POPULAR

ASTRONOMY.

BY THE WORD OF THE LORD WERE THE HEAVENS MADE.

PLAINLY WORDED AND UNTECHNICAL IN LANGUAGE.
AMPLY ILLUSTRATED.

ISSUED MONTHLY, EXCEPT FOR JULY AND AUGUST.
SUBSCRIPTION PRICE, $2.50 IN ADVANCE.

VOL. I.

1893-4.

EDITORS:

WILLIAM W. PAYNE. CHARLOTTE R. WILLARD.

OFFICE OF PUBLICATION:
GOODSELL OBSERVATORY OF CARLETON COLLEGE,
NORTHFIELD, MINNESOTA.
1894.

CONTENTS BY NUMBERS.

SEPTEMBER.

OCTOBER.

NOVEMBER.

DECEMBER.

JANUARY.

FEBRUARY.

MARCH.

APRIL.

MAY.

JUNE.

ILLUSTRATIONS.

PUBLISHERS' NOTICES.

The accompanying Star map, title page and indexes, completes Vol. I of POPULAR ASTRONOMY.

About one-fourth of the subscribers to the first volume have responded to the early request made respecting continuance and increase of support. Some have renewed, and sent in new names also.

The Poole Star Maps, and Professor Upton's splendid articles on Constellation Study, are alone worth the price of Volumes I and II. These excellent helps for teachers of Elementary Astronomy can now be procured at $2.50 per volume, pamphlet form. They should be ordered early, for teachers' reference, and the High School library.

It is especially requested of *all subscribers*, who have not already done so, that they promptly inform the publisher of this magazine if they desire its continuance for Volume II., that its September number may be mailed to all by the *20th of August.*

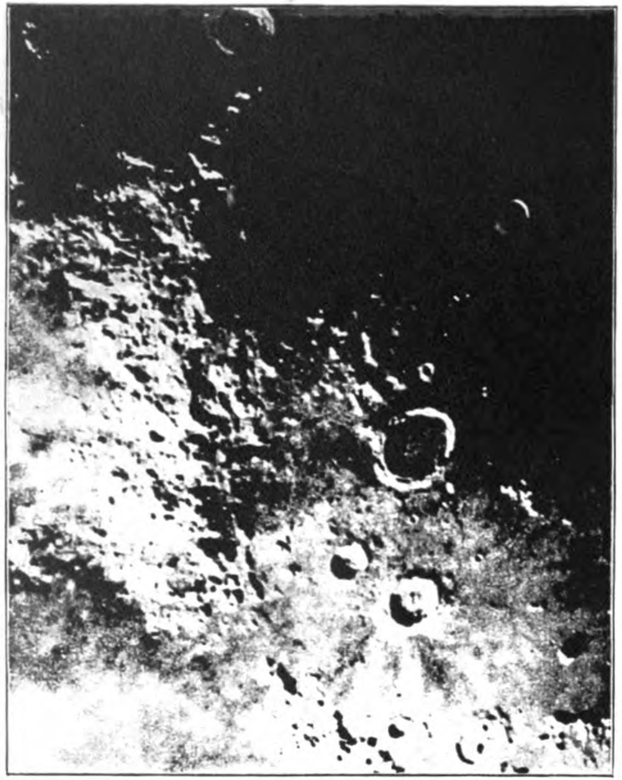
Poole Brothers, of Chicago, the publishers of Poole Brothers' Celestial Planisphere and Handbook, will soon bring out a new, large Map of the Moon. Some notice of this was given in our June issue. As the work progresses, under the skillful hand of Mr. Colas, we have become more and more interested in it, and have spent much time in examining its details, compared with those given by the standard authors. They are very accurate

In binding Volume I, the accompanying Star Map should be placed immediately after the one in the June number for July 15, and the index by months should follow title page, and the general index be placed at the end of the volume.

The coming year may be one of large results, for those who want to advance in the study of Astronomy, if such students are willing and anxious to work for it. We call attention, again, to the great advantage of associated study, in some particular line, if no other or better plan can be devised. Three or four persons, formed into a class, with a persistent purpose, can accomplish surprising things, by self-instruction in evening hours, without the apparent loss of valuable time. How much better is it to use some evenings in this way, than to devote so much time, as many people do, to *Society.*

It is in our plan to give soon some hints on courses of reading. This would have been done earlier, but for the want of space. The many interesting themes that have crowded upon us during the last year, have made it hard to keep up a useful variety and still be thorough, elemental, and up to the latest knowledge in it all. We believe we can do better in the year to come.

PLATE I. POPULAR ASTRONOMY.



Copy of an Enlarged Negative of the Lunar Appennines. Made at the Lick Observatory, 1891, July 14. 8 hours, 12 minutes, 26.5 seconds. P. S. T.

Reduced about half for this plate.

Photograph of the Moon, made at Goodsell Observatory, June 21, 1893, with 8¼ inch Photographic Telescope and Amplifier, by A. G. Sivaslian.

Popular Astronomy.

Vol. I. SEPTEMBER, 1893. No. 1

CONSTELLATION STUDY.

WINSLOW UPTON.*

INTRODUCTORY.

The study of the constellations forms a very attractive part of a popular course in Astronomy. Few persons can look at the stars attentively without forming figures among them which are ever afterward associated with the stars thus grouped. The figures are frequently geometrical, such as triangles or quadrilaterals, or sometimes they are made up of groups of neighboring stars which form no special shape but which seem to be associated together. It is generally known that the ancient astronomers classified the stars in this way, and that their classification is still in use in modern times. The student therefore wisely desires to make his groupings accord with those sanctioned by tradition and accepted by the astronomers of to-day, though he may not know just what use is made of them in modern science.

The study of the constellations is too often attempted in a desultory manner. A few figures are traced and learned when in certain parts of the sky, or when seen in the direction of certain terrestrial objects, and they are not recognized under other conditions. Even the conspicuous "Dipper," which is so generally recognized when low in the northwest, is a far less familiar group when seen inverted and nearly overhead. It is quite possible for any one, who will pursue the subject faithfully and systematically, to master the leading configurations so that they will always be recognized, no matter at what time of year or in what part of the sky they may be observed; and an intelligent following of the leading groups in their apparently changing positions for a few hours of some night and for a few months in the year, will give a very clear idea of the effect which the earth's rotation on its axis and its revolution about the sun produce upon the apparent position of the stars.

It is the design of this series of articles to aid in a systematic study of the constellations. At the outset a classification will be

* Director of Ladd Observatory, Brown University, Providence, R. I.

given which will arrange the groups in an orderly way, and in a manner in close accord with the more modern system of designating the position of stars. Then suggestions will be offered for taking up the study in detail, by a progressive method designed to give a good knowledge of the constellations in their leading characteristics, and which can be continued to a more minute acquaintance with them as desired.

But before entering upon this subject, there are a number of preliminary statements which ought to be made, regarding the history of the classification and its present use by astronomers. In this way perhaps a clearer idea will be given of the place of constellation study in any scheme of instruction in Astronomy. For, if the truth is candidly spoken, this classification of the stars, while interesting historically, is of very minor importance in the science of Astronomy. Many professional astronomers do not use it at all, and would prefer that the system should become obsolete in whole, as it already is in part. The system is used wholly as a rough means of identifying certain of the brighter stars, and of forming certain grand divisions of the sky, much as a country is divided into states or provinces. Even this territorial subdivision is not as important as might first appear, for the system of designating stars by their positions, on the same general plan as places on the earth are designated by their latitudes and longitudes is more satisfactory as well as more accurate. But while a minor part of the science of to-day, it still has a place in it, and it possesses certain features which make it a profitable study, if not one of the highest importance.

