg.		7 07	"	I Tr. Eg.
	9 12	"	II Oc. Dis.		8 27	"	I Sh. Eg.
24	6 17	"	III Oc. Re.	8	5 45	"	I Ec. Re.
	8 26	"	III Ec. Dis.	9	9 36	"	II Tr. In.
25	6 55	"	IV Tr. In.	11	9 16	"	II Ec. Re.
	7 05	"	II Sh. In.	12	4 27	"	III Tr. Eg.
	7 14	"	II Tr. Eg.		5 30	"	IV Tr. Eg.
	9 55	"	II Sh. Eg.		6 28	"	III Sh. In.
	11 06	"	IV Tr. Eg.		9 42	"	III Sh. Eg.
27	11 15	"	I Oc. Dis.	13	4 28	"	II Sh. Eg.
28	8 23	"	I Tr. In.		9 36	"	I Oc. Dis.
	9 44	"	I Sh. In.	14	6 45	"	I Tr. In.
	10 42	"	I Tr. Eg.		8 05	"	I Sh. In.
29	5 43	"	I Oc. Dis.		9 04	"	I Tr. Eg.
	9 20	"	I Ec. Re.		10 22	"	I Sh. Eg.
30	5 11	"	I Tr. Eg.	15	7 40	"	I Ec. Re.
	6 31	"	I Sh. Eg.				

Configuration of Jupiter's Satellites at 7 p. m., for an Inverting Telescope.

Dec. 1	4 3 ○ 1 2	Dec. 12	3 4 ○ 1 2	Dec. 22	3 1 ○ 2 4
2	4 1 ○ 3 ♃	13	3 4 2 1 ○	23	○ 3 2 4 ♃
3	2 4 ○ 1 3	14	4 3 2 ○ 1	24	2 ○ 1 3 4
4	1 ○ 2 4 3	15	4 3 ○ 2 ●	25	1 2 ○ 3 ♃
5	3 ○ 1 2 ♃	16	4 1 ○ 2 3	26	○ 3 1 2 4
6	3 2 1 ○ 4	17	4 2 ○ 1 3	27	3 ○ 1 4 ♃
7	3 2 ○ 4 ♃	18	4 1 ○ 2 3	28	3 2 ○ 1 4
8	3 ○ 1 2 ♃	19	4 ○ 1 2 ♃	29	3 4 1 ○ 2
9	1 ○ 2 3 4	20	3 1 2 4 ○	30	4 ○ 3 2 ♃
10	2 ○ 1 3 4	21	3 2 ○ 1 4	31	4 2 ○ 1 3
11	1 ○ 4 3 ♃				

Approximate Central Times when the Great Red Spot passes the Central Meridian of Jupiter.

	h	m			h	m			h	m	
Nov. 16	3	52	P. M.	Nov. 26	2	08	P. M.	Dec. 6	10	20	P. M.
17	9	39	"	27	7	55	"	7	6	11	"
18	5	31	"	28	3	47	"	8	11	58	"
19	11	18	"	29	9	34	"	9	7	49	"
20	7	09	"	30	5	25	"	10	3	41	"
21	3	00	"	Dec. 1	11	12	P. M.	11	9	28	A. M.
22	8	47	"	2	7	04	"	12	5	19	"
23	4	39	"	3	2	55	"	13	11	06	"
24	10	26	"	4	8	42	"	14	6	57	"
25	6	17	"	5	4	33	"	15	2	49	"

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.	$0^h\,52^m\,32^s$
Decl.	$+81^\circ\,17'$
Period	$2d\,11^h\,50^m$
Nov. 16	5 P. M.
19	5 A. M.
21	5 P. M.
24	5 A. M.
26	4 P. M.
29	4 A. M.
Dec. 1	4 P. M.
4	4 A. M.
6	4 P. M.
9	4 A. M.
11	3 P. M.
14	3 A. M.

ALGOL.

R. A.	$3^h\,01^m\,01^s$
Decl.	$+40^\circ\,32'$
Period	$2d\,20^h\,49^m$
Nov. 17	2 A. M.
19	10 P. M.
22	7 P. M.
25	4 P. M.
Dec. 4	6 A. M.
7	3 "
9	midn.
12	9 P. M.
15	6 P. M.

R CANIS MAJ.

R. A.	$7^h\,14^m\,30^s$
Decl.	$-16^\circ\,11'$
Period	$1d\,03^h\,16^m$
Nov. 16	8 P. M.
17	11 P. M.
19	3 A. M.
20	6 "
24	8 P. M.
25	11 "
27	3 A. M.
28	6 "
Dec. 3	9 P. M.
4	midn.
6	4 A. M.
11	9 P. M.
12	midn.
14	3 A. M.
15	6 A. M.

S ANTLIÆ.

R. A.	$9^h\,27^m\,30^s$
Decl.	$-28^\circ\,9'$
Period	$0d\,07^h\,47^m$
Nov. 15	2 A. M.
19	7 "
20	6 "
21	6 "
22	5 "
23	4 "
24	4 "

S. ANTLIÆ, CONT.

Nov. 25	3 A. M.
26	2 "
27	2 "
30	7 "
Dec. 1	7 "
2	6 "
3	5 "
4	5 "
5	4 "
6	3 "
7	3 "
8	2 "
12	7 "
13	6 "
14	6 "

Y. CYGNI.

R. A.	$20^h\,47^m\,40^s$
Decl.	$+34^\circ\,15'$
Period	$1d\,11^h\,57^m$
Nov. 18	11 P. M.
21	11 "
24	11 "
27	11 "
30	11 "
Dec. 3	11 "
6	10 "
9	10 "
12	10 "
15	10 "

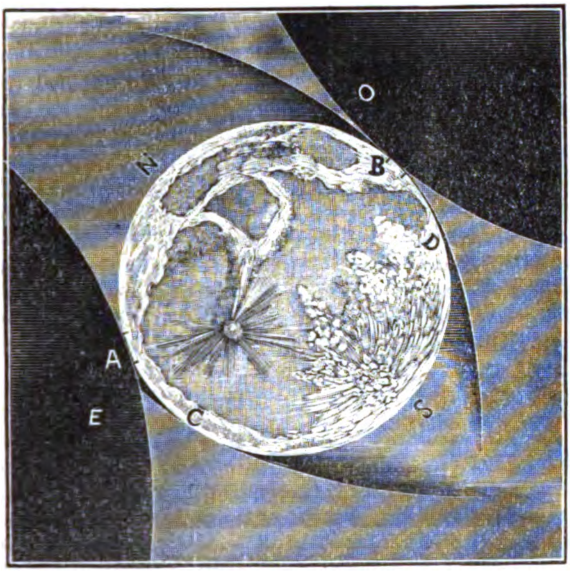
Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m
Nov. 17	139 Tauri	5.3	18 32	95	19 27.8	312	0 56
Dec. 7	τ^1 Aquarii	5.8	8 22	147	Star 0′.9 S. of moon's limb.		
7	τ^2 Aquarii	4.1	9 15	92	10 5.6	205	0 51
9	14 Ceti	6.0	11 28	341	11 42.4	314	0 14
9	15 Ceti	6.8	12 7	74	13 3.0	229	0 56
10	μ Piscium	5.0	12 35	37	13 29.5	269	0 55
13	56 Tauri	6.0	13 58	167	Star 0′.9 S. of moon's limb.		
13	κ^1 Tauri	4.7	16 15	80	17 12.4	266	0 57
13	κ^2 Tauri	6.3	16 16	100	17 11.2	245	0 55
14	118 Tauri	5.7	17 40	67	18 31.0	293	0 51

Phases and Aspects of the Moon.

	Central Time.	d	h	m	
Last Quarter	Nov.	23	2	26	A. M.
Apogee	"	25	2	48	P. M.
New Moon	Dec.	1	5	45	A. M.
First Quarter	"	8	11	13	A. M.
Perigee	"	11	12	6	P. M.
Full Moon	"	15	6	53	A. M.

Total Eclipse of the Moon Nov. 15, 1891. We refer our readers to our last number for the data concerning this eclipse, chart of the stars in the moon's path, and the list of occultations. The moon will enter the penumbra of the earth's shadow at $3^h\ 36^m$ central standard time. This phase of a lunar eclipse, is, however, never noticeable. The moon will touch the umbra or the dark part of the shadow at $4^h\ 35^m$. For some time before this a faint shading will have been noticed creeping upon the east side of the moon, but at this moment it will become much darker at the edge. The accompanying cut will show at what point of the moon's limb the shadow must be looked for. The first contact will be at *A*. *D* indicates the last point of the moon to be covered as it enters wholly within the shadow at $5^h\ 37^m$. *C* marks the points which will first emerge from the shadow at the end of totality, at $7^h\ 01^m$; and *B* the point which is last to leave the umbra at $8^h\ 03^m$. For a few minutes after this the penumbral shadow will still be visible, but this will fade out long before the end of the eclipse at $9^h\ 03^m$ central time.



Minor Planets. Notices of the discovery of the minor planets are resumed from the May issue of this journal:

No. 310, discovered by Charlois May 16, 1891, Mag.
No. 311, discovered by Charlois June 11, 1891, Mag.
No. 312, discovered by Palisa Aug. 14, 1891, Mag.
No. 313, discovered by Charlois Aug. 28, 1891, Mag. 12.
No. 314, discovered by Palisa, Aug. 30, 1891, Mag. 11.
No. 315, discovered by Charlois, Sept. 1, 1891, Mag. 13.
No. 316, discovered by Palisa, Sept. 4, 1891, Mag. 13.
No. 317, discovered by Charlois, Sept. 8, 1891, Mag. 13.
No. 318, discovered by Charlois, Sept. 11, 1891, Mag. 11.
No. 319, (probably); by Palisa, Sept. 12, 1891, Mag. 13.
No. 320, (probably); Palisa, Oct. 15, 1891, Mag. 12.

Reappearance of Saturn's Rings. Saturn has been observed with the 15½-inch equatorial telescope of the Washburn Observatory on every clear morning for some weeks past, the observations being usually made by Mr. S. D. Townley, but occasionally by myself. The atmospheric conditions have been rather unfavorable, but on the morning of Friday, Oct. 16, the seeing was good, and the planet was carefully examined by both observers, neither of whom could detect any trace of the rings except the fine dark shadow projected upon the disk of the planet.

Upon the next clear morning, Tuesday, Oct. 20, the planet was again examined under fairly good atmospheric conditions by both observers, who agree that no trace of the rings could be seen at 6^h 50^m local sidereal time, the zenith distance of the planet being then 75°. Tweuty minutes later, the seeing having improved somewhat, owing to the increased altitude of the planet, Mr. Townley saw the ring extending out from *each* side of the planet as a very faint line of light, seen by glimpses and with difficulty, but certainly. At 7^h 30^m, although the twilight had become quite bright, I saw the ring on each side of the planet faint and difficult but steadily visible except at intervals of temporary bad seeing. The ring was a trifle more conspicuous on the preceding than on the following side of Saturn. A magnifying power of 145 diameters was used in all the observations.

Washburn Observatory, Oct. 20, 1891. GEO. C. COMSTOCK.

COMET NOTES.

Comet d 1891 (*Barnard Sept. 27, Tempel-Swift?*) Two new comets have been discovered since our last issue, both by E. E. Barnard at the Lick Observatory. The first was discovered on the evening of Sept. 27, in the northwest corner of the constellation Aquarius. Sept. 28.6986 GR. M. T. its position was R. A. 20^h 53^m 45.4^s; Decl. —1° 22′ 36″. This is probably the periodic comet Tempel-Swift, which was expected not far from that part of the heavens. The error's of Bossert's ephemeris, + 15^m in R. A. and + 3° in Decl., are larger than was to be expected, yet if one plots the predicted path of the Tempel-Swift comet upon squared paper, together with the observed path of Barnard's comet *d* 1891, the similarity is very striking. No elements computed from the recent observations have yet reached us. The comet is very faint, but increasing in brightness. It is almost round with a slight condensation in the center. On Oct. 21 it was just visible in the 5-inch finder of our 16-inch telescope. Its position at 7^h 55^m P. M. central time was approximately R. A. 21^h 04^m 02^s; Decl. +3° 32′. During November this comet will move northeast from Equuleus through Pegasus. We continue the ephemeris of the Tempel-Swift comet which may be used for finding the new comet by subtracting about 14^m in R. A. and 4° in Decl.

		App. R. A.			App. Decl.		log Δ	Light.
		h	m	s	°	′		
Nov.	19	22	52	01	+21	50	9.3247	18.92
	23	23	16	23	+24	11	9.3159	19.56
	27	23	43	49	+26	24	9.3119	19.68
Dec.	1	0	13	53	+28	20	9.3138	19.19
	5	0	45	45	+29	49	9.3223	18.06

Comet e 1891 (*Barnard Oct. 2*). The second comet was discovered by Mr. Barnard on the morning of Oct. 3 in R. A. $7^h\ 31^m\ 24^s$; Decl. — 27° 54′, and is described as a bright comet. It was moving rapidly southward, and is already out of range of northern observers. The comet's position was determined at Lick Observatory on Oct. 3, 4 and 5, and an orbit was at once computed by Mr. Campbell and distributed by telegraph, so that it reached observers in America on the evening of Oct. 6. The following are Mr. Campbell's elements and ephemeris:

$$\begin{array}{l} T = \text{Nov. } 8.75 \text{ GR. M. T.} \\ \left.\begin{array}{l} \omega = 262^\circ\ 06' \\ \text{☊} = 215\ \ 38 \\ i = \ \ 75\ \ 50 \end{array}\right\} \text{Mean Eq. 1891.0} \\ q = 1.0166 \end{array}$$

Gr. Midnight.	R. A.	Decl.	Light.
	h m s	° ′	
Oct. 6	7 52 00	— 32 52	1.05
10	8 18 00	— 38 18	
14	8 46 20	— 43 08	
18	9 16 44	— 47 14	1.05

Wolf's Periodic Comet is moving southwest through the constellation Eridanus, which is the next southwest of the familiar constellation Orion. The comet is slowly receding from the earth and sun, so that its light is diminishing, but we will be able to follow it for several months yet.

Encke's Comet is out of view behind the sun.

Ephemeris of Comet 1891 (*Wolf's Periodic Comet*).

(Continued from page 421.)

	App. R. A.	App. Decl.	log Δ
	h m s	° ′	
Nov. 13	4 35 55	— 8 06.9	
14	35 20	8 30.5	9.9207
15	34 45	8 53.4	
16	34 08	9 15.7	9.9249
17	33 31	9 37.2	
18	32 53	9 58.1	9.9295
19	32 14	10 18.2	
20	31 35	10 37.6	9.9344
21	30 56	10 56.3	
22	30 16	11 14.2	9.9397
23	29 36	11 31.5	
24	28 55	11 47.9	9.9452
25	28 15	12 03.6	
26	27 35	12 18.6	9.9511
27	26 55	12 32.8	
28	26 15	12 46.3	9.9573
29	25 36	12 59.0	
30	24 57	13 11.0	9.9637
Dec. 1	24 19	13 22.3	
2	23 41	13 32.8	9.9704
3	23 04	13 42.6	
4	22 28	13 51.7	9.9773
5	21 52	14 00.2	
6	21 18	14 07.9	9.9844
7	20 45	14 14.9	
8	20 13	14 21.3	9.9917
9	19 42	14 27.0	
10	19 12	14 32.1	9.9992
11	4 18 43	— 14 36.5	

NEWS AND NOTES.

Maine is very much like Minn. when carelessly written, hence our correspondents will please write the name or abbreviation of our state plainly and so avoid the delay or loss of letters. It is also noteworthy that there are almost as many Northfields in the United States as there are separate states, and it is sometimes true that letters have visited as many as *three* different Northfields in as many different states before reaching the right one.

Quite large space is given to our leader in this issue because the paper is deemed to be one of the most important that can be brought to the attention of our readers, on account of the careful and full statement of principle and method in the use of the spectroscope. We do not know of any source of practical information better adapted to the wants of the student and worker with the spectroscope than this article furnishes.

In our last issue, Wm. H. Knight, whose present address is Los Angeles, California, published a pretty full list of the telescopes of the United States whose apertures were 4 inches or greater. This heavy task was undertaken some time ago at our urgent request, Mr. Knight very well knowing what it meant. He did not expect to get in the first publication all the telescopes that should be in the list, but it was thought that such a provisional list would serve to call the attention of those having instruments not in the list and that they would most likely report them, especially if urged to do so in order to secure an accurate table. We have already received many letters giving just the information desired as far as it goes. Now, if every reader of these pages, will take the trouble to look over the table of telescopes published in the October MESSENGER, and inform us or him of errors or omissions in it, we are sure thatMr. Knight will esteem it a favor in carrying out a piece of useful work which he has undertaken that involves labor and personal expense.

Note on the August Meteors. The August meteors were more numerous this year than at any previous return that I have witnessed, judging from recollection alone.

They first became noticeable about July 27th, and were persistent at least until August 12th, the maximum occurring, August 10th.

On August 9th, one of these meteors of remarkable brilliancy was observed at 15^h in the south. Its path, about 5° long, was vertical. It appeared 4° or 5° east of Alpha Capricorni. The explosion of this object illuminated the mountain for a moment almost as bright as day. It was many times brighter than the maximum light of Venus. A distant trail remained visible to the eye for about one minute. This was examined with the comet seeker, and was seen to twist and writhe into a serpentine form, with numerous bright condensations. It was watched for some time. In passing over the stars, it seemed to have no effect upon either the intensity or steadiness of their light. (In speaking of this meteor train, I would like to call attention to a paper of mine upon the subject of meteor trains and high atmospheric currents, which appeared in THE SIDEREAL MESSENGER, Vol. I., pp. 174-180, since the subject has been recently brought up again in THE MESSENGER (see No. 87 for August, 1890, p. 329).