The division of the sky into constellations is prehistoric; it seems to be the oldest part of that science which was studied in ancient Chaldea and Egypt, received and enlarged by the Greeks, and transmitted to us by the Arabians and the monastic scholars of the Middle Ages. The design of the classification was, we may believe, primarily, for identifying the stars, but it received its plan from association with the poetry and astrology of that time. Poetry gave the names to many of the groups, and allowed the fancy to pass beyond the geometrical shapes to imaginary figures of animals or other creatures, of which the stellar groups formed, as it were, the skeletons. Astrology determined some of the grosser subdivisions, such as the twelve parts of the zodiac, and gave a motive to the science, by requiring close observation in order to determine the subtle effects upon mankind which the several groups exercised. Our earliest precise knowledge of the classification is in the catalogue of the Greek astronomer Ptolemy, in the second century of our era. In this catalogue* are given 1028 stars, including most of the brighter stars visible in northern latitudes. They are classified in forty-eight constellations, which are all given upon modern star maps, though in a few instances the names have been changed. The positions of the stars are given by their celestial latitudes and longitudes, which is the beginning of this satisfactory method of designating their places. Each star is named by its position in the figure supposed to include the stars of the group. Thus the Constellation Draco contains thirty-one stars which are named "The star upon the tongue," "the star in the mouth," "the star above the eye," "the star upon the cheek," "the star above the head," etc. This method of naming the stars continued in use until the eighteenth century, though it was gradually supplanted by the system proposed in the seventeenth century, in which a letter or a number with the Latin genitive of the constellation was used instead of the long phrase. Thus the stars in Draco mentioned above are now designated as μ, ν, β, ξ and γ Draconis respectively.

A curious fact regarding the early division of the sky into constellations is that no attempt was made to include all the visible stars in the constellations. Apparently it was not intended that this should be a method of subdividing the visible heavens into districts, but only certain conspicuous groups were singled out, and gaps left between them. In Ptolemy's catalogue, 102 stars are given, which do not belong to any constellation; among these unclassified stars is the brilliant star Arcturus which is placed near, but not within, the constellation Boötes.

Our knowledge of the artificial figures surrounding the stellar groups is obtained from the designations of the stars themselves. It is possible to reproduce thereby the outlines of the figures with approximate accuracy, but the details of the figures cannot be given. In some cases the stars are not sufficiently numerous to allow the figure to be drawn, as in the case of the constellation Canis Minor in which but two stars are given; and in every case there is ample room for an imaginative artist to exercise his talent. It is probable too that there was no general agreement as to the groups themselves, not to mention the figures drawn about them, and if other of the early writings than Ptolemy's had been preserved, we should undoubtedly find many unexpected divergencies. Ptolemy's classification was made the basis of the

---

* Baily's translation in Memoirs, R. A. S., vol. XIII.

subsequent classifications of mediæval astronomers, and was materially enlarged by the addition of new groups, to fill in the gaps between those he gives. Occasional discrepancies are to be expected here also, and it is only by the arbitrary adoption of some one arrangement as authoritative, just as Ptolemy's had been adopted before, that a recognized system can be obtained. An interesting example of the uncertainty in drawing the outline figures may be found in the Atlas of Argelander, which is considered the standard authority for the northern heavens to-day. The constellation Boötes appears on two plates; in the one the figure of the hunter faces the west and his right arm holds the leashes of the hunting dogs which form the next constellation; in the other the figure faces the east, and the raised hand (in this position the left hand) holds a sickle, while the right hand, which is not shown in the other position, carries a shepherd's staff. The latter, it may be said, accords more nearly with the descriptions of the ancient catalogues, but the former is equally possible if, as is done in some atlases, the left arm rather than the right holds the leashes.

The defect in the ancient system, that the constellations did not cover the whole sky, was remedied by the addition of new constellations in the intervening spaces. As an example, the constellation Canes Venatici was added by Hevelius in the seventeenth century, to fill the gap between Boötes and Ursa Major. In so doing he built upon the traditional story of the former constellation, which was sometimes called the Bear Driver because it follows the Bear in its daily movement, and added hunting dogs. To these was due the change in drawing the figure mentioned above. But unfortunately the astronomers who engaged in this work did not work together, nor did the later astronomers adopt the suggestions of their predecessors. In the seventeenth and eighteenth centuries more than sixty new constellations were added, filling the gaps in the northern sky and continuing the system to the southern pole. Not all of these commended themselves to later astronomers, and as there was no authoritative body to decide such matters, and is none today, it is impossible for any one to state the exact number of constellations, much less to define their boundaries.

The astronomers of this century have been obliged to face the question what to do with the ancient system of constellations and its later additions. Some would abandon it altogether; others would retain its leading features but would simplify the subdivisions, by discarding many of the additions and straightening the boundaries, but departing as little from the primitive scheme as is possible. The latter view seems to have prevailed by general consent without concerted action. The German astronomer, Argelander, whose efficient labors in cataloguing the stars about the middle of the present century gave him general recognition as an authority on such matters, incidentally performed this revision while preparing his Atlas. With but little dissent, his work is accepted as authoritative. It contains fifty-seven constellations visible in northern latitudes, which are made up of forty-six of Ptolemy's and eleven added by later astronomers, chiefly by Hevelius. Had Argelander's work been extended to the southern pole, the whole system thus revised would have been generally accepted. As it is, there is still some indecision as to the acceptance of the schemes suggested by various astronomers. The tendency is to accept only those constellations of long usage, and to limit the number as far as consistent with covering the space satisfactorily. The whole number of constellations in current use is between eighty and ninety, the exact number depending on the acceptance or rejection of minor groups in the southern sky.

From this brief account of the development of the system of constellations it will be seen that even at the present time the subject is not quite as satisfactory as might be expected. The system has been one of growth, and the growth has not always been wisely directed. As it now stands, accepted as it is by modern astronomers as an inheritance not to be lightly thrown aside, it contains some very curious characteristics. Most notable of these is the great difference in the size of the several constellations. One of these, Argo Navis, in the southern sky, is so enormous that its subdivisions into four or five parts named from the several parts of the vessel is quite commonly accepted. Another, Ursa Major, with its imposing array of bright stars, and its curious collection of pairs in close proximity, occupies a commanding space in the northern sky. Camelopardalis and Monoceros are examples of large constellations which contain but few stars visible to the naked eye—relatively blank spaces. Some of the groups, as Equuleus and Scutum Sobieski, are so small that it seems unfortunate that they were not included in the territory of their neighbors, as was done in the case of Taurus Poniatowski and some other constellations which for a time were on the accepted list. Another characteristic feature is the great diversity in the brilliancy of the different groups. This feature is of course quite to be expected, indeed no system could be devised which would not have a like diversity because of the unequal distribution of the stars according to brightness. Another feature, however, which might have been prevented had it been desired, is the great diversity in the shape of the regions assigned to the several constellations. Snake-like figures, winding about over large areas, but leaving much adjacent territory for other constellations, seem to have beeen quite a favorite form. Draco, Serpens and Hydra are the best examples of this form, and from their shape are easily traced. In several instances constellations crossed each other, but this has been remedied by readjusting the boundaries, except in the case of Serpens which now crosses the serpent bearer Ophiuchus. Another characteristic feature is the winding of the division boundaries. This was made necessary by attempting to adhere to the original shapes of the figures as far as possible, and not to transfer stars from one constellation to another in straightening the division lines. In this way the division lines are drawn in a very meandering manner. Another evident characteristic is the slight resemblance between the stellar groups and the figures which give the names to the groups. In a few cases the resemblance is genuine; in the majority of cases no resemblance exists, and it need not be supposed, as is sometimes done, that the ancient astronomers detected such resemblance when they assigned names to the groups.