On the 10th, before midnight, the meteors seemed unusually frequent. Many appearing as bright as 2nd or 3rd magnitude stars. On this night, a continuous count from 14^h 15.6^m to 14^h 49.0^m, Mt. Hamilton M. T. showed 95 meteors: all but seven of these belonged to the Perseid radiant. This gives an hourly rate of 160 for the observed Perseids. The eyes were kept fixed on the place of α Persei, and only about one third of the sky was under observation. The majority of the meteors were faint. The display was intermittent. From one to two minutes at a time no meteor would be seen; this quiescence would be followed by a quick succession of meteors, as many as three being seen at once.

The peculiarities were. Intensity of light; rapidity of motion; shortness of path—those seen averaging 4° to 5°. Each left a train covering the entire path and persistent for nearly a second. Meteors with long trains were seen in the west before and after this. During the count, there did not seem to be so many bright meteors as were visible in the first part of the night, and at 16^h there seemed to be a still less number.

On the 11th, fewer still were noticed and a count from 13^h 2^m to 13^h 15^m gave 23 meteors, or at the rate of 106 per hour; they were still seen coming from the radiant as late as 16^h 15^m.

On the 12th a few were seen belonging to this shower.

The 13th was cloudy. E. E. BARNARD.

Mt. Hamilton, 1891, August 14.

Distribution of the Moon's Heat. Last month we called attention to the prize essay on the distribution of the moon's heat, and its variation with the phase, by Frank W. Very, Allegheny Observatory, Pa., but for want of space we could only make the merest reference to it. As then stated the essay was presented to the Utrecht Society of Arts and Sciences, and obtained the prize in the General Assembly of the Society, held at Utrecht on the 2d of July, 1890. The problem of the variation of the moon's radiant heat with the phase, is attacked, in this paper, by Professor Very, by the aid of an extremely sensitive apparatus known as the bolometer and by a novel method. The plan of work was to form an image of the moon of a little more than one and one-fourth inches in diameter, by means of a concave silvered-glass reflector of 11.93 inches diameter, and 10.29 feet focal length, and to measure, not the heat of the whole of this image, but only that in a limited portion of it, from one-twenty-fifth to one-thirtieth of the area of the apparent disc. The observation being repeated at different points on the moon's disk, and at different phases, gives the material for a series of maps showing the distribution of the heat of this image, and by summation the total heat, at each of the several epochs from the first to the last quarter of the moon.

The sensitive surface of the bolometer was about three-fourths of a square inch, which was covered by diaphragm of white card pierced by a central circular aperture of a little more than one-fifth of an inch in diameter. Connected with the bolometer is a siderostat by which the image of the moon is kept on the white card, the image being bright enough to show much of the detail of the lunar surface, so that setting of the sensitive surface of the bolometer on any part becomes easy and definite. The heat from that fractional area of the moon's surface that falls on the sensitive face of the bolometer is measured by the deflection of the magnetic needle of a sensitive galvanometer in metallic connection with it. The apparatus which Professor Very used in this work was sufficiently delicate to show a deflection of the needle through nearly 100 millimeter divisions on the galvanometer scale when a small area near the center of the full moon was exposed to the bolometer for measurement. The constancy of an instrument so delicate as this would naturally suggest itself to the reader's mind, and information on this point is given in the early part of the paper.

A series of ten observations of the radiation from a boiling Leslie's Cube, with this bolometer, gave a mean deflection of 342.4 divisions ± 0.6 divisions where the probable error amounted to less than 0.2 of one per cent. In general it seems, that this instrument sensitive as it is, is capable of giving repeated measures on a source of unchanging radiation with an error less than one per cent. of the quantity measured. Of course, it is not meant by this that the constant now referred to does not change in time, that must be expected, but, in this particular the instrumental errors are known, or eliminated by a method of standardizing. It may be added here that the bolometer is not primarily for absolute measurement, yet its indications may be transformed into units of ordinary measure whenever desired. For example, in this research one millimeter division of the galvanometer scale corresponded approximately to a radiation of about 0.000004 small calories per minute on the face of the bolometer, of which only about one-sixth, or 0.0000007 calories was retained by the bolometer strips. By small calorie is doubtless meant the amount of heat necessary to raise the temperature of one gram of water one degree centigrade. The "solar constant" of heat thus figured would be the number of these *small* calories received per square centimeter of solar surface in a minute of time.

This paper next discusses the geometrical representation of distribution of heat in the lunar image, and an algebraic form of four terms is derived, the first representing the varying radiation from the bright path of the moon which it is desired to measure, another, the radiation from space which always has the negation sign and other terms to represent radiations of parts of the instrument and the dark part of the lunar disc. In the use of this mathematical expression it is a profitable study to see how the author applies its terms to obtain an independent measure of the heat radiation of parts of the lunar surface desired. The astronomical, meteororogical and instrumental data used in this work extend over a period from Jan. 12, 1889 to April 15, 1889. From a reduction of these, seven maps were prepared showing heat contours of equal temperature on the lunar surface for particular phases, the whole disc of the moon being represented by a circle about 6 inches in diameter. The following final table is of peculiar interest:

Phase-angle from full moon	Total heat	Percentage of total heat at full	Light according to Zollner	Heat according to Lord Rosse
−100°	50	14.9		11.4
− 90°	63	18.8		15.4
− 80°	75	22.3		21.9
− 70°	92	27.4	14.4	29.4
− 60°	116	34.5	22.3	37.1
− 50°	153	45.5	32.1	46.2
− 40°	200	59.5	43.7	56.4
− 30°	259	77.1	56.8	68.6
− 20°	310	92.3	70.9	83.6
− 10°	334	99.4	85.5	97.9
− 0°	336	100.0	100.0	100.0
+ 10°	315	93.8	85.5	91.4
+ 20°	282	83.9	70.9	80.5
+ 30°	246	73.2	56.8	69.3
+ 40°	211	62.8	43.7	58.4
+ 50°	180	53.6	32.1	47.9
+ 60°	151	44.9	22.3	38.3
+ 70°	126	37.5	14.4	32.3
+ 80°	104	31.0		25.5
+ 90°	84	25.0		19.8
+100°	67	19.9		13.7

The author's final words fittingly close this review:

"This table shows conclusively, first, that visible rays form a much larger proportion of the total radiation at the full than at the partial phases, the maximum for light being much more pronounced than that for the heat.

Next, as has been foreseen from the eccentricity of the heat areas, their greater extension toward the western limb, and the greater steepness of the sunset than of the sunrise gradient, the diminution of heat from the full to the third quarter is slower than its increase from the first quarter to the full.

Finally, there is a fair agreement between these results and those of Lord Rosse which extends even to some minor details such as the attainment of the highest heat a little before the full. This deviation of the maximum from strict symmetry is probably real, and is perhaps attributable to the greater proportion of bright areas in the western half of the moon, the brighter parts, as we have learned, giving a larger radiation under a high sun, than the dark. It is possible that this effect is reversed with a low sun, the dark parts radiating more than the bright, and that the greater heat of the lunar afternoon may be due less to a retention of heat, than to the greater darkness of the region exposed to view at that time. That there must be some retention of heat by the substances of the lunar surface, cannot, however, be doubted in view of the contrast in the heat of polar and equatorial regions under identical illumination, which has been described in connection with the observations of April 15th.

Previous investigations have dealt with the heat produced by the radiation from the entire moon, but the method pursued in the present research has been to study the thermal effect of small portions of the lunar disc, thereby eliciting many new facts concerning the distribution of heat in the moon and its variation through the lunar day for each of these circumscribed regions. The relative radiations of dark and bright surfaces under high or low sun, and of high and low latitudes, in the lunar morning, afternoon, or noon, have thus been measured, and the accompanying maps present (it is believed for the first time) a picture of the distribution of heat on a planet, where seasons and the climatic influences of land and water must be unknown."

Students' Astronomical Observatory of the State University of Iowa. The following description of the Students' Astronomical Observatory recently established at the State University of Iowa, has been furnished by Professor L. G. Weld, under whose direction the new observatory has been erected and equipped:

The Students' Observatory building is situated upon the University Campus and comprises an upright twelve feet square, and a wing ten by twelve feet. The upright, which accommodates the equatorial, is surmounted by a turret twelve feet in diameter, which rolls with great ease on ten *lignum vitæ* balls. This turret is of the cylindrical form and is covered with galvanized iron.

The wing, in which the transit instrument is mounted, is provided with a clear opening twenty inches wide from north to south.

The building rests upon a solid stone foundation and is heavily framed of thoroughly seasoned and dressed timbers.

Both equatorial and transit are mounted upon insulated piers of stone and brick laid in cement and sunk six feet into the ground.

The Grubb equatorial telescope, which has been moved from the old brick Observatory to this more convenient location, is of five inches aperture, seventy-seven and one-half inches focal length, and is furnished with a driving clock, circles, etc. It has recently been refinished throughout by Mr. M. E. Kahler of Washington. While in his hands the objective was "re-worked," a position micrometer with illumination by electric light, a helioscope, a direct-vision spectroscope, and a diagonal prism were added, and the slow motions and clamps brought down to the eye end. The mounting is very rigid and the telescope is, for its size, a thoroughly efficient instrument.

The transit, by Wm. Würdemann of Washington, is of one and seven-eighths inches aperture and twenty inches focal length. It is an excellent little instrument.

Time is kept by a Seth Thomas clock and a Bond chronometer.

A four-inch portable equatorial by Fitz, and a prismatic sextant and artificial horizon by Pistor and Martins, also belong to the Observatory.

A small chronograph has been ordered from Fauth & Co.

Our object has been simply to establish an Observatory which will meet the requirements of students in astronomy. L. G. W.

Iowa City, Iowa, October 8th, 1891.

Black Transit of Jupiter's III Satellite. On the evening of Sept. 24, I witnessed what appeared to be a "black transit of Jupiter's III Satellite.

L. G. W.

Erratum. On page 407, No. 98 of THE MESSENGER, in place of v read r, and in place of r read v.

Professor Frank H. Bigelow of the Nautical Office, Washington, D. C., has been assigned to the study of cosmical and terrestrial magnetism, in its relations to meteorology, in connection with the U. S. Weather Bureau, Department of Agriculture, Washington. His work will be facilitated by the aid of publications on the subjects of solar and terrestrial physics and meteorology. Professor Bigelow will be a strong man in this new place.

Regarding my list of telescopes published in your October issue I beg to submit the following criticism made by Mr. J. A. Brashear.

. . . "First, you say the Clarks are now grinding an object glass of 40 in. Now the facts are, there has never been any contract made for the glass and only one disc is in the shop of the Clarks—in the box as it came from Mantois. Only $50,000 has been subscribed and that, I think, on condition that the balance to build the mounting, Observatory, and road to the top of Mt. Wilson, estimated to cost $500,000 [should be subscribed]. . . . Then they might have to wait ten years for the mate of the disc, for Mantois told me in Paris when I saw the lump of glass from which the disc was made that it was a stroke of good fortnne to get such a disc, but while he hoped to get a mate to it, it was a matter of great uncertainty."

"Second, you quoted Smithsonian Physical Observatory as having a 20 in. Grubb Refractor while the facts are the instrument was a 20 in. Grubb Siderostat, the great mirror of which (flat) was made at our place. Proffessor Langley has a 20 in. mirror of 90 ft. focus and a 20 in. mirror of one metre focus which were made at our place for special work in Professor Langley's determination of unselective absorption of solar energy."

Mr. Brashear also calls my attention to the fact that I did not include in my list some telescopes with upwards of 6 in. aperture. But the heading of my table "Some Telescopes" shows that I was aware that my list was not complete. WM. H. KNIGHT.

A Non-Interfering Break-Circuit for Clocks. In the application of the electric break-circuit to clocks not provided with the gravity escapement, there appears to be some prejudice, on the score that it may slightly interfere with the performance of the clock, and that it is not desirable for the clock itself to do anything in the way of "key manipulating." The following arrangement experimented with by the writer appears to do away with this objection. A microphone is made, consisting of a piece of arc amp carbon about four inches long, and pointed at the ends, loosely held between two small pieces of carbon with recesses to contain the ends of the larger piece, the whole to be mounted on a base of seasoned wood and fastened to the side of the interior of the clock case as high as convenient, the higher the better, and with the longer carbon vertical. Some form of gravity battery is then connected up with the microphone and a relay; and great care is to be taken that any splices in the wire are well scraped twisted and soldered, and further that all connections are firmly made.

The armature of the relay is to be so adjusted that it approaches the magnet cores as closely as possible without touching, say one-thousandth of an inch; and its play must be *vanishingly* small. The adjusting spring is now to be strained up, and if the relay cannot be made to break with the clock beat, the battery must be diminished by a cell, or a stronger spring used; in any case quite a tension on the spring is necessary.

All the conditions being properly fulfilled it will be found that the relay breaks in exact unison with the beats of the clock, and this fact may be taken advantage of to compare for difference of personal equation in the two cases where the eye and ear and chronograph methods are used. It is to be noted that no part of the line wire is to be outside of the Observatory, or subject to any possible swaying contact, and it would be well for all wires to be covered and paraffined. F. G. Blinn.

East Oakland, California.

Origin of Comets. In a recent letter, W. H. S. Monck of Dublin, Ireland, calls attention to some points of interest about the origin of comets. It will be remembered that Professor Newton of Yale University, some time ago, examined the theory of Laplace in regard to the origin of comets, and decided that that noted author was right in concluding that these erratic bodies are visitors from extended space, instead of being members of the solar family in the matter of origin as was claimed by Kant's theory. One particular fact that weighed in this judgment was the large preponderance of those comets whose orbits have high inclinations as compared to the ecliptic. Mr. Monck remarks that on examining Kleiber's orbits this preronderance disappears, and the theory of Kant seems to be indicated by the meteoric orbits if computers have correctly represented them.

Comets Swift and Wolf. Under date of October 14, E. E. Barnard of Lick Observatory writes: "I have secured some good positions of Swift's Comet which I rediscovered Sept. 27. It was so far from its ephemeris place, that, at first, I was uncertain whether or not it was the long-expected comet for which I had made careful search for over three months." Mr. Barnard also speaks of observations of Wolf's Comet as it passed over some of the stars of the Pleiades. He says Mr. Burnham's measures show a slight change in $\Delta\delta$, in measuring the difference of declination of 21 Asterope and 22 Asterope at nearest approach by the aid of the 36-inch refractor. Does this indicate a refraction of the star's light as it passes through the comet?

Fog Bow. On the morning of August 31, eight minutes before seven o'clock, a fog bow was seen at Northfield, Minn. Its highest point was nearly west and about 30° in altitude, and its general width was about 5°. There was a little of the reddish brown color near the horizon on the outer edge. Ten minutes later the whole bow was brighter and better defined. On the inside of the curve was a dark band about three degrees wide. There were trees 300 feet away in the direction of the horizon, and the color was seen on them for the whole width of the bow which was at this time about eight degrees, apparently, and a blueish shade was the color of the inner border, while the outer was a stronger red. It was also noticed that this belt of color could be traced on the ground, at most favorable times, from the foot of the bow on each side nearly to the point where the observer stood. But a small portion of the circle was wanting;

a part of it appeared to lay on the ground, the remainder on the haze of the sky, and the observer in the circumference. The cause of the bow was the light of the sun shining through a fog (east of the observer) rising rapidly from a broad valley in that direction. The unusual thing about it was the appearance of the observer on the circumference of the bow, when in fact he must have been at the center of the real phenomenon.

Mr. Blinn's Mode of Time-Signals. Elsewhere will be found a suggestive mode of communicating clock-beats to electrical lines without any manner of actual contact with the clock train. There is, doubtless, more in the suggestion than appears at first sight, for Mr. Blinn has tried it, and therefore knows whereof he speaks. The fact that delicate adjustment seems necessary to ensure constancy of the service may not prove so great a drawback after all when the apparatus is well made. Time keepers will look into this suggestion with interest.

The Annual Parallax Oeltzen 11677. Dr. Julius Franz, of Königsberg has favored us with a copy of his work on the annual parallax of Oeltzen 11677 determined by the aid of Königsberg heliometer and the results, published only a short time ago, are:

$$\pi = + 0''.10 \pm 0''.01$$

In light years 29.6 to 36.2

Yale University 28-inch Refractor. Some of our readers may wonder that Mr. Knight's list of telescopes should credit Yale University with a refracting telescope of 28 inches aperture, when in fact that institution has no such telescope at the present time. The statement of the case is substantially this: Fifteen years ago, the late Professor Lyman purchased a 28-inch disc by Chance, to be used in making a 27-inch lens, and that disc is now said to be in Clarke's safe, Cambridgeport, but the other disc to match it has never been purchased, nor has work on the telescope mounting ever been ordered so far as we know. Professor Lyman expected Mr. Winchester to furnish the telescope, but that friend of the University died without doing more than to authorize the purchase of the single disc. In the light of these facts, it does not seem fair to credit Yale University with a telescope larger than that of Princeton, University of Virginia, or Harvard College Observatory. It certainly was not Mr. Knight's intention to do this injustice, or ours in printing the table. There is possibly a grain of excuse for us in not looking up this matter more carefully beforehand, when we remember that the 28-inch Yale telescope figures at the head of the list in Johnson's Encyclopedia, and in the list given in Newcomb's Popular Astronomy, it is named as "under construction" with the Lick and Pulcowa telescopes.

BOOK NOTICES.

College Algebra. By Webster Wells, S. B., Associate Professor of Mathematics in the Massachusetts Institute of Technology. Publishers, Messrs. Leach, Shewell & Sanborn, Boston and New York.

In 1890 Professor Wells published a college algebra, very complete in subject matter, and so far as noticed in a hasty review, in excellent arrangement for class use in college or school of technology. The first eighteen chapters of the book are arranged for the convenience of those who wish to review that part of algebra which precedes the subject of quadratics, and hence theoretical parts of the themes there treated are purposely omitted.

The book begins in formal way with the subject of quadratics treated in the ordinary way, after which is a good discussion of the theory of quadratics. Illustrative problems follow, and a fuller consideration of how the quadratic equation can be used to solve examples involving equations of higher degrees. The treatment of logarithms and their applications is prominent and useful for aid to the higher mathematics; so also is the subject of probability, continued fractions, series, determinants, and especially the theory of equations. There is also an interesting appendix giving a demonstration of the fundamental laws of algebra for pure, imaginary and complex numbers that will attract the attention of teachers of mathematics, and students curious to know something of the methods of reasoning and operations of imaginary numbers.

Recently this book has been bound, omitting the first eighteen chapters (the review part), presenting only the College Algebra proper. The publishers, as they always do, have done their part neatly and substantially.

An Introduction to Spherical and Practical Astronomy. By Dascom Greene, Professor of Mathematics and Astronomy in the Rensselaer Polytechnic Institute. Publishers, Messrs. Ginn & Co., Boston. pp. 150.

This new book deserves the attention of teachers of practical astronomy, and also that of students looking forward to extended study in the same branch. It will be found useful because it aims to give the essentials in principle and method concerning the more common operations in practical astronomy in so plain and direct a manner that a student without practice may easily start in this kind of work and soon gain confidence in himself and his mathematics so as to go on to higher works and more difficult topics, and master them independently. The first chapter is concerned with definitions and spherical problems which are to be performed by the general formulæ of spherical trigonometry applied to the celestial sphere. In adapting the formulæ to ready computation by logarithms, the neat expedient of the auxiliary angle is used in the same way as is done in the standard works on astronomy. The proof that the assumptions of these auxillary angles in a given case are consistent with the notation used, as exemplified in Article 36, pages 10 and 11, is very simple, neat and direct. The second chapter considers the conversion of time and the hour-angle. The relation of sidereal and mean solar time is well stated, and the precepts for the conversion of one kind of time into another, through the aid of auxiliary tables, is made so plain that the beginner will not be confused. So much can not be said of most texts in use for converting time in the Observatory. Chapter third discusses the transit instrument, giving a description of the instrument, its adjustments, and its uses in observation. In the latter part of this chapter, the correction for transit observations is given fully as it ought to be. The meaning of the terms of the formulæ is shown by a geometrical figure, and Bessel's, Hansen's and Mayer's formulæ are derived in a way to interest the reader and to give him clear understanding of the nature of instrumental errors and the method of measuring them. Chapter four treats of the sextant, and chapter five tells how to find time by this instrument as well as by the transit instrument. Then follow methods for finding the differences of longitude between two places by telegraph, transportation of chronometers, and by moon culminations, finding the latitude by six different ways; finding the azimuth of a given line, and a study of the figure and dimensions of the earth. In an appendix of thirty pages is found a statement of the method of least squares, and tables of refraction and for computing the reduction to the meridian. We are sure this book will fill a place of felt need, and it is commended on account of its merits.

Woodbridge School Essays Number One. Theoretical Astronomy. Dynamics of the Sun. By J. Woodbridge Davis. Published by Messrs. D. Van Nostrand Company, 1891. 156 pp. Quarto form.

We have been much interested in a hasty reading of number one of the Woodbridge School Essays in the line of theoretical astronomy. A want of time for it has prevented a careful study of this number, as was our choice under more favoring circumstances, yet we are pleased to give our impressions thus obtained.

The order of topics in this number is: Matter—Gravity—Heat; The Outlying Atmosphere; The Quiescent Atmosphere; The Solar Atmosphere; Planetary Atmospheres; Planetary Magnetism; Cometary Atmospheres and the Index.

Under the head of matter, gravity and heat, the author begins by assuming a free body in space supposed to consist of some mixture of solids, liquids and vapors with some quantity of heat. A spheroidal form, density, temperature, pressure, rigidity, and other conditions follow from the action of its own inherent forces.

From knowledge of these forces it is possible to form typical equations and discuss the varying conditions of this hypothetical body in a very direct and definite way, so that the reader may easily follow the development of the argument. This is done under five different forms represented by the letters A, *B*, *C*, *D*, *E*. As an illustration of the condensed form of the argument in its final statement we copy that belonging to *A*:

Dynamic Equilibrium—Progressive.

Vapor and mist descending.
Heat < Gravity.
$f''(r_0) > f'''(r_0)$
$[f''(r) > f'''(r)]_0^{-a}$; Condensation.*
$[f''(r) < f'''(r)]_{-a}^{-\infty}$; Limpidity.
r_0, m_1, g_0, increase.
r, v, m', Q', I, are negative.

The meaning of the letters above are respectively:

r_0, r, the absolute temperature of any concentric stratum of atmosphere.

f'', f''', are functions of r.

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* Limits are in values of time for conditions *A*, *C*, *D*, *E*; in values for distance *B*.

t, the time required for a particle to flow from the nucleus of the body to this stratum.

v, is the velocity of a particle of this stratum.

Q is the quantity of thermal energy expended in any time.

m_1, m' are respectively the mass of the nucleus, and the quantity of matter vaporized per second.

g_0 is acceleration due to gravity due to this stratum.

I is the quantity of thermal energy expended in molecular or atomic work.

This is intended only to give the merest outline of the way these important studies are carried forward by the author, and of course will be most interesting to those who are accustomed to the statement of argument in this way by mathematical symbols. We have not the space to consider the results reached by the author in these essays, but hope to give full statements of them later. We are sure this work will receive the prompt and deserved attention of scholars in various lines of science.

Pictorial Astronomy for General Readers. By George F. Chambers, F. R. A. S. Publishers: Messrs. Whitaker & Co., 2 White Hart Street, Paternoster Square, London, England. 1891. pp. 268. Price 4 shillings.

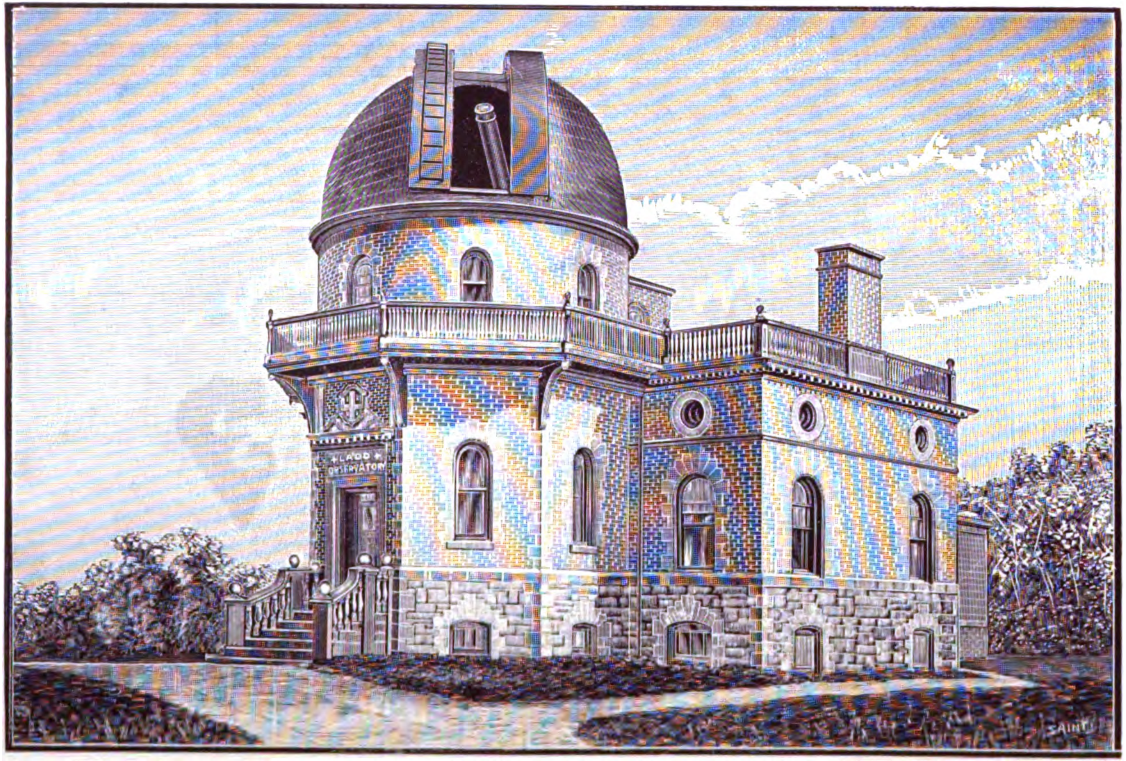
The writer of this new popular book in astronomy is too well known to our readers to need any formal introduction; and it does not seem strange that he should write such a book in view of all the other laborious and difficult work in the line of standard authorship through which he has passed during the last score of years, for such experience is the most fitting school in the world for elemental instruction in the same things. The table of contents follows the order of the author's higher works, beginning with brief reference to the solar system, then the sun; planets collectively, individually; the phenomena of eclipses, occultations and transits; comets, meteors, stars, clusters and nebulæ; and then gives interesting chapters on the telescope, the spectroscope, as applied to astronomy, and the history of astronomy, concluding with the usefulnees of astronomy. We have thought that chapter on the history of astronomy so well considered and presented that we have copied it entire in this issue. We also think it a fair sample of the work done in preparing this new book. Our readers will be able to judge of its merits for themselves. The text is accompanied by 134 good illustrations and followed by tables of the planets and satellites, giving a large amount of useful data, and by catalogues of celestial objects for telescopes of three inches aperture, clusters and nebulæ, and other miscellaneous objects.

Plane and Solid Geometry. By Seth T. Stewart, A. B. 12mo. Cloth, pp. 416. Price by mail $1.12. Publishers, American Book Co., Chicago.

Among the things to attract attention in this new book are the facts that each book is preceded by a synopsis of its contents, the careful typographical arrangement of the page, the large number of original exercises; definitions appearing as needed; theory, figure and demonstration all in easy sight; and that in the solid geometry the figures are well shown in perspective. The book is in clear type and tastefully and substantially bound and at reasonable price.

Six Place Logarithmic Tables, together with a Table of Natural Sines, Cosines, Tangents, and Cotangents. Prepared by Webster Wills, A. B., Associate Professor of Mathematics in the Massachusetts Institute of Technology. Publishers, Messrs. Leach, Shewell & Sanborn, Boston and New York.

These tables are arranged in the usual way, on a large open page, using a good figure for ready and continued use by the computer. They compare very favorably with any six place figures we know of.



LADD OBSERVATORY OF BROWN UNIVERSITY,

PROVIDENCE, RHODE ISLAND.

THE SIDEREAL M

CONDUCTED BY WM. W.

GOODSELL OBSERVATORY OF CARLETON COLLEGE, N

VOL. 10, NO. 10. DECEMBER, 1891

ANCIENT AND MODERN OBS

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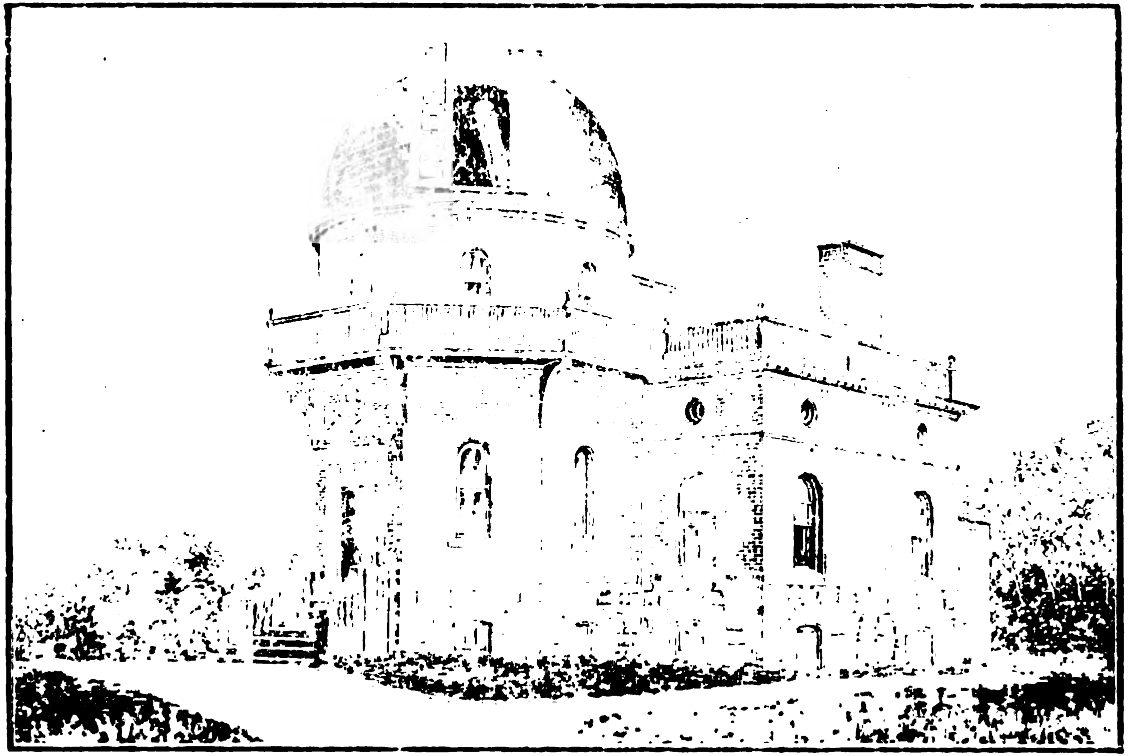

LADD OBSERVATORY OF BROWN UNIVERSITY

PROVIDENCE, RHODE ISLAND

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

VOL. 10, NO. 10. DECEMBER, 1891. WHOLE NO. 100

ANCIENT AND MODERN OBSERVATORIES.*

WINSLOW UPTON.

The building of an Astronomical Observatory naturally suggests many queries relative to its construction and equipment, and the work to be carried on within its walls. The peculiar form of the structure with its revolving dome, and its strange instrumental equipment distinguishes it from the ordinary buildings about us. But the Observatory of to-day is not the creature of modern times. It is a child whose ancestry reaches back to the earliest days, just as the science to which it belongs had its beginning long before history began to be written. The fragmentary records of the very earliest history contain snatches of astronomical observations, from which we can learn something of the science as then understood, and how it was studied by primitive astronomers.

Modern Astronomy is the lineal descendent of the Chaldean Astronomy which flourished before Abraham (who was an astronomer, according to Josephus) left Chaldea for the land of Canaan. It uses to-day many of the symbols and the arbitary conventions of that time, such as the division of the circle into degrees with 60 as the unit for subdivisions, the signs of the Zodiac, the division of the year into twelve months, with the subdivision of the month into the week of seven days.

Primitive Astronomy was at first observational. The astronomer, without instruments, simply noted the varying positions of the heavenly bodies, and pondered upon their explanation. Then a few simple instruments were invented

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* Address at the presentation of the Ladd Observatory to Brown University.

and their installation upon the ground or upon some building formed the first equipped Observatory. The aim of the science was two-fold; to study the movements of the heavenly bodies in order to understand and account for them, and to study them in order to determine their influence upon human welfare. Astrology and astronomy were one, the former furnishing a large part of the incentive for astronomical labors, and though the ties binding them were gradually loosened with advancing years, their divorce was not accomplished until the 17th century of our era. Kepler and Tycho Brahe were both astrologers and astronomers. The motive for study supplied by the attempt to foretell human destiny by the configurations and movements of the heavenly bodies, was very much like that furnished by the working hypotheses of modern science, and was productive of valuable records by which the true science of Astronomy was advanced.

Many of the early Assyrian cities had watch-towers from which the heavens could be scanned, and these were the primitive observatories. If we assume, as is done by many scholars, that these towers were often identical with the tower temples of these cities, we may picture to ourselves the appearance of a Chaldean Observatory.

Herodotus, describing the temple of Bel at Babylon, as quoted by Perrot and Chipiez, says: "In the middle of the precinct there was a tower of solid masonry, a furlong in length and breadth, upon which was raised a second tower, and on that a third, and so on up to eight. The ascent to the top is on the outside, by a path which winds round all the tower." [I. p. 369].

The remains of a tower recently excavated near the ruins of Nineveh, and called the "Khorsabad Observatory," indicate a solid tower built of sun dried brick which consisted of seven square towers one above the other, each smaller than the one beneath. It was about 140 feet square at the base and 140 feet high and was ascended by an inclined plane running around the sides of the tower. On its summit was probably a temple, for the prime object of the structure was religious, and here too, may have been made some of those observations whose records have been deciphered upon the tablets constituting the royal libraries.

As an illustration of these records, I quote the following, kindly translated from the tablets in the British Museum by Rev. R. H. Ferguson, a graduate of our University:

"The sixth day of Nisan. The day and the night were equal. Six kasbu to the day. Six kasbu to the night. May Nebo and Merodack unto the king my lord be propitious."

"On the twenty-ninth day watch we kept. The Observatory was filled with cloud. The moon we did not see."

The instruments of this time were of two kinds: The gnomon or simple pillar whose shadow cast by the sun gave by its direction and length an indication of the sun's place in the sky, and various combinations of arcs of circles with "sights" upon them so that angular distances could be measured. The obelisk and the armillary sphere were the successors of these early instruments in the mediæval period. In modern times the clock and the transit instrument take the place of the gnomon, the arcs of circles are still used, but the telescope is attached to them instead of the simple "sights" which they carried.

Such was the patriarchal Observatory of 4,000 years ago. Should it look to-day upon the adjoining building it might not at first recognize its offspring, but it would do so at very short acquaintance, and would greet the newborn babe with paternal affection.