The present scientific use of the constellations is wholly for purposes of notation. There are several distinct ways in which stars are named. The earliest method, that of describing the position in the figure occupied by the star, is entirely obsolete, and the method of naming it by a letter or number followed by the Latin name of the constellation in the genitive case is used for all bright stars. The letters are usually of the Greek alphabet, and were assigned by a German astronomer, named Bayer, in the early part of the seventeenth century. The numbers are usually those assigned by the English astronomer, Flamsteed, who lived a little later than Bayer in the same century. Many of the stars have been given individual names, but with few exceptions these are nearly or quite obsolete. To take a concrete example, the bright star which is nearest the northern celestial pole was called in Ptolemy's catalogue "the star at the end of the tail"; it is known to-day in star catalogues as α Ursæ Minoris, or 1 Ursæ Minoris. It has also received the names Gjedi, Polaris, Cynosura and Alruccabah, only the second of which survives. These various methods of designating a star apply only to the few bright stars which have been catalogued for many centuries as visible to the naked eye. All telescopic stars, and many of the fainter ones visible to the naked eye, are distinguished by their position in the sky, their right ascension (corresponding to longitude) and their declination (corresponding to latitude)—to give the technical names of the science. If a star is in any of the published catalogues of stars, it is frequently mentioned by its current number in that catalogue. Thus the pole star might be distinguished as B. A. C. 360, because it has that number in the Catalogue of the British Association. It is customary, too, in star catalogues to give the constellation within which each star comes, even if it is too faint to have a letter or a number in that constellation. Thus the use of the system of the constellations is limited to-day to the naming of the brightest stars, and these may in every case be designated without reference to the constellation, by some of the alternative methods just named. The figures have ceased to be used, but the names remain, designating now regions of the sky within which the figures were formerly drawn. The figures are not always drawn on modern star atlases, but when given in faint outline so as not to obscure the stars, they are of interest from a historical point of view, as well as frequently for their help in fixing the stellar groups themselves.

The study of the constellations has, it is true, ceased to have the prime importance in Astronomy which it possessed in former years. But it still has its merits and its interest. The professional astronomer is at a disadvantage in his technical researches who does not know the leading groups and the names or letters of the most conspicuous stars in the groups. The general student of the science also should know the important constellations, and their positions at different times of the night and the year. He will not simply gain the direct knowledge which this gives, but he will have clearer ideas of the movements of the heavenly bodies. No one who prizes the history of any science will despise a branch of it, which has indeed become of less importance in late years, but which is interwoven with the development of the science in a very marked degree.

There are other advantages in constellation study than those named, especially for the amateur or the person only casually interested in Astronomy. The stars which stud the firmament, like beacon lights in the darkness of the night, become almost like personal friends when they are recognized in their varying annual positions. The ancient Egyptians knew when the overflow of the Nile might be expected by the rising of the star Sirius just before the Sun in the summer, and the Phœnician navigators knew when the navigation season was to commence in the spring by the corresponding rising of the group to which the Greeks gave from this circumstance the name of Pleiades. A certain constellation which rises in mid-winter in the early evening always suggests to the writer the coming of the spring. Other constellations have like associations with the different seasons. Just as in primitive times the movements of the constellations formed an infallible calendar, written upon the face of the sky, before the printed calendars were invented, so now they mark the passing seasons for those who will acquaint themselves with their forms and movements. Constellation study is also especially valuable for strengthening the power of observation and for training the memory. A casual glance at the sky leaves only a vague impression of points of light, but a closer inspection reveals the relative positions of these points of light, their varying brightness and color, their abundance in some places and their fewness in others. The fixing of the groups in the mind is by no means an easy matter, and gives therefore excellent training to the memory. The imaginative faculty is also strengthened, not so much by striving to see resemblances which do not exist, as by forming the stars into orderly groups and connecting them by lines or imaginary cords which seem to unite them into a family. All this is quite apart from the significance of the study as a beginning subject in Astronomy. As the stars must be named and grouped somehow, it is well to adopt the ancient system, whatever its defects, rather than to invent another, which lacks the associations of the old one, and which no one but the inventor would use. The outlines of the system once mastered and the leading groups learned, the less important groups may be added at pleasure and to whatever degree of refinement is desired. A good foundation is thus laid for subsequent use, and the interest excited in one branch of stellar Astronomy may lead to further studies in the same inviting subject.

"Consult with reason, reason will reply
Each lucid point which glows in yonder sky
Informs a system in the boundless space,
And fills with glory its appointed place;
With beams unborrowed brightens other skies,
And worlds to the unknown with light supplies."

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

JAMES E. KEELER.*

1. Principles Involved in the Construction of the Instrument.

The editor of POPULAR ASTRONOMY has asked me to write a series of short articles on the spectroscope, which will be readily comprehended by those who have no previous knowledge of the subject, and which may serve as a guide to readers who have small instruments in their possession. This is the first of such a series, and the others will follow in due course. I shall hope at least to fulfil the requirement of making my meaning perfectly clear at all times, and although it will be necessary to use some technical terms in dealing with such a subject as the spectroscope, the new terms will always be explained when they are used, so that they ought to cause no difficulty to the beginner.

Few instruments assume such a variety of forms as the spectroscope. It may be a short piece of tube no larger than the eyepiece of a telescope, or it may be a large and complicated piece of apparatus filling a whole physical laboratory. To recognize the relations of instruments which differ so greatly in appearance we must understand well the principles on which they are based, while to recognize immediately the meaning of all the curious appearances seen in a spectroscope under different circumstances, requires, in addition to this, much experience in practical observation.

The chief use of the spectroscope is to study the constitution of a body by means of the light which it emits. Light is the agent which brings us the desired information, and if there is only enough of it when it reaches us, it is a matter of indifference how far it has traveled on the way. It is this independence of distance which makes the results of spectroscopic analysis seem so wonderful to one unfamiliar with its methods. Fifty years ago they were almost undreamed of. The chemical constitution of the stars, now a regular field of inquiry in many observatories, was once mentioned by an eminent metaphysician as an example of the knowledge which must remain forever beyond our reach. If our sense of admiration is blunted by custom, let us try to imagine what a philosopher of the last century would have said, if the results of modern spectroscopic analysis had been laid before him, without any explanation of the way in which they had been obtained.

* Director of Observatory, Allegheny. Pa.

To illustrate the principle of the spectroscope, let us consider some simple experiment, in which we shall not be confused by a complexity of apparatus. Perhaps the best one will be the historic experiment of Newton, which, indeed, every beginner should repeat. We first, then, make a hole, say half an inch in diameter, in the shutter of a darkened room, so that a beam of sunlight enters the apartment and falls upon the floor. Next we take a glass prism, which for this purpose need not be a very good one, —a prism from a chandelier will answer, if it has a considerable angle,—and hold it in the path of the beam, with the sharp edge downward. The beam of light is immediately bent upward, out of its original direction, and on the opposite wall of the room appears a beautiful rainbow-tinted band, red at the lower and violet at the upper end. To this colored band of light Newton gave the name of spectrum.

White light, therefore, is made up of light of many different colors, which Newton roughly designated as red, orange, yellow, green, blue, indigo and violet, but the colors blend into each other so that the number of shades is really infinite. We shall see that the different kinds of light separated by the prism differ in other properties as well as in color.