As the centuries advanced, the aim of astronomical science was quite single, and the pursuit of the science was almost wholly dominated by it. This was to discover what were the *true* movements of the heavenly bodies, as deduced from the rather complicated movements seen by us. The observatories devoted their energies to noting the positions of the heavenly bodies, using instruments similar to those described, and the astronomers tried to represent these different positions in a system. Their efforts were wonderfully successful, and the old Ptolemaic system was able to account for all the planetary movements in spite of its two assumptions that the earth was at the centre of the system, and that all the planets must move in circles (not ellipses) about it and with uniform velocity. When doubt was thrown upon the truth of this system, which had become more complicated as observations became more refined, and when new theories were advanced to form bases for new systems, the question was settled by the observations of the Danish astronomer, Tycho Brahe, which were discussed by the great master Kepler, and from them, the true system discovered. The Observatory of Tycho Brahe deserves more than passing mention because of its historical importance in this respect, and because it was the best as well as the last of the mediæval observatories, which were equipped before the telescope was invented.

It was erected on the little island of Hveen, 14 miles north of Copenhagen, and was a very curious structure probably built of brick with sandstone ornaments.

It would be difficult to describe it without a drawing, but it may be roughly imagined as a square house 2½ stories high, flanked on all four sides by towers which did not rise to the height of the house, and surmounted by a pavilion having a dome, above which was a spire and vane. The towers on the east and west walls were small, and attached to the house like bay windows with ornamental spires for roof, but the two towers on the north and south were circular and covered each with a pyramid for a roof, whose triangular faces were removed when observations were made. There were two smaller towers beyond these and two others upon the roof of the main building with domes for roofs flanking the large pavilion. Galleries were built about each tower, so that the whole structure was very unique in outward appearance. Within were rooms for the residence of the astronomer and his family, for students and observers, besides a library and chemical laboratory. Of the nine towers or domes, the four on the north and south contained the chief instruments.

The instruments of the Observatory consisted of various combinations of circles or arcs of circles, and of triangles for measuring angles, for the sole work of the Observatory was the locating of the position of the heavenly bodies in the sky as accurately as possible. The largest instrument was a great quadrant,—a large brass arc of about 7 feet radius fastened to the wall of a room. The center of the arc was marked by a hole in the wall running at right angles with that to which the arc was fastened and two moveable sights could be made to slide on the arc. The observer looked through one of the sights on the arc through the hole at the center of the arc to the star beyond, and noted the reading on the graduated arc.

Another instrument consisted of "a vertical semi-circle, (8 feet in diameter) turning round a vertical axis and furnished with a horizontal circle for measuring azimuths." Another instrument was a huge sextant of 5½ feet radius mounted on a stand. Another, the armillary sphere, consisted of two circles of steel inclined to each other at the proper angles to represent the celestial equator, and the meridian, while a third circle moved upon the axis of the celestial equator, thus representing the various hour circles of the celestial sphere. There were several instruments of these and other types, and in them are the germs of the different methods now in use for mounting telescopes. Tycho's instruments were made in his own workshop and their special merit consisted in peculiar devices for reading the angles as well as in superior workmanship, so that his observations, which were continued for twenty years, far excelled any which preceded in accuracy. In his library he placed an immense globe, five feet in diameter, upon which he marked the stars in their true positions as fast as he determined them, and after twenty-five years his globe was completed. He also constructed a second Observatory, the rooms of which were under ground, with only the roofs above the surface, in order that the instruments and observers might be protected from the wind. (See Dreyer's Tycho Brahe).

Tycho's observations were the crowning work of the whole era of astronomy. By their aid, Kepler, in the following century, finally overthrew the old system of Astronomy and led the way for the establishment of the new system upon the theory of Gravitation at the hands of Sir Isaac Newton.

At the same time the telescope was invented, and the modern Observatory came into being. The invention of the telescope caused a reconstruction of the old instruments, and made it possible to make observations of the positions of the stars and planets with greatly increased accuracy. It also opened the new field of Descriptive Astronomy. It showed at the very first that the sun has spots, that Venus passes through the same phases that our moon does, that the dark and light spots on the moon indicate level plains and craters, that Jupiter has four satellites, that Saturn has rings,—in short, it made a new branch of the study, the examination of the appearance of the heavenly bodies. This study was pursued with ever increasing skill as telescopes were enlarged and improved. Less than a generation ago the invention of a new instrument, the spectroscope, made an additional extension of astronomy, and now the heavenly bodies are studied with a view to finding out their constitution and present physical condition as well as their movements. Other physical instruments, such as light measurers, and heat measurers have been added, and finally the camera with the extra-sensitive plates of modern photography, has furnished a wonderful increase in the facilities at the service of the astronomer.

The modern Observatory cannot be described by a single example. The aim of the science is no longer single; as its resources have increased, so have its aims, and now its professed desire is to learn all that can be learned of the wonderful universe whose foundations were laid when only the eye of the omnipotent Creator beheld them.

No single Observatory pretends to devote its energies to all the branches of astronomy, and we must know the purpose for which the institution is designed if we would properly understand its equipment. Some Observatories, like the government Observatories at Washington and Greenwich, devote the larger part of their energies to observing the positions of the heavenly bodies, calculating star places, computing orbits and similar work,—which is the modern phase of the old Astronomy. Others cultivate especially the newer fields which the introduction of the methods of the physical laboratory have opened, as the Observatory at Harvard College, one of the best equipped in this country. Very many have no single aim, but pursue a variety of subjects as occasion may suggest. Then not all the observatories are devoted to research; some are designed for instruction, some for recreation. Indeed it would be possible to arrange the observatories of the world roughly into three or four classes: Those for research alone, those for instruction, those which combine instruction and research and those which are used for entertainment chiefly.

In the first class come those which have independent endowments or are supported by government grants, like the Imperial Observatory at Pulkowa, Prussia, the Lick Observatory and those already named. Their equipment varies with the nature of the investigations they are carrying on, but all have telescopes of large size with other instruments for special work.

In the second class are found those Observatories which are attached to Colleges or Universities. Not as distinct departments for research (as is the case with the Harvard and the Lick Observatories), but to aid in the astronomical instruction. The undergraduate instruction in astronomy in our colleges has materially changed in recent years. Formerly attention was bestowed almost exclusively upon the mathematical side of the science. Now a general course in astronomy is given, and technical courses follow for the relatively small number who wish to pursue them. In this way the laboratory courses in Physics, Chemistry or Biology have a counterpart in the Observatory courses in Astronomy, while graduate instruction of a more advanced character is sometimes offered, as at the University of Virginia and at Carleton College, Northfield, Minn.

In the third class may be placed many observatories which are in part devoted to instruction, and in part to research, such as the two observatories last named. The proportion given to research and to instruction will, of course, vary in individual cases, but the best opportunity for obtaining advanced instruction is furnished at those observatories where regular research is carried on and where the special student is also welcomed.

In the fourth class—those for entertainment—are included observatories which do little or no regular work either of research or of instruction but are used for the entertainment of friends of their owners. This is no unworthy object, and no pleasanter evening can be spent than with a telescope enjoying the beauties of the universe. Many a professional astronomer knows less of the detailed appearance of the planets, nebulæ, clusters, etc., than the owner of some telescope who amuses himself with examining these objects as opportunity offers. The proper attitude of an Observatory to the entertainment of visitors is one of the most perplexing questions of the administration of such institutions. The decision is usually against such a use of the equipment of the Observatory, especially of one whose funds are in trust for research, because time devoted to such purpose, while in itself perfectly laudable, is time taken from the work of the institution hour for hour, and occasions direct loss. Several attempts have recently been made to establish observatories for the express purpose of instructing and entertaining visitors. Such an institution exists in Berlin where regular courses of lectures are given and where the chief purpose is to edify those who wish to learn something of astronomy. A similar Observatory has been established in California, the Chabot Observatory at Oakland, where entertainment and instruction are placed at the disposal of the general public. Such institutions would be very valuable adjuncts to the courses in a University extension system. If established adjacent to some regularly equipped Observatory the two together would unite in serving the science of astronomy, the University and the community in a very practical and efficient way.

The Ladd Observatory belongs to the second or to the third of these classes of observatories. It is primarily established and equipped for the students of Brown University, and its first aim is to furnish instruction in astronomy to those students who wish to secure it. The general courses in astronomy, taught as heretofore at the college, will be illustrated by the resources of the Observatory.

Technical courses for undergraduates will include the theory and use of astronomical instruments and advanced courses for graduates will be open to any who wish to specialize still further.

The instruments are examples of the leading instruments of the science at the present time. In the circular room with the revolving dome is the chief telescope, whose optical power and mechanical support are equal to any telescope of its size. It is of sufficient power for all purposes of instruction and is admirably suited to research besides. It contains the best modern forms of eye-pieces and micrometer, has improved attachments for its manipulation and is further supplied with one of the best spectroscopes ever constructed.

The eastern ell of the building contains transit instruments where time observations may be made for the regulation of clocks, or latitude determinations secured. Two standard clocks are enclosed in the masonry pier which supports the telescope; in order to secure freedom from jar and also uniformity of temperature. A chronograph, by which the observer may record the timeof any occurrence by simply pressing a telegraph key, is of special use for refined observations. Several chronometers and sextants are used to instruct the student in the astronomical part of navigation, while Meteorology is represented by a recording barometer, thermometer, hygrometer and rain gauge as well as by the ordinary instruments.

The general plan of the equipment which the generous donor has followed has been to secure the best of its kind for the purpose at hand. The instruments are adapted to research as well as instruction, and it is the intention to attempt scientific work just as far as our resources will allow.

May this Observatory do its part in diffusing the knowledge which accumulates from the labors of the astronomer, and may it also have some humble part in the development of the science.

NEW BINARY STARS, β 416, SCORPII 185.

S. W. BURNHAM.

FOR THE MESSENGER.

The wide double star, H 4935, was found by Herschel in 1837 at the Cape of Good Hope, and entered in the catalogue of double stars in the *Cape Observations*. No distance is given and the angle is stated to be estimated from a diagram. In 1876, while observing with the 6-inch refractor, I came across this pair, and at once saw that the principal star was also double. At that time it was a very easy pair, even at the low altitude of this star in latitude of Chicago. It was not measured at this time, but the angle and distance were carefully estimated and these estimates are of some value in showing the rapid motion which has taken place during the last fifteen years. Two sets of measures have been made at this Observatory. It should be remarked concerning my measures given in *A. N.* 2957 that the result is a mean of four nights' measures. One of these measures was made in 1888 and three in 1889. The first made the position-angle some 13° more than the last three. This difference was assumed to be due to errors of observation, and therefore the mean was taken of all the measures. It is now evident that this difference was real, and due to the rapid change in the relative positions of the stars; and that the measures of those years should be given separately. The following are all the measures to this time:

A AND B.

1876.52	240° ±	1″.8 ±	6.0	8.5	β	1*n*
1877.53	222.6	1 .80	7.0	8.0	Cin^4	1*n*
1877.64	224.4	1 .77	.7	.9	Russell	1*n*
1888.72	147.5	1 .89	6.0	7.5	β	1*n*
1889.47	134.1	1 .35	6.4	7.5	β	3*n*
1889.63	131.9	0 .97	.6	8.5	Pollock	1*n*
1891.53	82.3	0 .51	6.9	7.6	β	3*n*

It is obvious from an inspection of these measures, laid down on paper to scale, that this change is not the result of proper motion; and it is equally certain that it is a binary of short period. A period derived from these measures would perhaps be too rough for any useful purpose, although the minimum time could be readily determined by the graphical method, but the measures of one year more should be sufficient to fix it with reasonable accuracy. The distance will probably decrease still further, and it may be too difficult for accurate measurements in this latitude. The foregoing measures of mine were all made with the 12-inch Clark refractor. It was well enough seen this year for good measures, but a decrease in the distance of one or two tenths of a second would make it a very difficult pair here. It is unusual for so wide a pair as this, taking the average distance to this time, to have an orbital motion so rapid; and it suggests the possibility that this pair may be much nearer than most of the pairs having corresponding relative motions.

There seems to be no evidence of change in the place of the Herschel star, but the distance is much too large to make it probable that any connection exists between this and the close pair. The measures are all of very recent date, but we have the estimated angle of Herschel which is in close agreement with the later measures.

A AND C (= H 4935)

1837.	130° ±			H	1*n*
1876.	130 ±		10	β	1*n*
1877.64	132.4			Russell	1*n*
1889.43	128.6	31″.03	10.5	β	3*n*
1891.53	128.8	30 .52	12	β	3*n*

This star is *Scorpii* 185 = B. A. C. 5825 = *Lacaille* 7215. The estimates of magnitude cover quite a wide range. In B. A. C. it is 6^m; Gould 6.1; Washington Catalogue 7.0; and Stone (Cape Catalogue) 7.6.

The place of this star for 1880 is:

$$\left.\begin{array}{l} \text{R. A.}\quad 17^h\ 10^m\ 47^s \\ \text{Decl.}\ -34^\circ\ 51'\ 12'' \end{array}\right\}$$

It is very desirable that observers in the southern hemisphere should follow the close pair, and measure it each year if possible.

LICK OBSERVATORY, Oct. 24, 1891.

ADDRESS AT THE DEDICATION OF THE LADD OBSERVATORY.

WILLIAM A. ROGERS.[*]

I can rejoice most heartily with all friends of Brown University upon the addition of a thoroughly equipped Obervatory to her educational facilities. I have noted with great satisfaction the evidences of the skillful and intelligent direction of a trained astronomer, not only in the general design of the building, but in the special appliances and conveniences which will contribute largely to its usefulness and will enable its director to do the greatest amount of the best scientific work with the least friction and in the least time. I cannot refrain from extending my congratulations to my old-time co-worker, Professor Upton, upon the fulfillment of long cherished plans. If I may be allowed, I should be glad also to express my appreciation of the wise confidence of the donor in committing the general design and equipment of the building to one who is to be responsible for the work to be done here. It is too often the practice to erect and equip buildings of this character and then appoint the person who is to direct its affairs. All this is reversed here.

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[*] Professor of Astronomy and Physics, Colby University.

I take the greater pleasure in saying this because I am myself the chief beneficiary of a similar gift given under similar conditions. When Colonel Shannon gave the funds for the erection of an Observatory and physical laboratory at Colby University, he said: "You are supposed to know what you need; I hold you responsible for the wisest possible disposition of the funds at your command. If the building does not meet your needs, you alone must bear the blame." It hardly needs to be added that this broad commission was accepted with great promptness and with great thankfulness.

In a city devoted to the development of a great number and variety of industries, it is very natural to ask, what is to be the practical outcome of this large expenditure? How is the building and the equipment of this Observatory to be justified in a practical way? The utilitarian view of a question naturally appeals to us the most strongly. I answer then, that the cultivation of the science of astronomy cheapens the production of cotton cloth, of woolen goods, of calico, of machinery, indeed of every staple product. Do you ask how this can be? I answer that one of the elements which enter into the cost of production is the cost of water transportation. The cost of water transportation depends on the skillful application of the science of navigation; and navigation is a branch of astronomy. It is true that astronomical methods and astronomical tables are now adequate to all the demands of the practical navigator, but it is not so very long ago that the proportion of the number of wrecks to the number of vesssels in the merchant marine was largely affected by the rudely approximate data upon which the position of a vessel at sea was determined. Consider a single illustration. It is not difficult to understand that the profits of ocean steamship service depend largely upon the skill with which the chronometer is handled in the determination of longitude. As soon as an ocean steamship reaches port, her chronometer is either directly or indirectly committed to the charge of an Observatory to have its rate determined in preparation for the next voyage. Without this previous rating, the skill of the navigator in taking sights and in reducing his observations will be of little avail.

But there is a larger sense in which an active and well conducted Observatory may be a useful adjunct of commerce, viz.: in shaping and elevating the character of the men who follow the sea as a profession. Why should the influence of a college be limited to the elevation of men in the three learned professions? Why should not the influence of the college be felt upon every stratum of society as an uplifting and regenerating power? This is exactly what university extension is attempting to do.

This college has honored itself in accepting gifts for the establishment of a Grand Army Professorship. I do not understand that this has been done as a matter of charity, or even as a matter of obligation, great as that obligation is. The purpose of this foundation I understand to be to educate a generation of men who by manly living shall serve their country even better than their fathers did in dying for it.

The Observatory is a distinct help to the college in providing facilities for special work on the part of advanced students whose tastes lead them to the pursuit of astronomical science. The younger generation of astronomers must receive their first inspiration and their initial training from this source. Certainly, what may be called the older school of astronomy, in which the ability to pursue profound mathematical investigations is united with practical experience in observations, must receive its recruits from the college in which the theoretical and the practical are recognized as equally important.

There is yet another view in which a well equipped Observatory may stand as a potent factor in scientific work. There is a tendency at the present time to insist that what is called the scientific method of investigation shall be the criterion by which all questions of philosophy and even of religion shall be settled. The various schools of the higher criticism base their plea for recognition upon this view. It is becoming recognized that there are divine laws in the structure of society as well as in nature. Sociology is something more than political economy. What is meant when it is said that the scientific method is alone competent to deal with these problems? Astronomy furnishes a complete and perfect answer. All astronomical theories are based upon observed facts. I well remember the definition of a theory which Professor Chase used to give when I was in college.

He defined a theory to be a working hypothesis which is useful only as an aid to the interpretation of the facts of observation. When sufficient facts have been accumulated to prove its truth or its falsity, it is no longer a theory. In astronomy we have theories which have passed to this second stage and have been transformed into laws of nature. Thus the Copernican theory expresses a law of nature as definitely determined by observation. We no longer say the theory of gravitation, but the law of gravitation. On the other hand, the existence of luminiferous ether is still within the realm of theory, because observation has not positively demonstrated even its reality, to say nothing of its nature. The nebular hypothesis is still a theory, because it is sustained by only a very few observed phenomena. An astronomer's first duty is always an appeal to observation. His interpretation of the observation may be wrong, but the observation will remain.