The solar spectrum obtained in this experiment, although beautiful enough to the eye, is what is technically called an "impure" one; that is, the different kinds of light are not perfectly separated on the screen, but overlap and are confused. To obtain a pure spectrum we must employ somewhat more elaborate apparatus; still the spectrum which we have is good enough to illustrate many points of the greatest importance in practical spectroscopy, and we shall use it for this purpose before going further.

The beam of light which comes through the hole in the window shutter is bent out of its course, or *deviated*, by the prism, and it is evident that the colors are separated because the blue light is more deviated than the red. The separation of the colors is called *dispersion*, and like the deviation, is measured in degrees. Thus, if the deviation of red light is 50° and that of violet light 54°, the spectrum will be 4° long, and the prism is said to have a dispersion of 4° between the red and the violet parts of the spectrum. If the reader will refer to an elementary text-book on physics, he will find that the action of a prism is due to the fact that light travels more slowly in glass than in air, and that the violet rays are more retarded by glass than the red rays.

Now let us experiment by rotating the prism about its lower edge, or refracting angle. We shall find that no matter how we turn the prism, we cannot make the deviation of any given part of the spectrum *less* than a certain amount, called the minimum deviation. When the prism is in the position which produces minimum deviation the light enters and leaves the prism equally inclined to its two surfaces.

Starting from this position of the prism, let us turn it so that the light falls more directly on the first face. The spectrum is thrown higher on the wall and at the same time it is lengthened; the dispersion is increased. If we turn the prism in the opposite direction the deviation will also increase, but the spectrum will shorten, *i. e.*, the dispersion will be diminished.

In the spectroscope, the prism is almost invariably used in the position of minimum deviation, but it is sometimes an advantage to know how to vary the dispersion by the simple method just described.

A technical term much used in spectroscopic literature is "monochromatic" light, and we may illustrate its meaning with the apparatus which we are supposed to have before us. The meaning, according to the construction of the word, is light of a single color, but color is here used in a stricter sense than in ordinary language. The light transmitted by red glass, or the red of the rose, is not by any means monochromatic.

If we receive the spectrum from the prism on a screen, and make a small hole in the screen so as to let through a beam of, say, red light, we obtain a beam of light which is approximately monochromatic. It is not perfectly so, on account of the overlapping colors on the screen, and because the hole is of considerable size, but if we imagine the spectrum to be very pure and the hole extremely small, we can form an idea of what is meant by monochromatic light. Such a beam would be refracted by a prism placed in its path, and changed in direction, but it would not be dispersed like a beam of white light.

It is not an easy matter to obtain really monochromatic light, but for all ordinary experiments a spirit lamp, in the wick of which a little salt has been placed, gives a flame which will answer quite well. The flame really radiates two slightly different kinds of yellow light, so nearly alike that no eye could distinguish their difference in color, and there is also some blue and green light from the alcohol flame, but these rays are quite faint. Professor Michelson has shown that certain red rays from burning cadmium are almost ideally monochromatic.

Let us now consider a somewhat more elaborate optical arrangement, which will give a pure spectrum, and which, carried out practically in glass and metal, will rise to the dignity of being called a spectroscope.

I must assume that the reader is familiar with the ordinary properties of lenses, for it is hardly possible to go back to first principles in every branch of our subject. If he has not this knowledge, he should by all means acquire it by reading the proper part of an elementary text-book of physics. I will however mention the principal property of a convex lens, which at once finds an application in constructing our new apparatus. If parallel rays of light fall upon a convex lens, they will be converged to a point on the other side called the principal focus, and conversely, if a luminous point is placed in the principal focus of a convex lens, those rays which fall upon the lens will emerge parallel.

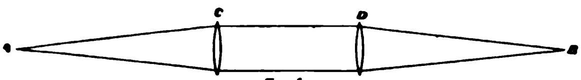


Fig. 1

Let *A* (fig. 1) be a point emitting monochromatic light, which we may suppose to be yellow, and let it be in the principal focus of the convex lens *C*; then the rays emerging from *C* will be parallel. Let *D* be another similar convex lens, placed in the path of these rays. By this lens the parallel rays will be converged to a point *B* in its principal focus, and this point is an image of *A*. A single lens could be employed to produce the same result, but then in no part of the system should we have parallel rays, the use of which will soon be apparent.

Perhaps I should say here that the image *B* is not really a point, even if the lenses are perfect, but an extremely minute disc, surrounded by fine rings of light. The reader who has used a telescope is familiar with the appearance described, for it is that of every star image. For our purposes *B* may be regarded as a point, although the fact that it is really a very small disc is of great importance in the complete theory of the spectroscope.

Light diverging from a point just below *A* would be converged to a point above *B* and equally distant from it. Every point near *A* has its corresponding point near *B*, and thus an image of any object placed at *A* is formed at *B*. The image is of the same size as the object, and it is inverted. The luminous object might be the salt (or sodium) flame already referred to, and then an inverted image of the flame would be thrown on a screen held at *B*.

Now let us suppose that a glass prism is placed between the lenses where the yellow rays from the point *A* are parallel, as in fig. 2. If the first surface of the prism is flat, all the parallel rays from *C* meet it at the same angle, and they will all be refracted, or bent by the same amount on entering the glass, if the glass is homogeneous, or of the same refracting power in every part; the rays will therefore still be parallel in passing through the prism. If the second surface is also flat, all the rays will again be equally refracted toward the base of the prism, and they will pass out with their parallelism undisturbed, although in quite a different direction from that of entering. Passing through the lens *D* the rays are converged to a point *V* in its principal focus, as before. We may turn the prism until *V* is displaced as little as possible from its original position *B*, and in the figure the prism is shown in this position of minimum deviation.

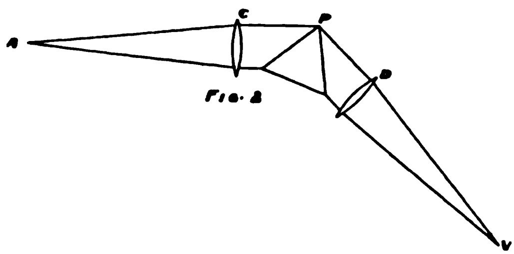


Fig. 2

If with the prism so adjusted, we place a sodium flame at *A*, we shall obtain an image of it at *V*, precisely similar in every respect to the image when there was no prism, as in fig. 1.

If we suppose *A* in fig. 2 to be a point emitting *red* monochromatic light instead of yellow, then the course of the rays will be the same as before, *except* that the red rays being less deviated by the prism, the red image or point in the focus of *D* will be formed higher up, nearer to the place it would have in the arrangement shown in fig. 1.

Now let us suppose the point *A* to emit both red and yellow monochromatic light (and nothing else). Until they fall on the prism, both kinds of light pursue the same course, but by the prism they are separated. On leaving the prism all the yellow rays are parallel to themselves, and all the red rays are parallel, but the two sets of parallel rays are travelling in slightly different directions, and when they pass through the lens *D* the yellow rays are converged to a point *V* and the red rays to another point *R* (fig. 3) above the first. If *A* is a *flame* emitting the same two kinds of light, then we shall get a yellow image of the flame at *V* and a red image at *R*, alike except in color, and both of the same size as the flame itself. The apparatus serves to analyze the light, and shows that the flame emits two distinct species of rays, which could not be recognized by the unaided eye.

As both images of the flame are quite large, it is probable that they will overlap, and not be entirely separated. We may, however, cover up the sides of the flame, and prevent their light from entering the apparatus. The images will then be formed of the uncovered part of the flame, and will be narrower. If, for instance, we make a round hole in a card, and place the hole exactly at *A*, with the flame close to it on the outside, each image will consist of a round disc of light. Perhaps the images still overlap on their nearest sides. We make a smaller hole in the card, and now the images, being smaller, are completely separated. Whatever shape we choose to give the aperture in the card, the images will have exactly the same shape.