I do not remember to have seen a clearer statement of the true scientific method than an incidental one by George Kennan, in his defence of the method which he employed in studying the penal system of Russia. He says: "All that fairness and impartiality require of the investigator in any particular field is that he shall set forth conscientiously and in due relative proportion, and without prejudice, all the significant facts which he has been able to gather in that selected field, and then that he shall draw from these collected facts such conclusions as they may seem to warrant." The sentiment here expressed breathes the true scientific spirit; and whatever the field of investigation, it is the first duty of every man who cultivates exact science, to resist every departure from it. This protest is made by an astronomer by virtue of his profession.

It is quite true that the nature of the facts sought varies with every field of research, and every investigator must in fairness recognize this truth. For example, the nature of the facts derived from the observations by Wundt and Fechner in their experiments upon sensation are radically different from those which the astronomer seeks. Especially must the nature of the facts sought be clearly defined in the application of the principles of criticism to questions of religious belief, unless, indeed, we find it better and more safe to agree with Pascal that it has pleased God that the divine verities should not enter the heart through the understanding, but the understanding through the heart.

A well equipped Observatory established in connection with a college has, at least, two distinct duties to perform. It should be an aid to the general course of instruction in astronomy, and it should undertake some special investigation which gives promise of useful results. It is a common impression that nearly all of the great problems of astronomy have been solved, and that the minor ones are hardly worth the effort at solution. On the contrary, the demands in this direction were never more pressing and the promise of useful results was never more assured, especially in the related fields of economic research. As a single illustration, the development of the laws of climatology and its elevation to the position of an exact science would affect the life and welfare of every human being in the world.

But it is not true that all the great problems of astronomy have been solved. We have only taken the first step in the solution of the greatest problem of any age concerning which our knowledge at the present time is so limited that theories concerning it are not much better than guesses. I refer to the motion of the solar and the sidereal systems in absolute space. The confirmation of mathematical analysis by observation has reduced the theory of the motion of the planets and their satellites around the sun to a degree of exactness which leaves little to be desired; but who can say with any degree of certainty whether the solar and the sidereal systems are stationary in space, or, if they are moving through space, in obedience to what laws this motion takes place?

It is indeed true that the present evidence is fairly conclusive that we are hastening with amazing velocity towards some point near the constellation of Hercules. Granting that this is true—is this motion in a right line or in a curve? If in a curve, what are its elements? If it is an ellipse, where are its foci and is this movement in obedience to the same laws as those by which the planets are carried forward in their orbits around the sun?

The first step in the preparation for an answer to these questions has been taken in the determination of the exact position of all the stars in the heavens down to a given magnitude under the auspices of the German Astronomische Gesellschaft. Several of the principal Observatories of the world have united upon a common plan formulated by the Gesellschaft in executing this work, and though the work was begun nearly a quarter of a century ago, it is not yet completed. It may be of interest to state that the northern zone undertaken by Harvard College Observatory was begun twenty-two years ago on the tenth day of November next, and that the Introduction to the volume containing the results of the observations was sent to the printer only a fortnight ago. The southern zone undertaken by Professor Pickering is progressing towards completion.

I have said that only the first steps towards the solution of this great problem has been taken. After a lapse of 50 or 100 years this work will be repeated, and after the catalogue for that epoch has been constructed, the astronomers of another generation will, by the study of these two great catalogues, be in a position to give an answer to the question: "Whither are we drifting through space, and under the operation of what laws does this motion take place?" The steps taken to solve this great problem furnish, it seems to me, a typical illustration of the true scientific method.

I do not know what particular problem may be taken up by Professor Upton; but whatever the field chosen, whatever the investigation undertaken, I feel sure that this Observatory with its magnificent equipment will occupy an honorable place in the history of astronomical research.

THE NEW AURORA-INCLINOMETER.*

PROFESSOR FRANK H. BIGELOW.

Magnetic phenomena, in the neighborhood of the surface of the earth, derive their complex nature from the superposition and interaction of several distinct magnetic fields. Two of these have been surely distinguished, and there may be a third and perhaps a fourth that yet remain to be separated.

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* [Communicated by permission of the Superintendent of the U. S. C. & G. Survey.]

The first is due to the so-called permanent magnetism of the earth; the second is generated by the direct radiant energy of the sun; the third is theoretically ascribed to the coronal action of the sun; the solution of the problem of the rapid variations of the needle may lead to the discovery of a fourth field.

It is evident therefore that every resource of science may legitimately be invoked to aid in the separation of the action of these fields. Up to the present time the magnetic needle has been our chief reliance in this study. There are however, very clear reasons for supposing that the auroral streamers will add no little evidence to the determination of the question; likewise some other common phenomena may possibly be called into consideration for the same purpose.

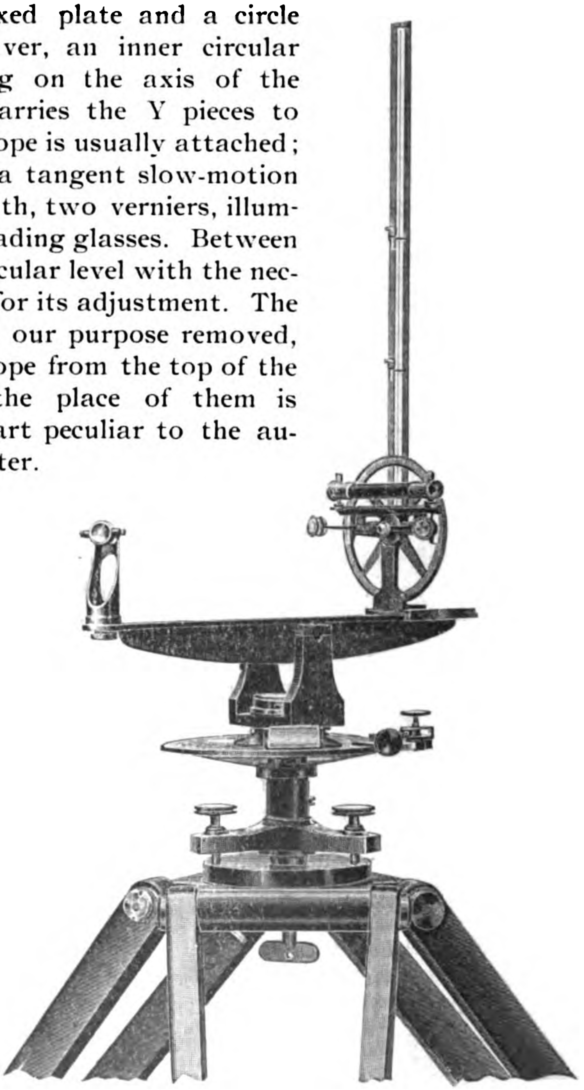
In this paper it is proposed to describe an apparatus for measuring the position of the auroral streamers in space, hoping to secure such data as will admit of useful discussion. The instrument was constructed by the U. S. Coast and Geodetic Survey Office, in a very excellent manner, and the courteous service thus rendered is heartily appreciated.

The aurora itself, as is well known, tends to groups of maximum frequency of display around an oval belt, embracing the magnetic and the geographical poles, and about the plane which passes through the magnetic poles, whose position in space is an hour and a half behind the sun. The direction of the rays is said to be parallel to the lines of the forces of permanent magnetism. But this should be tested, because in the same region the forces arising from the radiant field make generally an angle of say 20° with the first field, and taking account of the fact that auroral displays and solar outbursts of energy are apparently responsive, we may not go far astray in saying that these fields mutually affect each other, and that, therefore, the aurora rays, if not generated by this interaction of two magnetic fields, at least may be so modified as to exhibit, upon close examination, some variation from either type. Whether this idea be wholly true or not, it is worth while to know what relation these streamers hold to the lines of magnetic force surrounding the earth. No mention is made of the influences from the third or fourth fields, because the mode of their action is not yet clearly conceived.

The Aurora-Inclinometer.

This apparatus may be described briefly as follows, reference being made to the accompanying picture of it.

It is mounted upon the ordinary tripod of a theodolite, which is surmounted by a head plate and levelling screws. There is a fixed plate and a circle divided on silver, an inner circular plate revolving on the axis of the outer circle, carries the Y pieces to which a telescope is usually attached; there are also a tangent slow-motion screw in azimuth, two verniers, illuminators and reading glasses. Between the Ys is a circular level with the necessary screws for its adjustment. The Y caps are for our purpose removed, also the telescope from the top of the Ys, and in the place of them is screwed the part peculiar to the aurora-inclinometer.



It consists of:

1. A horizontal bed plate 36 c.m. long, 3.7 c.m. wide on the upper surface and 4 m. m. thick. It is stiffened by a thin arch-shaped rib, like the keel of a boat, running from end to end, about 3 c. m. deep at the center, the

boundary meeting the plate near its ends. This bed plate has a shallow groove along the middle of it leaving two smooth, brass tracks on either side, 1 c. m. wide, upon which travels a piece of brass 6.5 x 5 X 0.8 c. m.; this supports the inclinometer itself. On the other end of the bed piece is fixed a circular diaphram 2 c. m. in diameter with a hole in the center, about the size of the pupil of the eye. The diaphram has two motions at right angles to each other, one produced by the rotation about its base of the circular standard to which it is fixed, and the other on the axis of two opposing screws, being thus designed to meet a ray of light from any direction without interfering with its direct transmission. On the other end the block slides on dovetailed grooves and is provided with a clamp. From its inner edge rises a short arm 8 c. m. high, carrying a small divided circle, 11.5 c. m. in diameter, having two verniers and glasses, also a fixed level. The center of this circle and the centre of the diaphram are on a line parallel to the surface of the bed plate, and this forms the base of the triangle which essentially constitutes the geometry of the apparatus, the observed point forming the apex, as seen on the vertical scale to be described. The length of this base is measured on a scale engraved on the bed that lies along the plate, having c. m. marks and a vernier for subdividing to millimetres.

One other part remains to be mentioned. The sliding piece carries from the circle on one side two small parallel bars, 4 X 3 X 40 m. m., set 11 m. m. apart from each other. They are solid at the ends and carry a smooth taut wire through the middle of the opening. This wire passes through the centre of the circle at right angles to the zero line. Hence it may be accurately adjusted to the vertical astronomical plane of the station by means of the level. The reading being noted any angle made by it with the vertical plane can be read on the circle. Along the side of one of the parallel bars is a c. m. scale along which slide two vernier scales with fingers projecting across the opening at right angles to the thread. They can be run up and down, and being placed for example on the upper and the lower extremeties of an auroral streamer, they form the altitude of the angle, referred to the base line scale, which the measured point makes with the horizon.

Thus we have the two circles and two linear scales, one of each in the horizon and the others in the vertical plane. Hence a complete reading on any point gives its location in space, except as to its absolute distance from the observer.

Recapitulation of The Formulæ.

[See the American Journal of Science, Vol. XLI, February, 1891.]

The following formulæ are required in making the reductions:

Represent by

O, The center of the earth.

A, The station of the observer.

B, The radius of the earth extended through the effective magnetic pole to meet the plane tangent to the earth at A.

C, The point in the plane of the horizon from which the auroral ray springs.

$r =$ the radius of the earth.

$u =$ the angle AOB.

$w =$ the angle AOC.

$\vartheta' =$ the angle BOC.

$AB = c,\quad AC = b,\quad BC = a,\quad OB = c',\quad OC = b'.$

Then

$$AB = r \tan u = c. \qquad AC = r \tan w = b.$$

$$OB = r \sec u = c'. \qquad OC = r \sec w = b' = r'.$$

$$\tfrac{1}{2}(C + B) = 90 - \tfrac{1}{2}A.$$

$$\tan \tfrac{1}{2}(C - B) = \frac{c - b}{c + b} \tan \tfrac{1}{2}(C + B).$$

$$a = \frac{c . \sin A}{\sin (A + B)} . \qquad \tan \tfrac{1}{2}\vartheta' = \sqrt{\frac{(s - b')(s - c')}{s(s - a)}}.$$

$$2 \cot \vartheta' = \cot l.$$

$S \sin l \sin(A + B) = \Delta A$, (measured azimuth).

$S \cos l \cos w = \Delta h$, (measured altitude).

$$\tan l \sin(A + B) \sec w = \frac{\Delta A}{\Delta h}.$$

$$N = \frac{8\pi}{3} . \frac{\sin^2\vartheta'}{r'} .$$

$$\sin^2\vartheta = \frac{3N}{8\pi}.$$

$r' - r \cos(\vartheta' - \vartheta) =$ height of C above the ground.

ΔA should be corrected by the quantity

$$+ S \sin l \cos(A + B) \tan \alpha,$$

and Δh by the quantity

$$- S \cos l \sin w \tan h,$$

to reduce them to projection on a plane perpendicular to the line AC, as seen by an observer at A.

ΔA is properly $b \tan \alpha$, and

Δh is properly $b \tan h$, where

α and h are the differences in azimuth and altitude respectively of a point on the ray and the base of the ray at the plane of the horizon.

Method of Taking the Observations.

1. Set up the tripod and level the azimuth circle. Adjust the vertical circle by sighting the inclinometer wire on a plumb line and reading for the index error.

2. The geographical meridian of the station being known and the direction of the magnetic meridian, or the mean declination of the magnetic needle east or west, the azimuth readings of each of these meridians are taken. Also give the longitude and latitude of the station.

3. The auroral streamers present many appearances; some being fairly steady, and some vibrating. In all cases at a given point in the heavens there are *direction lines*, more or less sharp, which radiate through the light spaces. It is only necessary to get this direction, and not important to measure any one individual ray. The simplest plan is to set the inclinometer approximately at the proper vertical angle, then watch the transits of the auroral lines across the wire. By adjustment they can be made to *pass parallel to the wire*, and that is the observation. At the same time set the upper and the lower index finger to the top and bottom respectively of the rays as they appear to the observer.

4. Read the horizontal scale to millimeters; the linear scale on the inclinometer for the upper and the lower index; the azimuth circle; and the vertical circle.

5. On a given evening of observation it is important to take inclinations from the middle of the arch in both directions in azimuth towards the ends at various well distributed positions. Those rays which are most inclined will furnish the most valuable data, but all available inclinations should be included in the observations.

6. The meteorological conditions must be noted, the barometer, the thermometers wet and dry, the direction and force of the wind, the condition of the sky and the appearance of the stars. A clear and precise description of the aurora at the time of the observation should be given.

7. The local mean time of all the observations within the nearest minute is desired.

Observers not having a regular inclinometer with them, can yet obtain observations by means of a plumb line and inclined rod, which with some care may be made sufficiently accurate to be valuable.

THE LADD OBSERVATORY.

WINSLOW UPTON.*

FOR THE MESSENGER.

The Ladd Observatory was formally presented to Brown University by the donor, His Excellency Governor Herbert W. Ladd, of Rhode Island, on October twenty-first. The purpose of the generous donor to make this gift was first announced two years ago, soon after his inauguration as Governor. For some time, it had been his intention to make some contribution to the resources of the college, and it took the form of an Observatory, in accordance with the suggestion of President Robinson at the Commencement in 1889. Governor Ladd did not give a definite sum but promised to build and equip the Observatory and present it, when completed, to the University. The equipment was to cost $10,000, and the building $10,000, or as much more as the donor might determine. A more elaborate building was decided upon than at first intended, so that the whole gift of building and equipment cost nearly $30,000.

The illustration shows the building as seen from the south-west. It is situated on the summit of a hill in a sparsely settled part of the city of Providence, and is 200 feet above sea level. It is one mile north of the other college buildings. The building is constructed of brick with stone trimmings, except the ell for the transit instruments,

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* Professor of Astronomy, Brown University.

which is of wood. The tower is octagonal up to the second floor, and cylindrical from that floor to the revolving dome. The following dimensions may be of interest: Main part of building, 43′ × 27′; transit ell, 25′ × 15′, with piers for two transits; equatorial room—inside diameter 20′, height to base of dome, 10′. The front entrance is on the west, and opens into the octagonal tower which is largely occupied by the masonry pier supporting the equatorial. The central part of the main building is a broad corridor running to the transit ell, which is separated from it by a small hall containing two side entrances. On the south of the corridor is one large room for the library, and on the north, a smaller room for a study and computing room. The remaining part of the main building is taken up by the stairway to the equatorial room and a small room for the janitor. There is a half story above the main building which is available for storage purposes. The roof is flat and surrounded by a railing; a balcony extends around the equatorial room. The revolving dome is made of copper and has a slit covered by two shutters which move sideways in either direction giving an opening of four feet. It was made by the Providence Architectural Iron Works. The running gear is a live ring, something after the Grubb pattern with conical rollers, and the dome is turned by a rope which hangs from a wheel attached to the moveable dome, and geared to the track on the wall of the building. By this arrangement (which is found in a few other domes) the fixed windlass is done away with, and the person who turns the dome is always behind the opening and thus knows when to stop turning. The equatorial pier is of brick with granite capstone, and is sunk four feet below the surface. It rests upon a thick bed of concrete and is packed with sand on the sides. The building is warmed by the Gurney hot-water system which secures equability of temperature.

The chief instrument of the Observatory is an equatorial telescope of 12.2 inches aperture and 15 feet focal length. The instrument was made by G. N. Saegmuller, the objective constructed by J. A. Brashear. It is one of three recently made by Mr. Brashear from the formulæ of Professor C. S. Hastings,—the crown glass by Mantois, and the flint from the optical works at Jena, Germany; the others are the

16-inch of the Goodsell Observatory, at Northfield, Minn., and the 12-inch of the Kenwood Physical Observatory, at Chicago. The mounting possesses several noteworthy characteristics: the pillar is of iron and cylindrical; upon it is a cubical box of iron containing the driving clock which is controlled by the Young governor. The pillar rests upon a tripod which may be adjusted for altitude and azimuth. The tripod bolts extend downward into the masonry pillar for six feet and are firmly embedded in it. There are three pairs of setting circles;—(1) the usual finely graduated circles which are read by microscopes, the declination circle from the eye end, the hour circle from the pillar; (2) coarsely graduated circles, the one on the polar axis, the other on the edge of the 500-lb. counterpoise weight on the declination; (3) Saegmuller's finding circles, which are at the eye-end and operated by rods and gearing running through the tube to the axes. The illumination is by one-candle electric lights. The pillar micrometer and eyepieces are also by Saegmuller, the helioscope by Brashear.

The spectroscope is of especial excellence and was made by Brashear. It is supplied with both prism and grating, comparison and reversion apparatus and camera attachment.

The clock room is a chamber in the equatorial pier, and contains a Howard sideral clock and a Molyneux meantime clock.

The other instruments are a 3-inch portable transit, by Saegmuller; a smaller transit for students' use; a chronograph, by Warner & Swasey; several chronometers and sextants, a barograph, thermograph and recording hygrometer by Richard Frères; a recording rain and snow gauge, by Ferguson, and ordinary meteorological instruments.

The Observatory is designed primarily for the instruction of students and also for research. The equipment has been planned for a possible extension of the latter as the resources of the Observatory may allow.

The exercises attending the presentation were held in a tent adjoining the Observatory. The Chancellor of the University, Colonel William Goddard, presided and made brief introductory remarks. Governor Ladd then read a brief address, speaking of the circumstances attending the making of the gift, his growing interest in the Observatory as it has neared its completion, and his satisfaction in its plan and equipment. President Andrews received the keys of the building and accepted the gift in behalf of the corporation of the University. He referred in his address to the good which such an institution would do, not only to the college, but to the community, and to the example thus furnished of a noble gift for educational and scientific purposes. The Director of the Observatory, then read a paper upon Ancient and Modern Observatories, describing especially the early Chaldean Observatory, the Observatory of Tycho Brahe, and showing the changes in the aim of the science of Astronomy as well as in its facilities for research in modern times.

Congratulatory addresses followed from Professor E. C. Pickering of the Observatory of Harvard College, Professor William A. Rogers of Colby University; Professor C. S. Hastings of Yale University, and Mr. J. A. Brashear of Pittsburg. Professor Pickering referred especially to the excellent work done at American observatories, comparing in quality with that of European institutions. Professor William A. Rogers, of Colby University, then gave an address in which he discussed the relation of an Astronomical Observatory to the industrial and educational interests of the community and to scientific research. Professor Hastings spoke of the history of telescope making, especially of the recent improvements in objectives, and gave an account of the special difficulties encountered in making the equatorial for this Observatory. Mr. J. A. Brashear spoke of the special need of endowments for astronomical research and related several anecdotes illustrating this subject.

The exercises were enjoyed by a large company, more than filling the improvised hall. Among the visiting astronomers present were Professor H. A. Newton, of Yale; D. P. Todd, of Amherst; E. E. Reed, of Camden, N. J.; J. R. Edmands, of Harvard, and Alvan G. Clark, of Cambridgeport, Mass. The Observatory thus starts its work with the most cordial sympathy of similar institutions, and it is hoped that its future history may be in keeping with its auspicious beginning.

AN ALT-AZIMUTH MOUNTING FOR A SMALL REFLECTING TELESCOPE.

GEORGE S. JONES.

FOR THE MESSENGER.

Some years ago the writer had occasion to mount a silver-on-glass reflector, of 5¼ inches aperture and 45 inches focal length, and was therefore led to examine all the descriptions and illustrations of mountings for such an instrument which were easily obtainable. Not wholly pleased with any of these, he devised (perhaps *evolved* would be a better word) a style of mounting which seemed to suit the exigencies of the case—it was not practicable to mount the instrument equatorially, for lack of a suitable location for it—which mounting has proved in every way so satisfactory that he may possibly render a service to some similarly perplexed amateur by giving a description of it.

The mounting consists of a tripod stand surmounted by a small turn-table, which, with its accessories is shown in the annexed Figure I. This sketch should need but little explanation. The tube of the instrument rests upon the saddle *a*, being held loosely by means of a pair of leather straps, so that it can be readily turned about its axis. A couple of bosses on the tube impinge against the upper end of this saddle and prevent the tube from slipping downward. By means of a pair of hand-wheels, *b* and *c*, a slow movement in altitude and azimuth may be given to the instrument; by means of a small dependent pin, *d*, the azimuth mechanism can be thrown out of gear, when the table is free to be turned completely around, if desirable. A rack, *e*, is provided for the eye-pieces.

Figure II. shows a vertical section of the table, in the plane of the movement in altitude; figure III., a horizontal section at the dotted line *ff*.

The movement in altitude is obtained by means of a ribbon, *g*, one end of which is secured to the table, and which passes over a roller at the upper end of the saddle and can be wound or unwound upon the roller, *h*, by means of the hand-wheel *c*. The upward movement is caused by the weight of the lower end of the tube, which is supported above its centre of gravity. The tube can be turned from a horizontal to a perpendicular position, and can, therefore, be directed to any point in the heavens between the horizon and the zenith.

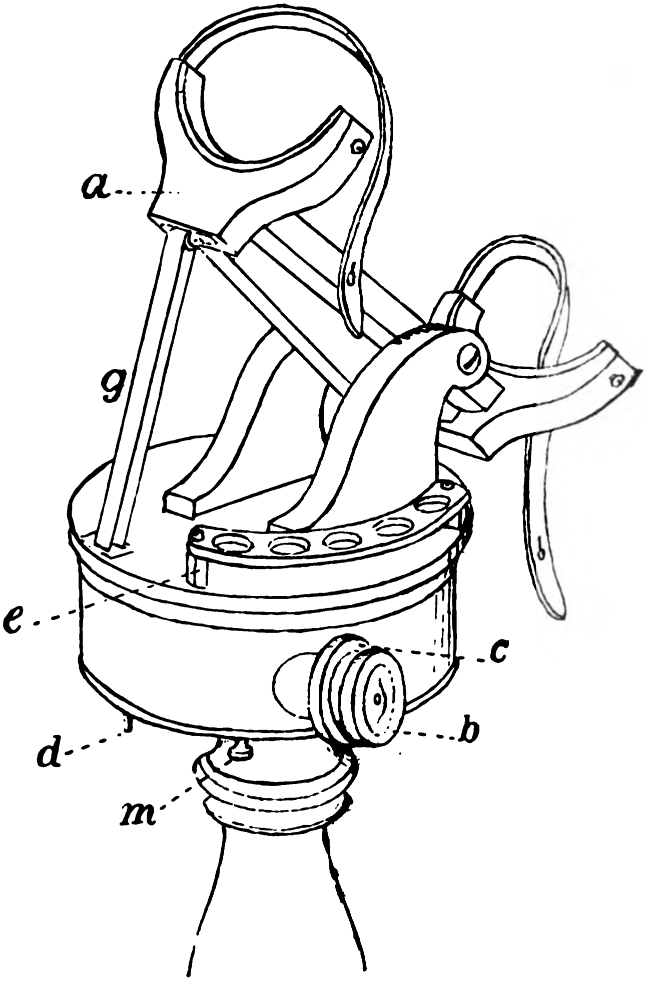

FIG. I.

The connection between the hand-wheel *c* and the roller *h*, which winds the ribbon, is shown in Figure III. This wheel is affixed to a hollow mandril, *i*, (made in this instance of a short piece of brass tubing, one-half inch in diameter, turned carefully round and smooth), to the inner end of which is soldered a toothed wheel, *k*, three-fourths of an inch in diameter, the centre of which was cut away in the lathe, so that it could be slipped over the end of the mandril, little more of it than its teeth being left. This wheel gears with a larger wheel, *l*, attached to the pinion of the roller, *h*. The mandril, *i*, turns freely in its bearings—it passes longitudinally through a cylindrical block of wood, which is glued into the table, in the manner shown in the drawing,—and in order to obtain for it a resistence sufficient to counteract the pull of the tube, the block in which it turns is out away on the under side to allow of the insertion of a brake shoe (not shown in the drawing) that is held in place by a

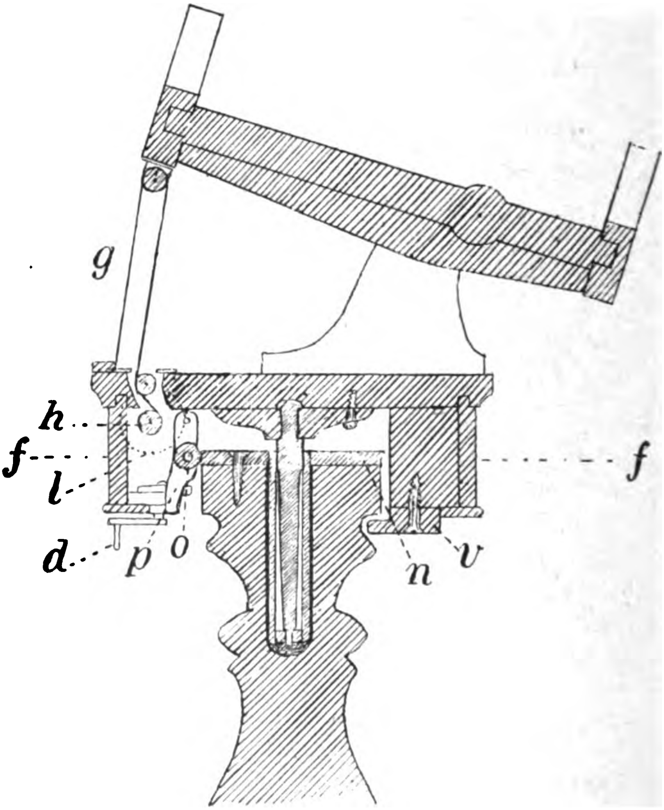

Fig. II.

spring, the pressure of which can be regulated by means of the thumb screw shown at *m*, Fig. 1. It will be seen that through this arrangement a very slow movement, either upward or downward, can be imparted to the tube. Moreover, this movement is the smoothest possible.

The main features of the structure of the table, for obtaining an azimuth movement, will readily be understood from a simple inspection of the drawings. The post of the stand is capped by an iron disc, *n*, which is toothed on its circumference to gear with a worm-wheel, *o*, which is connected, in the manner shown, with the hand-wheel *b*. The rod which carries this worm-wheel is journaled at its inner end to the post or stud, *p*, which has a jointed connection with the top of the table, so as to permit of the worm-wheel being withdrawn from its contact with the disc, *n*, when there is nothing to prevent the table from being turned freely on its spindle. The worm is kept in gear by the pressure of a spring, which acts against the stud, *p*, as shown at *s* in the detached portion of figure III. The

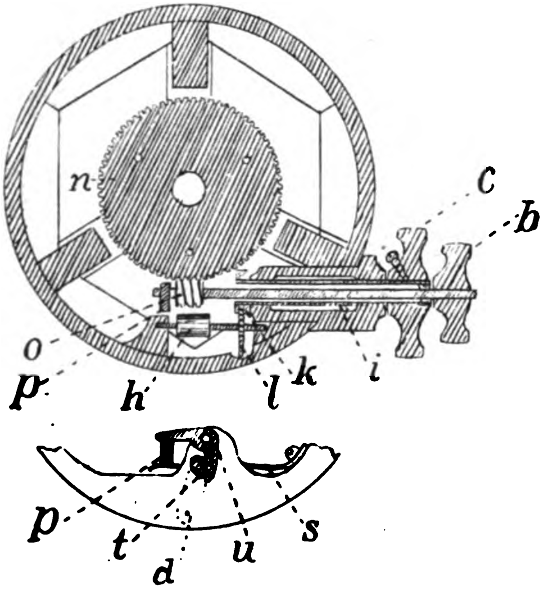

Fig. III.

mechanism for throwing the worm out of gear is shown in the same figure, where *t* is a cam which acts upon the stud *p* through the intervention of an elbowed lever, *u*, as illustrated, and which is connected with the pin and lever *d*, (Figure III.) beneath the table.

To secure the table to the stand yet permit it to rotate freely, a groove'is turned in the upper end of the post of the stand, into which project the ends of three clips, that are screwed to the under side of the table, one of which is shown at *v*, Fig. II.

The feet of the stand are shod with india-rubber pads, which I have found a very efficient protection against the jarring of the ground occasioned by the passing of wagons and street cars.

Of the advantages secured by this mounting, two principal ones may be dwelt upon. First, the wheels *b* and *c* are both turned with the same hand (right or left, as happens to be the most convenient) which can be held continually grasping them losely and can pass from one to the other without "fumbling." A little practice enables one to turn them simultaneously. One of the eye-pieces used with this telescope gives a power of 360 diameters, and I never have any difficulty in keeping an object in its field.

A second great advantage is that the tube may be turned so as to bring the eye-piece (which, of course, is at the upper end, the instrument being of the Newtonian form) into that position which is the most convenient for the observer, thus contributing to his comfort, which, as every one knows, is a great point in observing. A still further and perhaps an equally great advantage secured by the readiness with which the tube can be rotated, is, that one is thereby enabled to view an object under different aspects. Rotating the tube is equivalent to rotating the object, and every experienced observer knows the advantage of this. A quarter of a turn given to the tube gives the whole field a rotation of 90 degrees; directions which were right and left become up and down, and one who has tried this change for the first time, will be surprised to see how differently everything will appear. I have frequently been able to discern without difficulty with the tube in one position a faint object, of the existence of which I was rather uncertain when the tube was in another position.

In conclusion it may be remarked that the mounting above described being made principally of wood (walnut in this case) is calculated for home manufacture.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury, during the first half of December, will be visible to the naked eye just after sunset. The planet sets from an hour to an hour and a half later than the sun. Its altitude is so low, however, that good observations will be almost impossible in the northern hemisphere. Greatest eastern elongation occurs Dec. 11; inferior conjunction Dec. 28 at $3^h 53^m$ P. M. central time. In January Mercury will be "morning star," coming to greatest elongation west from the sun Jan. 19.

Venus is "evening star" with Mercury and Jupiter. Venus and Mercury will be in conjunction, the latter 1° 15′ south of the former, Dec. 5 at 9 A. M. The phase of Venus is nearly full, diminishing to about 0.9 on Jan. 1. Its brilliancy is increasing slowly and the planet will become more easily visible as it recedes eastward from the sun.

Mars is "morning star," rising about four hours before the sun, but is yet too distant from the earth for satisfactory observation, the diameter of his disk being only 5″. Mars and Uranus will be in conjunction, only 29′ apart, Dec. 15, 4 A. M. They will be seen in the same field of view of a small telescope. Uranus will be north of Mars.

Jupiter may be observed only in the early hours of the evening. The last number of the *Monthly Notices* (Vol. LI, p 543) contains an interesting paper by Mr. E. E. Barnard on observations of Jupiter and his satellites during 1890 with the 12-inch equatorial of Lick Observatory, illustrated by a complete drawing of the planet made July 30, 1890, and several partial drawings. The most interesting points are his observations of Satellite I in transit across the planet's disk on Sept. 8, 1890, and Aug. 3, 1891. On the earlier date the satellite traversed a white belt upon the planet and appeared as a double black spot or as two black spots one above the other. On the latter date the satellite traversed a dark belt and was seen as an elongated white spot, the elongation being almost perpendicular to the direction of the double black spot of the earlier transit. These two observations are very plausibly explained by Mr. Barnard as indicating that the satellite has a white belt encircling its equator. When the satellite is seen on the background of a white belt of the same brilliance of the planet, it takes the appearance of two dusky spots which are made round by irradiation. When it is seen in the background of a dark belt of the planet, the white belt of the satellite alone is seen.

Saturn is coming into better position for observation. He may be found toward the east after 1^h A. M. But few observations of the reappearing rings have yet been reported to us. Mr. Marth has published part of his ephemerides of Saturn's satellites in *Monthly Notices*, supplemental No. 1891, but we are sorry that this part extends only to Dec. 22, and that the next number is likely to be too late for this issue of the Messenger. The following are the phenomena of the satellites predicted for December:

	Central Time.	
Dec. 2	12.8 A. M.	Shadow of Rhea in transit. (?)
4	4.9 "	Rhea eclipsed.
6	9.8 P. M.	Shadow of Titan.
11	1.7 A. M.	Shadow of Rhea. (?)
13	5.8 "	Rhea eclipsed.
15	1.1 "	Titan eclipsed.
20	2.6 "	Shadow of Rhea. (?)
22	6.7 "	Rhea eclipsed.
22	9.0 P. M.	Shadow of Titan.

It is not known whether the shadow of Rhea can be seen or not, and it is very desirable that this should be looked for very carefully by those having the use of large telescopes.

Uranus is coming out from behind the sun, but not yet in good position. He may be observed after 4 o'clock in the morning. The conjunction of Uranus with Mars has already been referred to.