Now remembering that the images are always exactly like the aperture, and that their centers are always the same distance apart, let us consider what form of aperture it will be most advantageous to use. It is evident that the greatest amount of light will be admitted, with the greatest possible separation of images, if the aperture is a very narrow rectangle, with its longest side parallel to the refracting edge of the prism. The images will of course be equally narrow rectangles. If the aperture is very narrow we may call it a slit, and the images will then be mere lines of light, parallel to each other and to the edge of the prism. Now these two images constitute the spectrum of the flame, and in spectroscopic parlance it would be said that the spectrum of the flame consisted of two bright lines, one in the yellow and one in the red. *Lines* are always mentioned in describing a spectrum simply because the aperture which admits the light is always a *slit*.

It is important to observe that altering the width of the slit does not change the brightness of the lines,—merely their width.

A monochromatic blue flame placed in front of the slit would give a blue line in the spectrum, considerably further from the red than the yellow line, but in the same direction from it; and finally a flame which, like that of a candle, gives out all kinds of light, would give a spectrum consisting of a continuous band of color without interruptions of any kind, like the solar spectrum of our first experiment. The images of the slit, being infinite in number, blend together to form what is called a continuous spectrum. We shall see later what the solar spectrum is like with our new apparatus.

The spectra obtained with this apparatus are pure, for each kind of monochromatic light gives one, and only one bright line in the spectrum. At the same time there is a limit to the purity which can be obtained with it, for the slit must have *some* width, and we can imagine two kinds of monochromatic light so nearly alike that the two images of the slit would overlap, even with the narrowest slit that it would be practicable to use.

It remains now to show how the optical parts which we have considered are put into practical shape, so as to form a spectroscope.

The lens *C*, which in practice is an achromatic lens, and not a simple one as shown in the figure, is mounted in one end of a tube, and the aperture or slit is placed at the other. The slit is however attached directly to a shorter tube which slides in the first, so that by pushing it in or out it can be adjusted exactly in the principal focus of the lens. Sometimes a focusing screw is added to make the adjustment easier. The width of the slit is varied by turning a small screw. The whole tube carrying the lens and slit is called the collimator.

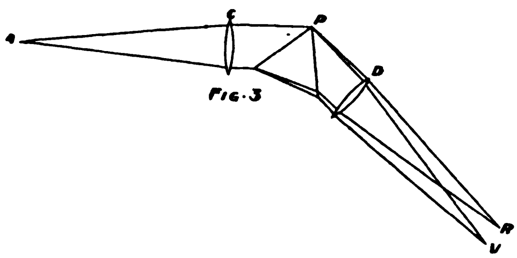


Fig. 3

The prism is placed on a little table, and in a good instrument it should rest on three small foot screws, so that its edge can be made vertical.

The lens *D* which should also be achromatic, is mounted in one end of a tube. The images which it forms are not thrown on a screen, but viewed directly by a magnifying glass, or eyepiece, placed at the other end of the tube just beyond the point *B*. A short sliding tube, like that in which the slit is mounted, enables the eyepiece to be pushed in or out, so that the spectrum may be seen distinctly. The whole tube therefore forms a small telesope, and the three parts now described—collimator (with slit), prism, and telescope,—are the essential parts of the ordinary and most generally useful form of spectroscope.

If the spectrum is very short and the eyepiece large, the whole spectrum may perhaps be seen at once, and then the telescope can be fastened in a position determined by trial; but it is much better to have it movable about a center under the prism, and then it can be brought in line with the collimator as in fig. 1, or turned so as to bring any desired part of the spectum to the center of the field of the eyepiece.

Next time I shall tell how to use a spectroscope of this form, and describe the solar spectrum as seen with it or any other instrument of small dispersion. I have dwelt at some length on the principles involved in its construction, but not, I think, more than their importance requires, for it is absolutely necessary that they should be thoroughly understood before proceeding to more complicated arrangements, and to the wonderful results which have followed the application of the spectroscope to astronomy.

THE MOON.

WM. W. PAYNE.*

A series of articles will be prepared for this magazine to show, in a general way, what is known about the Moon, the sources of information, something about the unsettled questions and the theories pertaining to them, and, at the proper time, a *résumé* of the discussion now going on in relation to the decay and possible dissolution of satellites generally.

In the study of the Moon writers generally begin with a description of its motions, figure and dimensions, then notice its physical features and, from its singular and varied formations infer its condition and physical constitution. From a study of its surface markings is obtained nearly all that is known, at present, about the Moon.

It will be very profitable for the reader to notice, in the outset, that this knowledge, in even its easy and elemental parts, was gained only by careful, persistent and long continued observation of such surface markings as could be revealed plainly to the unaided human eye. Those who have read any lunar history belonging to very early times will remember that very little useful knowledge was acquired by Chinese, Hindoo or Egyptian astronomers because they did not observe or work systematically. The Chinese probably made the earliest record of a lunar eclipse, 2158 B. C., but the account of it contains scarcely more than a mere mention of the event, while those of the Egyptians and Hindoos are said to be vague and even less complete. On the other hand,

* Goodsell Observatory, Northfield, Minn.

the Chaldeans appear to have made and recorded regular series of observations, from a very early period, although only those of later time have been preserved, as far as we now know. Ptolemy gives these later records commencing with the lunar eclipse of 720-719 B. C. As might be expected the Chaldeans were rewarded in the results of their work because it was done regularly, carefully and thoroughly. Instances of this are seen in the fact that they were able to find the length of the solar year, as 365¼ days, that they knew very closely the time of the Moon's revolution and that they should be able, from a very long series of observations of eclipses to determine the Saros, a period after which eclipses follow one another again, in the same order for another like period of time, and, on account of which coming eclipses could be predicted with considerable accuracy.

About a century later (650 B. C.) another important feature marks the progress of astronomical science. Greek philosophers introduced into the study of astronomy their own purely theoretical ways of thinking, so that from the time of Thales to Aristotle comparatively little observing was done; they were, however, very busy in constructing theories, mainly concerning the markings of the lunar surface and the resemblances between the Moon and the Earth, but their theories varied greatly at different times and in different schools of the philosophers. However it is pleasant to notice that Aristotle* (382-322 B. C.) taught that the Moon, on account of its phases and eclipses, must be a sphere always turning the same face to the Earth, and that it is nearer than the planet Mars because the former is known to occult the latter. The Greeks had knowledge of the Chaldean Saros and tried to improve it by better Cycles of their own, the most important of which was called the Metonic Cycle (432 B. C.) by Meton, an Athenian. This Cycle consisted of 6940 days (about 19 years) the error of which for the Sun was nine hours, for the Moon seven hours, with a difference for the two bodies of only two hours. The advantages of this Cycle were many and early astronomers held it in high honor, and its successive years were publicly designated by numbers in gold, hence the so-called golden number of the Metonic Cycle. In 330 B. C., Calippus improved this Cycle by multiplying it by four and subtracting one day, which made the new period to consist of 27,759 days (about 76 years), consisting of 940 lunations, making, at its end, a nearer coincidence of the Sun, Moon and seasons than the Saros; for, by this, not only was the order of the eclipses known, but

* Neisen's The Moon, page 81.

also the day on which particular ones came could be predicted for years to come. This Cycle was adopted by scientific astronomers of this period. In the year 320 B. C., began the use of better astronomical instruments and more systematic work in observing' though it should be borne in mind, that the time of which we now speak was nearly 2000 years before the invention of the telescope, it was also the beginning of the period of Aristarchus, Hipparchus and Ptolemy whose skillful work will have full notice in due time.

At 140 A. D. begins a period of fourteen centuries during which there was very little improvement in Astronomy, as may be illustrated by the fact that the lunar theory remained just where Ptolemy left it for all those centuries. When Tycho Brahe (1575 -1600 A. D.) began his work of exact observation, which was soon followed by Gallileo with the wonderful discoveries of the first telescope, the era of modern Astronomy began, in which the study of the Moon would naturally lead.

It will be the purpose of this series of brief papers to give an outline of lunar history arranged by topics and dates for convenience in reference, to present the methods of study used in early times, to compare the work by the naked eye and that done by the aid of the telescope, showing the use of the opera glass, the small telescope and the great instruments of the present time, to point out what celestial photography can do to reveal minute details of structure in the formations on the lunar surface, to give some knowledge of the amount of light and heat from the Moon, with illustrations showing how the instrument, called the bolometer, detects variations of temperature in the surface and its relation to light-phase, and, finally, to refer to such evidence as science gives on the question of its habitability by beings like ourselves in view of its present physical condition and possible state of dissolution suggested in the beginning of this paper. The illustrations belonging to this theme will be the best in kind and quality that can be secured, and we believe they will be a source of interest to the reader that could not possibly be awakened by any other means. They will have the accuracy of photography and all the clear detail needed for exact instruction. Those given in this number are intended for illustrations, and are not meant to be closely related to any particular points in this introductory paper.

THE ASTEROIDS AND THEIR RELATION TO THE PLANETARY SYSTEM.

DANIEL KIRKWOOD.

At the beginning of the nineteenth century a new field of research was opened to astronomers. A class of bodies till then unseen by human eye, and unimagined by the human mind; a class, indefinite in numbers—perhaps more difficult to enumerate than the stars as seen without a telescope; a celestial cluster, in short, within our own solar domain, was first revealed to telescopic view. To trace the progress of research in this zone of minor planets; to mark the conquests already achieved, and to inquire whether the time has yet come to co-ordinate the facts now known, is the principal aim of the paper which follows.

The name *asteroids* was given by Sir William Herschel to the telescopic planets found moving in the space between the orbits of Mars and Jupiter. The term *planetoids* is preferred by some writers, and *minor planets*, by others; the name given by Herschel, however, seems likely to be permanent.

Astronomical, as well as mathematical discoveries are sometimes prophetic. In other words, they give promise of other and still greater discoveries to follow. When the first asteroid was revealed to view, on the first night of the century, the fortunate Piazzi but little dreamed of the prospect which he had opened to astronomers. Our solar system as then known consisted of twenty-three planets, primary and secondary; it now contains over three hundred and eighty; of which more than three hundred and fifty are asteroids. The number to be added in another century is yet unknown. The progress of astronomical discovery, however, is not limited by the number or volume of the bodies revealed. This is eminently true of the planetary cluster now to be considered. What does it indicate in regard to the physical history of planets, or the laws by which the heavenly bodies are controlled? As elsewhere remarked, "if the universe is a book written for man's reading," only patient study may resolve the problem contained in these mysterious leaves.

From the time of the far-seeing Kepler till near the close of the eighteenth century, the thought of a missing or undiscovered planet was permitted to slumber; but when, in 1781, Sir William Herschel brought Uranus to light, and when it had been shown that its distance fell into the series of Titius, or Bode, the idea was again revived. It was in fact supposed to be realized in the discovery of Piazzi's telescopic planet. What then was the surprise of astronomers when within six years the harmony was again destroyed by the detection of three more, Pallas, Juno and Vesta? The result was the hypothesis proposed by Olbers to account for the phenomena. *Small* asteroids were not looked for by that astronomer, and their discovery was therefore suspended for thirty-eight years.

The search for minor planets was next resumed about 1831, by Herr Hencke, of Driesson. Success was first reached in 1845, and from this date laborers were numerous and discoveries frequent. About forty planet-hunters entered the lists, and the following numbers are now (1893) attached to the names of the most successful.

Discoverers.	Asteroids.	Discoverers.	Asteroids.
Palisa	85	Watson	22
Peters	45	Borelly	17
Charlois	28	Goldschmidt	14
Luther	24	Hind	10

Of the 352 members now known (1893), 270 have been discovered in Europe, 76 in America, and 6 in Asia. Seven has been about the average yearly number from 1845 to 1893. All the larger asteroids of the zone have doubtless been discovered. It seems not improbable, however, that an indefinite number of very small bodies belonging to the zone remain to be found. Photography is becoming an efficient means of discovery.

Laplace knew only of the first four minor planets—nothing of the wide spread swarm of hundreds composing the zone. Astronomers, however, who adopted his views on the origin of the system looked to the nebular hypothesis as the early history of the related planets. But between 1845 and 1853 more than twenty new members were added to the cluster. Within the same time, and before the invention of the spectroscope, it was announced that the nebula in Orion had been resolved by Lord Rosse's telescope. This startling claim—not sustained by later observations—was the signal for abandoning the nebular hypothesis by many of its former advocates. To others, however, the resolution of a nebula, even if confirmed, seemed hardly a sufficient reason for the theory's rejection. The question arose whether any probable test of Laplace's hypothesis could be found in the solar system itself. The train of thought was somewhat as follows: Several new members have been found in the zone of asteroids; its dimensions have been greatly extended, so that we can now assign no definite limit either to the ring itself or to the number of its planets; if the nebular hypothesis be true, the Sun, after Jupiter's separation, contracted successively to the various decreasing distances of the several asteroids; the eccentricities of these bodies are generally greater than those of the old planets; this difference is probably due, in some way, to the disturbing force of Jupiter; the zone includes several distances at which the peroids would be commensurable with that of Jupiter; in such case the conjunctions of the minor with the major planet would occur in the same parts of its path, and the disturbing effects would accumulate. We have thus a natural field for extraordinary perturbation. Can we still trace the creative plan in these works around us? Or has time been able to obliterate it in the long cycles of the past?

Not explosion but tidal action may have been Nature's ancient mode of separation.

The similarity between the elements of certain asteroids began to be noticed by the present writer about 1867; being first referred to in Meteoric Astronomy.* "A comparison of the elements of Clytea and Frigga," the author there remarks, "shows a striking similarity; and Professor Lespiault has pointed out a corresponding likeness between the orbits of Fides and Maia. For these four asteroids the nodal lines and also the inclinations are nearly the same; while the periods differ by only a few days. It is probable, therefore, that they are all fragments of the same narrow ring." The subject, however, though still occasionally noticed, received no special study for a number of years. The author's monograph on the Asteroids was published in 1887. On pp. 47 and 48 of that work the phenomena were again referred to; the writer specifying several marked instances of agreement in distance, motion, direction, etc. It was finally concluded that in view of the facts presented, the division of tenuous, primitive masses seemed certainly less improbable than the accidental coincidence of so many elements. The cause, of whatever nature, which has separated cometary masses in our own day, may have been operative also in the original condition of the minor planets. The fact—which might be shown as one of almost infinite improbability—that precisely where the inclinations, eccentricities, etc., are most nearly coincident, there also the orbits are most closely contiguous, seems capable of physical explanation on the theory of a common origin in the nebular hypothesis.

The author's first paper on this subject, read, in part, before

* Page 110.

the Astronomical Society of the Pacific, February 10, 1890,* and concluded March, 1891, contains ten binary and ten ternary asteroids. Subsequently, M. Tisserand, of the Institute of France, independently noticed a number of these striking coincidences and unhesitatingly remarked that they "cannot be accidental." Mr. W. H. S. Monck also in the *Sidereal Messenger* called attention to the phenomena in October, 1888, stating that "their number is far too great to be explained by chance."