Neptune, having just passed the point on the celestial sphere opposite to the sun, is in its best position for observation this year. As it passes the meridian at a high altitude the circumstances are all favorable for excellent views of the planet. The disk of Neptune is, however, so small that a power of 200 or more is necessary to recognize it. To see the satellite requires a large telescope and power of 300 or more.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Dec. 25	18 47.1	− 21 27	7 58 A. M.	12 31.1 P. M.	5 04 P. M.
Jan. 5	17 55.5	− 20 14	6 17 "	10 56.4 A. M.	3 35 "
15	18 05.7	− 21 28	5 54 "	10 27.2 "	3 00 "
25	18 50.6	− 22 34	6 05 "	10 32.9 "	3 01 "
			VENUS.		
Dec. 25	20 01.9	− 22 08	9 16 A. M.	1 45.7 P. M.	6 16 P. M.
Jan. 5	20 58.8	− 18 54	9 14 "	1 59.2 "	6 44 "
15	21 58.1	− 15 02	9 07 "	2 09.0 "	7 12 "
25	22 35.2	− 10 30	8 55 "	2 16.7 "	7 38 "
			MARS.		
Dec. 25	14 35.3	− 14 17	3 14 A. M.	8 20.0 A. M.	1 26 P. M.
Jan. 5	15 00.2	− 16 13	3 07 "	8 04.1 "	1 01 "
15	15 25.5	− 17 58	3 00 "	7 50.0 "	12 40 "
25	15 51.1	− 19 29	2 54 "	7 36.4 "	12 19 "
			JUPITER.		
Dec. 25	22 57.3	− 7 59	11 09 A. M.	4 40.6 P. M.	10 12 P. M.
Jan. 5	23 07.0	− 7 15	10 30 "	4 04.2 "	9 39 "
15	23 10.9	− 6 30	9 54 "	3 31.6 "	9 09 "
25	23 18.4	− 5 42	9 19 "	2 59.8 "	8 41 "
			SATURN.		
Dec. 25	12 03.4	+ 2 03	11 33 P. M.	5 44.6 A. M.	11 56 A. M.
Jan. 5	12 04.1	+ 2 01	10 51 "	5 02.1 "	11 13 "
15	12 04.1	+ 2 05	10 11 "	4 22.7 "	10 34 "
25	12 03.4	+ 2 12	9 31 "	3 42.7 "	9 55 "

URANUS.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Dec. 25	14 12.0	− 12 46	2 45 A. M.	7 56.8 A. M.	1 09 P. M.
Jan. 5	14 13.5	− 12 54	2 04 "	7 15.1 "	12 27 "
15	14 14.6	− 12 59	1 26 "	6 36.8 "	11 48 A. M.
25	14 15.3	− 13 03	12 47 "	5 58.2 "	11 09 "

NEPTUNE.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Dec. 25	4 21.6	+ 19 53	2 37 P. M.	10 04.0 P. M.	5 31 A. M.
Jan. 5	4 20.5	+ 19 50	1 53 "	9 19.7 "	4 46 "
15	4 19.8	+ 19 49	1 13 "	8 39.7 "	4 06 "
25	4 19.2	+ 19 48	12 33 "	7 59.8 "	3 26 "

THE SUN.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Dec. 25	18 16.2	− 23 24	7 36 A. M.	12 00.3 P. M.	4 25 P. M.
Jan. 5	19 04.8	− 22 37	7 37 "	12 05.6 "	4 34 "
15	19 48.3	− 21 07	7 30 "	12 09.6 "	4 41 "
25	20 30.6	− 18 58	7 27 "	12 12.5 "	4 58 "

Jupiter's Satellites.

	Central Time. h m			Central Time. h m	
Dec. 16	4 51 P. M.	I Sh. Eg.	Dec. 30	4 39 P. M.	III Ec. Dis.
18	6 27 "	II Oc. Dis.		5 12 "	I Tr. In.
19	5 10 "	III Tr. In.		6 25 "	I Sh. In.
	8 38 "	III Tr. Eg.		7 31 "	I Tr. Eg.
20	4 17 "	II Sh. In.		7 40 "	III Ec. Re.
	4 31 "	II Tr. Eg.		8 42 "	I Sh. Eg.
	7 06 "	II Sh. Eg.	31	6 00 "	I Ec. Re.
	9 03 "	IV Oc. Dis.	Jan. 3	7 04 P. M.	II Tr. In.
21	8 43 "	I Tr. In.	5	6 29 "	II Ec. Re.
	10 01 "	I Sh. In.	6	4 41 "	IV Oc. Dis.
22	6 04 "	I Oc. Dis.		7 12 "	I Tr. In.
	9 36 "	I Ec. Re.		7 15 "	III Oc. Re.
23	4 30 "	I Sh. In.	7	4 32 "	I Oc. Dis.
	5 32 "	I Tr. Eg.		7 56 "	I Ec. Re.
	6 47 "	I Sh. Eg.	8	5 07 "	I Sh. Eg.
25	9 11 "	II Oc. Dis.	10	9 50 "	II Tr. In.
26	9 25 "	III Tr. In.	14	4 13 "	II Sh. Eg.
27	4 21 "	II Tr. In.		6 32 "	I Oc. Dis.
	6 54 "	II Sh. In.	15	4 46 "	I Sh. In.
	7 14 "	II Tr. Eg.		5 53 "	IV Sh. Eg.
	9 43 "	II Sh. Eg.		6 01 "	I Tr. Eg.
29	8 03 "	I Oc. Dis.		7 03 "	I Sh. Eg.
	8 33 "	IV Sh. In.			

Configuration of Jupiter's Satellites at 7:30 p. m., for an Inverting Telescope.

Jan. 1	4 2 1 ○ 3	Jan. 12	3 1 ○ 4 ●	Jan. 22	4 2 ○ 3 1
2	4 ○ 3 1 2	13	3 ○ 1 2 4	23	○ 4 1 2 3
3	4 3 1 ○ 2	14	2 1 ○ 4 3	24	1 ○ 2 4 3
4	4 3 2 ○ 1	15	2 4 1 ○ 3	25	3 2 ○ 1 4
5	3 4 1 ○ 2	16	4 ○ 1 2 3	26	3 1 2 ○ 4
6	○ 1 2 ● ●	17	4 1 3 ○ 2	27	3 ○ 1 2 4
7	2 ○ 4 3 ●	18	4 3 2 ○ 1	28	1 ○ 3 4 2
8	2 1 ○ 3 4	19	4 3 1 2 ○	29	2 ○ 1 3 4
9	○ 1 3 2 4	20	4 3 ○ 1 2	30	○ 2 4 3 ●
10	1 3 ○ 2 4	21	4 1 2 ○ 3	31	1 ○ 3 4 2
11	3 2 ○ 1 4				

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A..............$0^h\ 52^m\ 32^s$
Decl.............. + 81° 17′
Period ....$2d\ 11^h 50^m$

Dec.	16	3 P. M.
	19	3 A. M.
	21	3 P. M.
	23	2 A. M.
	28	2 "
Jan.	2	2 "
	7	1 "
	12	1 "
	17	1 "
	21	midn.
	26	midn.
	31	midn.

ALGOL.

R. A.............$3^h\ 01^m\ 01^s$
Decl..............+ 40° 32′
Period..........$2d\ 20^h 49^m$

Dec.	18	3 P. M.
	30	2 A. M.
Jan.	1	11 P. M.
	4	7 "
	7	4 "
	19	3 A. M.
	21	midn.
	24	9 P. M.
	27	6 "
	30	3 "

λ TAURI.

R. A............ $3^h\ 54^m\ 35^s$
Decl.............. + 12° 11′
Period........$3d\ 22^h\ 52^m$

Dec.	16	6 A. M.
	20	4 "
	24	3 "
	28	2 "
Jan.	1	1 "
	4	midn.
	8	11 P. M.
	12	10 "
	16	9 "
	20	7 "
	24	6 "
	28	5 "

R CANIS MAJ.

R. A........... $7^h\ 14^m\ 30^s$
Decl............... −16° 30′
Period $1d\ 03^h 16^m$

Dec.	19	7 P. M.
	20	10 "
	22	1 A. M.
	23	5 "
	27	6 P. M.
	28	9 "
	30	1 A. M.
	31	4 "
Jan.	5	8 P. M.
	6	11 "
	8	3 A. M
	13	7 P. M.
	14	10 "
	16	2 A. M.
	17	5 "
	21	6 P. M.
	22	9 "
	23	midn.
	25	4 A. M.
	30	8 P. M.
	31	11 A. M.

S ANTLIÆ.

R. A........... $9^h\ 27^m\ 30^s$
Decl............ − 28° 9′
Period........$0d\ 07^h\ 47^m$

Dec.	16	5 A. M.
	17	4 "
	18	3 "
	19	3 "
	20	2 "
	21	1 "
	22	1 "
	22	midn.
	23	11 P. M.
	24	11 "
	25	6 A. M.
	26	6 "
	27	5 "
	28	4 "
	29	4 "
	30	3 "
	31	2 "
Jan.	1	2 "
	2	1 "

S ANTLIÆ, Cont.

Jan.	2	midn.
	3	"
	4	11 P. M.
	5	10 "
	6	6 A. M.
	7	6 "
	8	5 "
	9	4 "
	10	4 "
	11	3 "
	12	2 "
	13	2 "
	14	1 "
	14	midn.
	15	midn.
	16	11 P. M.
	17	10 "
	18	6 A. M.
	19	5 "
	20	5 "
	21	4 "
	22	3 "
	23	3 "
	24	2 "
	25	1 "
	26	1 "
	26	midn.
	27	midn.
	28	11 P. M.
	29	10 "
	30	10 "

S. CANCRI.

R. A........... $8^h\ 37^m\ 39^s$
Decl.............. + 19° 26′
Period.........$9d\ 11^h\ 38^m$

Dec.	30	9 P. M.
Jan.	18	8 "

U. CORONÆ.

R. A...........$15^h\ 13^m\ 43^s$
Decl...............+ 32° 03′
Period........$3d\ 10^h\ 51^m$

Dec.	17	6 A. M.
	24	4 "
	31	1 "
Jan.	24	5 "
	31	3 "

Lunar Eclipse at Northfield. During the greater part of the time of the eclipse at Northfield, Nov. 15, the sky was thickly covered with clouds, so that all observations of use were impossible.

Approximate Central Times when the Great Red Spot passes the Central Meridian of Jupiter.

	d	h	m			d	h	m			d	h	m	
Dec.	16	8	36	P. M.	Jan.	1	11	47	P. M.	Jan.	17	5	02	P. M.
	17	4	27	"		2	7	38	"		18	10	49	"
	18	10	14	"		3	3	30	"		19	6	40	"
	19	6	06	"		4	9	17	"		20	2	32	"
	20	11	53	"		5	5	08	"		21	8	19	"
	21	7	44	"		6	10	55	"		22	4	10	"
	22	3	35	"		7	6	46	"		23	9	57	"
	23	9	22	"		8	2	38	"		24	5	48	"
	24	5	14	"		9	8	25	"		25	1	40	"
	25	11	01	"		10	4	16	"		26	7	27	"
	26	6	52	"		11	10	03	"		27	3	18	"
	27	2	43	"		12	5	54	"		28	9	05	"
	28	8	30	"		13	11	41	"		29	4	56	"
	29	4	21	"		14	7	33	"		30	10	43	"
	30	10	08	"		15	3	24	"		31	6	34	"
	31	6	00	"		16	9	11	"					

Phases and Aspects of the Moon.

	Central Time.	d	h	m	
Last Quarter	Dec.	22	11	39	P. M.
Apogee	"	23		Noon.	
New Moon	"	30	9	20	P. M.
Perigee	Jan.	5	11	06	A. M.
First Quarter	"	6	7	12	P. M.
Full Moon	"	13	9	27	P. M.
Apogee	"	20	9	12	A. M.
Last Quarter	"	21	9	43	P. M.
New Moon	"	29	10	38	A. M.

Occultations Visible at Washington.

Date. 1891—2	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle from N. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle. from N. °	Duration. h m
Dec. 17	λ Canceri	5.7	12 36	128	13 57.9	256	1 22
18	B.A.C. 3138	6.3	11 30	77	12 44.4	311	1 14
19	η Leonis	3.3	13 48	141	15 10.2	272	1 22
Jan. 8	σ Piscium	5.5	6 04	15	7 01	276	0 57
10	τ Tauri	4.5	4 10	85	5 08	229	0 58
10	99 Tauri	6	13 03	128	13 53	221	0 50
11	139 Tauri	5	12 49	98	14 03	264	1 14
12	39 Geminorum	6	13 06	134	14 08	244	1 09
16	*i* Leonis	6	11 14	175	11 51	232	0 57
24	18 Ophiuchi	7	17 25	74	18 24	334	0 23

Dark Transit of Jupiter's Third Satellite. Last night, Nov. 6, at 5^h 17^m P. M. (90th M. T.), I observed a dark transit of Jupiter's third satellite—intensely dark and apparently smaller than its shadow which it preceded 5 hours. My observations extended from 6 minutes after ingress until egress, 4 minutes before which the intensity began gradually fading away until it was with difficulty held steadily with my 4¾-inch telescope.

At beginning of emersion the bright image protruded from the disk of Jupiter as in ordinary transits but wanting in brilliancy.

Charlestown, Ind. WILLIS L. BARNES.

COMET NOTES.

Ephemeris of Comet 1891 (Wolf's Periodic Comet).

(Continued from page 469.)

	App. R. A.			App. Decl.		log Δ
	h	m	s	°		
Dec. 12	4	18	16	− 14	40.4	0.0068
13		17	50		43.6	
14		17	26		46.3	0.0146
15		17	03		48.4	
16		16	41		49.9	0.0224
17		16	21		50.9	
18		16	03		51.4	0.0304
19		15	46		51.4	
20		15	30		50.8	0.0384
21		15	16		49.8	
22		15	04		48.3	0.0466
23		14	53		46.4	
24		14	44		44.0	0.0548
25		14	37		41.2	
26		14	31		38.0	0.0630
27		14	27		34.3	
28		14	25		30.3	0.0713
29		14	24		26.0	
30		14	25		21.2	0.0796
31		14	28		16.2	
Jan. 1	4	14	33	− 14	10.8	0.0879

Ephemeris of Winnecke's Periodic Comet.

(From Astr. Nach. No. 3062.)

Berlin Mid-night.	App. R. A.	App. Decl.	log. r.	log. Δ	$\frac{1}{r^2 \Delta^2}$
1891 Dec. 5	11 46 31	+ 13 07.1	0.4233	0.4150	0.021
6	47 43	05.1			
7	48 55	03.3			
8	50 07	01.6			
9	51 18	13 00.0	0.4179	0.4002	0.023
10	52 29	12 58.5			
11	53 40	57.1			
12	54 50	55.9			
13	56 01	54.8	0.4124	0.3850	0.025
14	57 11	53.8			
15	58 20	52.9			
16	59 30	52.2			
17	12 00 39	51.6	0.4067	0.3691	0.028
18	1 48	51.2			
19	2 56	50.9			
20	4 04	50.8			
21	5 12	50.8	0.4009	0.3528	0.031
22	6 19	50.9			
23	7 27	51.3			
24	8 33	51.8			
25	9 40	52.4	0.3949	0.3559	0.035
26	10 46	53.3			
27	11 51	54.3			
28	12 56	55.5			
29	14 01	56.8	0.3889	0.3184	0.039
30	15 05	58.4			
31	16 09	13 00.2			

Berlin Midnight.		App. R. A.	App. Decl.	log r	log Δ	$\frac{1}{r^2\Delta^2}$
1892 Jan.	1	17 12	02.1			
	2	18 15	04.2	0.3827	0.3004	0.043
	3	19 17	06.6			
	4	20 19	09.1			
	5	21 20	11.9			
	6	22 20	14.9	0.3763	0.2818	0.048
	7	23 20	18.1			
	8	24 20	21.5			
	9	25 19	25.2			
	10	26 17	29.0	0.3698	0.2626	0.054
	11	27 15	33.2			
	12	28 12	37.5			
	13	29 08	42.1			
	14	30 04	47.0	0.3632	0.2430	0.061
	15	30 59	+ 13 52.1			

Brooks' Periodic Comet, 1886 IV. In *Astronomische Nachrichten*, No. 3064, Dr. S. Oppenheim gives the results of his investigations of the orbit of this comet. He finds the observations of 1886 to be best represented by a period of 5.60 years. They are, however, fairly well represented by periods varying three months each way from this, so that the time of return to perihelion is very uncertain. The most probable system of elements would bring the comet to perihelion January 13, 1892. It would then be in unfavorable position to be seen from the earth and there would be little hope of detecting it. If perihelion should occur earlier than that time the conditions would be still more unfavorable. Should the comet delay its return until April or May it would be in the best possible position to be found. Dr. Oppenheim has calculated six search-ephemerides, varying the time of perihelion 30 days between each set. We give part of the first two

	Perihelion March 1.			Perihelion March 31.		
1892	α	δ	Light	α	δ	Light
	h m	° ′		h m	° ′	
Jan. 1	14 45.8	− 7 28	0.09	13 47.3	+ 1 46	0.10
11	15 17.6	− 16 33	0.11	14 15.8	− 0 52	0.12
21	15 51.3	− 13 33	0.13	14 44.6	− 3 34	0.14
31	16 26.5	− 10 20	0.15	15 14.4	− 6 17	0.17
Feb. 10	17 02.6	− 18 50	0.16	15 45.9	− 9 03	0.22
20	17 39.6	− 20 58	0.18	16 18.8	− 11 49	0.27

Double Shadow of Jupiter's Satellite I. On the night of Nov. 14, after the egress of Jupiter's Satellite I, I was watching the shadow as it hung on the edge of the great red spot, and while intently observing, the round shadow seemed to become oblong, in which form it stayed for at least thirty minutes and then the shadow seemed to open and presented a double shadow, both round and black, the one much smaller than the other.

Was it really a double shadow or was the second shadow a smaller interior body?

It might have been the result of the larger shadow's contact with a dark spot in the belt, but the little black dot remained after the egress of the shadow of I.

H. O. HOFFMAN.

Bloomington, Ill.

NEWS AND NOTES.

This issue closes the tenth volume of THE MESSENGER, and, with it, a large number of subscriptions expire. After reading the notices of change of plan of publication, for the next year, all those whose subscriptions have expired are respectfully asked to notify the publisher at Northfield, Minnesota, whether or not the publication is desired for the year 1892.

Materially Changed and Enlarged. Commencing with the January number the name of this publication will be *The Sidereal Messenger and Astro-Physical Journal.* The subscription price for the year 1892 will be four dollars, and the number of pages in each of the ten regular issues for the year, will be at least eighty, and a greater number when occasion requires it. The sizes and kinds of type, in general, will be the same as those heretofore used, but the size of the page will be somewhat increased to admit larger plates and cuts which may be called for in illustrated articles to which special attention will be given.