CONCERTED OBSERVATION OF THE AURORA.

M. A. VEEDER.

There has grown up in connection with studies in which the writer has been engaged a system of observation of the aurora which permits comparisons to be made between records from different stations. This plan has been in operation for several years and has gradually extended until, in connection with the Arctic observations undertaken by Lieut. Peary in very high latitudes, it has received such an impulse as promises to insure extremely valuable results. Observers are coöperating in pretty much every part of the Earth where auroras are seen at all, and in some localities those coöperating are sufficiently numerous and so distributed as to permit comparisons to be instituted in reference to what appear to be local peculiarities of displays. The most paradoxical and mysterious feature thus far encountered is the evidence that has occasionally been received which seems to indicate that an aurora may be visible at stations southward in the usual location looking towards the north, and at the same instant observers further north on the same meridian may record the sky as entirely clear and free from any appearance of the aurora whatever, whether toward the north or south. What seems to have been a notable instance of this kind occurred on the night of July 15th. The observer at Ottawa, Canada, reported that the sky became entirely free from traces of the aurora at 11:55 P. M. At the same instant at several stations southward in the vicinity of Lake Ontario the northern heavens were still full of flashings and flickerings together with considerable diffused auroral luminosity. Only eight minutes later at three of these stations, namely, Toronto, Sodus and Lyons, an auroral curtain with sharply defined lower margin was seen advancing from the north west leav-

* The first paper published on the subject, so far as I know.

ing perfectly clear sky underneath. Unfortunately there is as yet no report from stations northward at this exact instant, but it seems almost certain that this curtain had moved southward, leaving clear sky in its wake, and that it became entirely invisible soon after passing the zenith of the places of observation. In other words, it could be seen towards the north but not towards the south. Its lower margin formed such a prominent land mark in the sky and gave such evidence of parallax that it is quite certain that the altitude of this margin at 12:05 A. M. was not far from twenty miles above the south half of Lake Ontario.

This is adduced as an instance of the very puzzling peculiarities in the behavior of the aurora which it is extremely desirable to explain if possible by systematic, concerted observations. The same night there was another feature not so difficult of explanation but none the less interesting. At stations in the vicinity of Lake Ontario from 10:00 to 10:30 P. M. there was seen a narrow auroral band which is generally described by those who saw it at its first formation, as extending at that time from a point on the horizon north of west eastward just south of the zenith towards a point on the south eastern horizon. This being the case, this band could not have been either perpendicular or parallel to the true magnetic meridians of the places of observation, but must have conformed to a temporary magnetic system developed at the instant and having its own set of meridians, thus corresponding to the behavior of the magnetic needle which deviates from its usual position at such times in order to conform to the new system temporarily induced. So far as is known to the writer, the deviations of auroral arches and streamers from their ordinary positions relative to the magnetic meridians of the places of observation is a phase of the subject that had never so much as been thought of until the present system of observations was undertaken.

Another very important question is as to what it is in certain localities that attracts the aurora. It has been thought that Archaen rock and the mineral constituents of the soil have this effect. Perhaps this may be so, but in looking over the records that have been obtained by concerted observation the writer has been struck by the fact that auroras seem to be much more numerous and brighter in localities where the Coast Survey maps show that the magnetic meridians are much displaced. This bending and twisting of these meridians is most apparent along the courses of great streams flowing east and west, like the St.

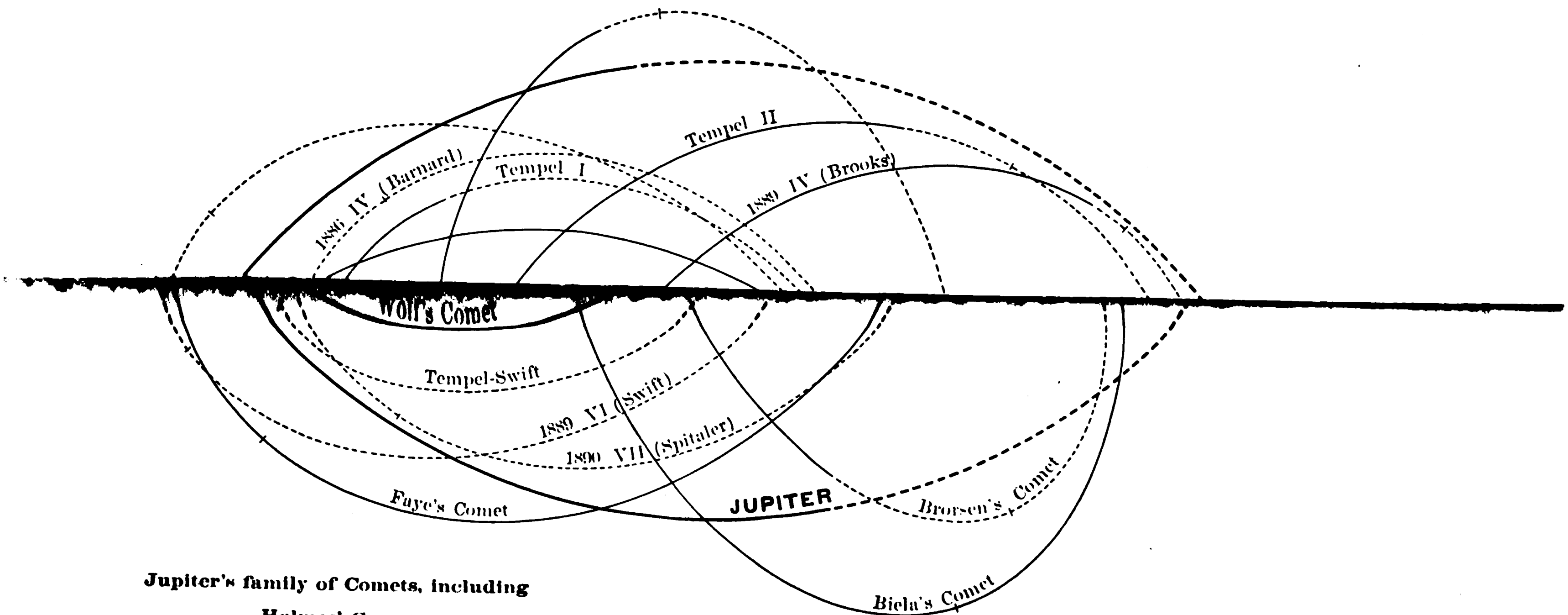
Lawrence, the Ohio and the Missouri. It has been thought that the motion of the streams carrying along mineral particles in suspension may have a modifying inductive effect locally, and may thus become responsible for the unstable state of magnetic equilibrium in these localities which is favorable for the development of the aurora. If this should prove to be the true explanation, it would follow that the arrangement of the magnetic system of the globe as a whole might depend to an important extent upon ocean currents, and even to some extent upon air currents. It is one of the features with reference to which concerted and systematic observations are most desirable, opening up as it does a new field in which pioneer work is to be done.

These are some of the problems involved which have been held in reserve so far as public announcement heretofore is concerned. The questions concerning the relation to specific solar conditions, and to atmospheric electrical conditions have already been put forth, and some of the conclusions respecting these questions that appear to be justified by the system of observations that has been inaugurated have been announced and are being discussed quite generally. So far as the writer is able to determine, electro-magnetic induction of solar origin depends upon what bears every mark of being volcanic activity at certain points on the Sun, and is propagated from the Sun outward throughout the Solar system dynamically, or, in other words, in definite relation to the motion of rotation. This is the root principle of the whole matter, and its various ramifications require to be traced out and confirmed by proper systematic observation, and may eventually be found to be of most far reaching and serious consequence.