Reasons for Change of Plan of Publication. In view of the recent wonderful discoveries in Astro-Physics by the aid of the spectroscope and the photographic plate, it has been thought wise to give more special attention to the theme of spectroscopy, and in order to do this, large increase of space is necessary to represent well the varied work that is now going on in this new field of science in Europe and America. To accomplish this in the best and most successful way, additional editorial help is also necessary, and it is our good fortune to announce, that Professor George E. Hale, Director of the Kenwood Physical Observatory, of Chicago, has recently decided to take charge of that part of the editorial work, and it gives us great pleasure to say that he will have full control of all the matter pertaining to research in this and kindred branches of Physics. For this responsible position, we are sure, no better choice could have been made, especially among our younger scientific men, for he is a ready writer, among the foremost in his chosen field of research, and his recent discoveries in photographing the solar prominences have justly drawn attention to his work from leading scientists in all parts of the world.

For a year or more, Dr. H. C. Wilson, Assistant Professor of Astronomy at Carleton College, has prepared nearly all the data that have appeared under the title of *Current Celestial Phenomena*, and it is a gratification to us to announce that he will continue in charge of this work for the coming year with such changes in plan as seems to him wise.

With all this very considerable increase of expense for the coming year, it is sincerely hoped that our old subscribers will stand by us, and thereby aid in making this publication in its new form one of the strongest and best journals possible in the kindred branches of Physics and Astronomy.

Chart of the Metric System. The American Metrological Society has recently published a chart of the Metric System, containing figures illustrating the length of the meter, decimeter, centimeter and dimensions of other units of the system. The chart is printed in bold type and the figures drawn to such a scale as to make it easy for any one not acquainted with the system to use it readily and intelligibly. This chart ought to be in every school room in the land. It costs only ten cents and it can be obtained by applying to the American Metrological Society, 41 East 49 Street, New York City.

New Superintendent of the British Nautical Almanac. Mr. Arthur M. W. Downing has been appointed to succeed Dr. Hind as superintendent of the British *Nautical Almanac.* He will enter upon the responsibilities of his office at the beginning of next year. Mr. Downing is, at present, one of the chief assistants at the Royal Observatory at Greenwich, having been connected with that institution for many years. He is also one of the secretaries of the Royal Astronomical Society. We but repeat the words of one of the prominent English astronomers in saying that no more competent man for the post could have been selected.

Underwood Observatory. The erection and equipment of the Underwood Observatory at Lawrence University, Appleton, Wis., is of interest from a scientific standpoint, and also because it shows what a man can accomplish if he is determined in his undertaking.

In June, 1886, Professor L. W. Underwood was elected to the chair of Astronomy and Mathematics in Lawrence University. At that time the only appliances for astronomical work in the institution was a 5-inch telescope on wheels, to be rolled from one side of the cupola of the University building to the other; the roof of the cupola prevented any observations within 45° of the zenith, and hence the whole outfit was practically a failure.

Enthusiasm in astronomical work, however, began to increase, and in the fall of 1889 Professor Underwood determined to have a first-class astronomical outfit for educational work. Accordingly he set to work to bring about the much needed addition to the University. Having planned a building he presented his case to the citizens of Appleton asking them to contribute the necessary funds to erect the building, on condition that the instruments be secured from outside parties. The money for the proposed building was readily pledged and at the annual meeting of the Trustees in June, 1890, Professor Underwood made the following proposition (quoted from his report at dedication) "I will undertake the completion of this enterprise provided you will pay my traveling expenses necessary to the raising of the money." The proposition was accepted, and in seven weeks time $17,000 had been secured to the enterprise and to-day Lawrence University has an astronomical outfit consisting of a ten-inch Clark equatorial, a four-inch transit, mean time and sidereal clocks, a chronograph and a spectroscope. For ***educational*** work there are, if I mistake not, but three observatories in the United States that have more elaborate outfits than has Lawrence, and this is due to the energy and perseverence of one man.

The telescope is a gift of Hon. Philetus Sawyer, of Oskosh, Wis.; the sidereal clock was donated by Mr. Woodard, of Clinton, Wis.; the mean time clock, by Mrs. Witter, of Grand Rapids, Wis.; the chronograph, by

Mr. and Mrs. Elmore, of Milwaukee and the spectroscope by Mr. Britten, of Green Bay, Wis.

The planning of the building, the securing of the money and, in fact, everything connected with the enterprise is the result of Professor Underwood's personal work and I am confident that, if properly used, the university will be known farther on account of this work than for any other it has ever accomplished.

Professor Underwood and those who have thus made liberal donations in the interest of science, are entitled to much credit, and the Professor should be generously treated by the board of trustees in order that this auspicious beginning may accomplish the utmost good, and that his services may not be required in other fields.

I had the pleasure of being present and delivering the address at the dedication, and also had an opportunity of visiting the Observatory. The building is exceedingly complete and convenient in all its appointments, and for all the purposes for which it is intended can not well be improved. The ten-inch Clark equatorial, mounted by Professor H. G. Sedgwick, of Nashville, Tenn,, is especially to be commended for the solidity and stability of its mounting and the convenience of its appointments, and is everything that can be desired for educational work.

M. D. EWELL, M. D., LL. D.

Variability of the Nucleus of the Great Nebula of Andromeda. On my first examination of the Andromeda Nebula with the 16-inch refractor of Goodsell Observatory on the night of Nov. 9, 1891, I was struck with the stellar appearance of the nucleus of the nebula. My recollection of the nebula in former years and with different telescopes was that the nucleus, although very much condensed, became diffuse on the application of high powers. On this occasion, however, there was a point in the nucleus which became more starlike with each increase of power above 200. The nebulosity faded out almost entirely, leaving a perfect star, about equal in brightness to the nearest star preceding the nucleus by about 11ˢ. This star is spoken of by Professor Young (SID. MESS. Vol. IV, p. 282) as of the 11th magnitude.

Again on Nov. 19, from 7:45 to 8:00 P. M., I examined the nebula and found the same stellar appearance with high powers. With low powers the point seems nebulous and is almost in the center of the nucleus, but with high powers it is in the lower (northern) part of the nucleus. It is equally bright with the star to the left (preceding) and less bright than the one directly above (south)

It will be remembered that in 1885 a new star appeared in this nebula a few seconds north of the center of the nucleus, which rapidly diminished in brightness until after a few months it became invisible in the largest telescopes. My impression on Nov. 9 was that this star had again appeared, but the present star seems to be nearer the center of nucleus; its distance cannot exceed 2″.

In the "*English Mechanic*" for Nov. 6, 1891, just received, Mr. D. Packer calls attention to the apparent variability of the nucleus of the Andromeda nebula. Collating observations from various sources, some of them made at the time when the new star of 1885 was visible, he derives a possible period of 45.2 days between maxima. The last maximum noted by Mr. Packer was about Sept. 11, 1891. Carrying forward the period 45.2 days would bring my own observations at about the time of a minimum.

Mr. Isaac Roberts had already announced photographic evidence of variability in the nucleus of this nebula in *Monthly Notices*, Jan., 1891. In some of his photographs of the nebula the nucleus appears strongly stellar, in others not at all so. The stellar appearance is independent of the duration of exposure, plates exposed 5^m, 15^m, 1^h and 3^h all showing it. The following is the summary of evidence from Mr. Robert's photographs:

1885, Aug. 30, exposure 30 minutes, no stellar nucleus.
1886, Oct. 24, 73 minutes, faint stellar nucleus.
1887, Oct. 10, 3 hours, very faint stellar nucleus.
1887, Nov. 15, 2 hours, 35 minutes, no trace of stellar nucleus.
1888, Oct. 1, 2 hours, no stellar nucleus.
1888, Oct. 2, 2 hours, 32 minutes, no stellar nucleus.
1888, Dec. 29, 4 hours, no stellar nucleus.
1890, Oct. 12, 3 hours, 5 minutes, not stellar.
1890, Nov. 1, 15 minutes, nucleus very strongly stellar.
1890, Dec. 9, 5, 15 and 60 minutes, nucleus strongly stellar on each plate.

It seems important, from the above that very close watch should be kept over the nebula of Andromeda, especially by those having telescopes of considerable aperture, so that data may be forthcoming from which to investigate the period and cause of variation of the nucleus. There are also several stars in the vicinity which seem to vary in light. H. C. W.

The Total Lunar Eclipse of Nov. 15 was not observed very generally because of cloudy weather, as we have learned by private correspondence. We are under obligations to Mr. J. R. Hooper of Baltimore for the following account of observations at Philadelphia: "The eclipse this evening was viewed with scientific care from the astronomical observatories at Haverford College and the High School. At the latter institution Professor Monroe B. Snyder was on hand with a class of fifty students. The cloudy weather that prevailed during the advent and consummation of the eclipse was a great disappointment to Professor Snyder, as it prevented all accurate views. At 7:52 o'clock, however, just before totality of eclipse was reached, the sky cleared, and the atmosphere became very propitious. The professor had hoped, during the time of totality, to observe the immersion and emersion of the stars, which can be viewed more conveniently at this period. The only stars that he distinguished, however, were of the eighth and tenth magnitude." These were not identified.

New Director at Detroit Observatory. Since the appointment of Professor W. W. Campbell to the position of Astronomer at Lick Observatory there has been a vacancy at Ann Arbor, in the Detroit Observatory, at least so far as resident director is concerned. At a meeting of the Board of Regents of the University of Michigan, Nov. 18, Professor W. J. Hussey was appointed Acting Director. We learn with pleasure that this needful provision is made that the old and well-known Observatory at Ann Arbor may continue its scientific work for which it has been so justly famed in the past.

History of the Telescope. In the address of Professor Hastings on the history of the telescope, given in your August number, I was surprised to read (p. 340):—"Another notable discovery of this period was that of the duplicity of the rings of Saturn by the Ball brothers in 1665, though its independent discovery by Cassini ten years later first attracted the attention of astronomers." It is now well known that the belief that the Ball brothers made this discovery was founded on mistake. More than ten years ago, I drew attention to the doubtfulness of it, and in consequence of the investigation which was soon afterwards initiated by myself (see "The Observatory," Vol. V., p. 331, Nov. 1882, Vol. VI, p. 185, June 1883), the nature of the misconception which attributed the discovery to William and Dr. Ball was fully explained. Cassini was the first to notice the principal division in Saturn's ring.

Aug. 31, 1891, London, W. W. T. LYNN.

The delay in publishing Mr Lynn's letter is partly accounted for by our vacation months of summer, and partly on account of delay in correspondence to account for the differences of statement by Mr. Lynn and Dr. Hastings. Speaking of Mr. Lynn's criticism, Dr. Hastings said "It led me to look at the original communication in Phil. Trans. 1666. It is truly surprising that it should have been assumed from that account that the Ball brothers saw the division in the ring: and yet Grant's History of Astronomy, Newcomb's Popular Astronomy and countless other works of less authority make the statement unreservedly that these observers anticipated Cassini by ten years.

"The order of discovery, arranged in order of difficulty, should have been, I am quite sure, Cassini's division and then the three smaller of the old five satellites; certainly the division should have been discovered before III and IV."

Mr. U. W. Lawton, of Jackson, Mich., favors us with a large photograph of his private Observatory and a brief description of its inside arrangement. He has a fine 4-inch Clark equatorial, and he now wishes to obtain a good driving clock and position micrometer. Also a two-inch transit instrument. Persons having good second-hand instruments of the kind named who wish to dispose of them may possibly do so from information herein given.

Professor F. H. Bigelow's Recent Discoveries. At the recent meeting of the International Polar Commission at Munich, General A. W. Greely brought to the attention of the Commission the discoveries and investigations of Professor Frank H. Bigelow in regard to magnetism, so fully described in *The Tribune* last September. General Greeley strongly urged some action on the part of the Commission toward the discussion of this important subject. Professor Neumayer, director of the Deutsche Seewarte, supported General Greely's view of the question. It appeared, however, that the delegates from a majority of the countries represented had limited powers, which terminated with the publication of the observations made by their own expeditions. As the reports of the delegates indicated that all the missing reports are in process of publication, the Commission dissolved. But before final adjournment the merits of Professor Bigelow's paper were discussed in the most favorable manner by several members of the Commission, especially by Professor Neumayer, of Germany, and the distinpuished representative from France, Professor Mascart, of the College of France. The sentiment was so favorable that the Commission delegated to a committee its powers, and authorized it to act in its name. General Greely was named as president, with Professors Mascart and Neumayer as colleagues. The committee was further to invite as co-operating members Professor Mendenhall, of the United States Coast and Geodetic Survey, and Professor Harrington, of the United States Weather Bureau. The committee believes that the work begun so successfully by Professor Bigelow will supplement largely, if it does not entirely perfect, the Gaussian theory of magnetism. It is hoped that through Professor Harrington's action in appointing Professor Bigelow a professor of the Weather Bureau, the latter gentleman may be enabled to pursue his researches far enough to reach results of importance to both magnetism and meteorology.—*N. Y. Tribune, Nov. 10, 1891.*

The Sydney Observatory. A pamphlet recently published by John Tebbutt sets forth some facts of interest concerning the Sydney Observatory of New South Wales. From this pamphlet we learn that the Minister of Public Instruction, Sept. 9, 1891, brought before the Legislature of New South Wales, a statement of the number of persons employed in the Government Observatory and the salaries paid in the years 1880 and 1890, together with the total cost of the establishment, including instruments for ten years, which was £41,103 and that of this sum £24,598 was paid for the maintenance of the meteorological department alone. These facts were published, and some public criticism was made in respect to the large amount proportionally expended for meteorology and the small results that had latterly accrued in the interest of astronomy. Mr. Tebbutt then wrote an article for publication in the "Herald," of Sydney which for some reason did not appear. The article gives a brief but interesting account of the work done in the past at the Sydney Observatory, and justly speaks of it with commendation, but it also calls attention to the small amount of published results that have appeared during late years and questions the wisdom of allowing observations to amass in this way, wherein the danger of loss of them is great to say nothing of the disadvantage to science in such delay of publication. Because Mr. Tebbutt's article was rejected, he has published the facts in pamphlet form.

Washington Amateur Astronomical Society. By kindness of Mr. W. E. Woods, Washington, D. C., information was given too late for last month's publication, that a project was on foot in the Capitol City, to form an Amateur Astronomical Society. Something of its plan, as then understood, may be gathered from the following brief statements furnished by Mr. Woods: The "Amateur Astronomical Society of Washington" is projected for the purpose suggested by its title. When organized, it will welcome all lovers of astronomy within its portals, and followers of other branches of science will be admitted to membership with an equal welcome. If it becomes a certainty, it will be especially favored in its investigations by the tendered use of two well-equipped private observatories, and a laboratory, also private, where the highest classes of astronomical, astrophysical, and analytical work can be performed. Further, it is intended in the future that the society will be addressed at least once a week by some eminent professor of science, and further considerations will probably be obtained from the Naval Observatory, when that is completed and all its instrumental arrangements are perfected. No city of this or any foreign country offers better facilities or inducements for the amateur scientist, than Washington, and the material for the organization to be obtained here is, if anything, superior to that of most other cities. The annual meetings of other societies in this city will give the new society superior advantages.

Astronomical Physics. Judging from the evidences that have come to hand during the last ten days, the large venture that THE MESSENGER makes in practically adding another and a new journal to its contents, we have not mistaken the wants of our readers or wrongly estimated the field of our patronage. As we have pondered this thing carefully, we are more and more certain that astronomy of position needs the help of Astro-physics and that the old and the new should be side by side, constantly lending to each other the mutual aid they are naturally calculated to give.

BOOK NOTICES.

Star-Land. Being Talks with Young People about the Wonders of the Heavens. By Sir Robert Slawell Ball, F. R. S., Royal Astronomer of Ireland. Publishers, Messrs. Ginn & Company. 1892, pp 384. Introduction. Price $1.00.

This book is just what its name indicates. It had its origin in two courses of lectures provided by the Royal Institution of Great Britain, at Christmastide by the author, in the years 1881 and 1887, and which were prepared for juvenile audiences. The course consists of seven lectures on the following themes, viz.: The Sun, Moon, Inner Planets, Giant Planets, Comets and Shooting Stars, Stars and How to Name the Stars. Each lecture presents the essential points belonging to its subject, in easy-worded language, and illustrations are given frequently where needed to avoid obscurity of statements, or to give more definite ideas for the grasp of young minds in dealing with the great thoughts common to the study of Astronomy. The verbal illustrations used by the author, in bringing out the various phases of his subjects, are very excellent, and we do not see how the presentation of this matter could have been made more useful or interesting. We wish young people everywhere could be favored as royally in this way, as is the custom in Great Britain by giving annually such a course of illustrated lectures. Where this is not done, the next thing is to provide for them good books and encourage the reading of them. This book is especially suited to interest and instruct young people in Astronomy.

Copernic et la Découverte du Systéme du monde. Par Camille Flammarion. Librairie Marpon & Flammarion, 26 Rue Racine, près l'Odéon, Paris.

This excellent little book of 249, 12mo pages is the first of a series of works which the able French astronomer, Camille Flammarion, is writing on the general subject of "Astronomy and its Founders." He takes Copernicus, Galileo, Kepler and Newton as the real founders of modern astronomy and proposes "to write the history of these great geniuses in a popular form which will set forth scientific truth at the same time with the life and works of these illustrious men." If the author succeeds as well in the later works as in the first one, he will certainly have performed a very useful service in bringing within reach of all the facts and causes in the lives of these men which led to their great success.

This book is written in very simple and pleasing style and is interesting throughout. The first chapter gives a statement of the ancient ideas of astronomy and the state of the science at the time of Copernicus. The following chapters give account of his ancestry, childhood, early influences and education, study of medicine at Cracow, choice of astronomical vocation, visit at Rome, first astronomical researches, etc. All those facts are given which one likes to know about a great man. His works are then taken up, and those studies which led up to his abandonment of the old theory of the universe and construction of the new system, his long hesitation and final decision to publish his book and dedicate it to the Pope, are treated in an interesting manner. The last chapter gives very brief accounts of the life and works of Copernicus' successors, Tycho Brahe, Moestlin, Galileo, Kepler and Newton. In an appendix a useful résumé of the works of Copernicus is given.

ALPHABETICAL INDEX.