It is evident that this is a class of observations to which nonprofessional as well as professionel students of natural phenomena may contribute materially. So far as the writer is concerned it has grown out of studies which were originally undertaken as a matter of amusement, but which have grown more and more serious as the importance of their consequences has been recognized, and an insight into the nature of the problems involved has been gained. It certainly is a most fascinating and may prove eventually to be a most fruitful field of research.

Lyons, N. Y., Aug. 10, 1893.

PLATE III.



Jupiter's family of Comets, including Holmes' Comet.

From a drawing by A. G. Sivaslian,
Northfield, Minn.

Goodsell Observatory,
Carleton College.

JUPITER'S COMET FAMILY.

WM. W. PAYNE.

As we have not seen anywhere a full illustration of Jupiter's comet family, as now known, we venture to give one in the accompanying large plate. This is called Jupiter's family of comets because they all seem to be, in some way, related to this great planet. Other large planets likewise have comet families. But this one is by far the largest of those known in the solar system. It consists of nineteen members varying in known historical age from more than 100 years down, if we say Encke's is oldest, and the Holmes' of 1892 is the youngest.

The line through the middle of the plate is the line of the equinoxes and the position of the vernal equinox is at the right hand end of the line and the autumnal at the left. The top of the plate is 90° of longitude and the bottom is, of course, 270°. The Earth's orbit is a solid ring because it lies in the plane of the ecliptic. All other orbits are broken because they are inclined to the ecliptic. The dotted portions are below the ecliptic *i. e.* towards the south pole of the heavens, while the continuous parts of these paths are above or north of the ecliptic. Now, notice some curious facts:

1. That nearly all the farthest points of these comet orbits from the Sun (aphelion) are on one side of Jupiter's orbit. The points are generally marked by short cross-lines.

2. Notice where the dotted portions of the orbits join the continuous ones; when the comets respectively are at these points, they are nearly in the plane of Jupiter's orbit, and all of them quite near his path, so that the influence of the planet on the comets must have been considerable when so near one another.

3. The Sun and the whole solar system is moving through space towards a point in the Constellation of Hercules, having right ascension of 267° and declination north 31°. Now, notice that the bottom of the plate is right ascension (or longitude) 270° and that direction is the way the solar system and all belonging are drifting in space at a probable rate of 16 miles per second continually. If Jupiter obtained his family by capture, why should he be more successful on one side of his orbit than on the other?

4. The motions of these bodies about the Sun are direct the same as the planets, *i. e.*, contrary to that of the hands of a watch. Jupiter's orbital velocity is 8 miles per second, hence on

one side of his orbit he is moving in space at the rate of more than 20 miles per second, while on the other, it would be about eight. Probably Jupiter will meet or overtake more comets and influence their courses at the former rate than at the latter, especially if we think of comets generally moving through space in any direction, and at the distance of Jupiter from the Sun, as having an average velocity of eleven miles per second.

5. The periods of revolution around the Sun of these comets is from three to eight years, being about one half of Jupiter's period around the Sun.

These are some of the reasons that have led astronomers to think that Jupiter has obtained his family of comets by capture on account of his great attractive force when they happened to come near enough to him to be under his control largely. If one should pass within 3,000,000 of miles of Jupiter, his attraction would exceed that of the Sun, and the comet might then possibly revolve like a Moon, though this is not at all probable, from the nature of the comet generally, nor is there such a known case in astronomy.

It should also be said that some prominent astronomers (notably Mr. Proctor), do not believe in the "capture" theory. We think the weight of opinion is in its favor. In 1884, Mr. Proctor advocated strongly that the origin of comets belonging to the solar system was from the Sun by ejection, also possibly from the larger planets in their process of development from the nebulous state. More will be said about these comet families at another time.

ASTRONOMY WITH THE SMALL CAMERA.

H. C. WILSON.

One of the simplest experiments for the amateur is that of photographing star trails. For this only the ordinary mounting of the camera is necessary, as the camera remains fixed during the whole exposure. The ray of starlight falling on the sensitive plate does not remain in the same position, but trails across the plate, producing an impression which on development is shown as a fine line of greater or less width and density according to the brightness of the star. If the camera is directed toward the celestial equator these star trails are nearly straight lines, but in other positions they are more or less curved. Near the pole they are arcs of small circles, which would be completed if the exposure could be continued for twenty-four hours. One of the most pleasing lantern views, and one which affords a striking illustration of the rotation of the Earth, may be made from a negative of the polar sky. The exposure for this purpose should be of at least an hour's duration.

The work of photographing star-trails is not only adapted to give pleasure to the amateur and his friends but also may be of scientific value. It is possible to determine from the width and density of the trails the relative brightness of the stars. There is here therefore a means of studying the fluctuations of variable stars and of discovering new stars. Of course with a small camera this would be limited to the brighter naked-eye stars, for only these would leave their trails upon the plate. There is also always the possibility of a meteor crossing the field of view and leaving a permanent record of its appearance, as was the case with the very interesting photograph obtained on Jan. 13, 1893, by Mr. John E. Lewis of Ansonia, Ct. (A reproduction from the original negative appeared in the *Photographic Times*, Feb. 3, 1893, and a fine enlarged photogravure is to appear in the September number of the *American Journal of Science*).

If one wishes to obtain pictures of the sky including as many as possible of the fainter stars, his camera must be rigidly attached to an axis parallel to the Earth's axis and turned by accurate clock-work. A very practical way is to fasten the camera to a telescope which is provided with a driving clock, as many of the telescopes owned by amateurs now are, and use the telescope for guiding the camera. Even if the driving clock be a poor one, the observer can, by patient watching correct the irregularities of motion by means of the slow motion screws of the telescope, and obtain perfect pictures with exposures of even several hours' duration.

The telescope should have an eyepiece of moderate power containing rather coarse cross-wires. A bright star thrown a very little out of focus will enable one to see the wires without any other illumination, so that the star may be quite easily kept bisected by the cross-wires. One of the wires should be placed parallel to the diurnal motion of the star so that if, by any accident or sudden irregularity of the clock, the star should leave the intersection, it may still be upon the parallel wire and be easily brought back to the intersection.

In this way the observer, looking at one star in the telescope and keeping it at the intersection of the cross-wires, causes the rays of each star in the field of view of the camera to continually fall upon the same spot upon the sensitive plate. The star images are thus formed round and thousands of faint stars are enabled by the prolonged exposure to produce impressions which are capable of development.

The ordinary form of camera with bellows and rack motion is not suitable for this work. The plate holder and objective should be rigidly connected, so that the changing position of the camera may produce no perceptible flexure. The best form is perhaps that of a rectangular box of light wood which may be conveniently strapped or fastened with brackets to the telescope tube. A cylindrical steel tube would perhaps be better were it not for its weight. The lenses should be mounted in a sliding tube so that the focusing may be done by pushing them in or out instead of moving the plate holder. There should also for this purpose be a fine scale on the sliding tube, so that for any picture the scale reading may be recorded. Then when the best focus has been found the scale may always be set at the proper reading.

The best focus must be found by experiment. It will not be very far from the visual focus. The best way will be to focus as nearly as possible with the stars or Moon on the ground glass, then draw the objective out a little, say one millimeter. Turn the camera toward the polar sky and make it stationary. Expose for five minutes; move the objective in a little, say two tenths of a millimeter; expose for five minutes again; move the objective in the same distance as before; expose again and so on until eight or ten exposures have been made at different readings of the focusing scale, all without altering the position of the camera. When the plate is developed the star trails will be found to be broken into as many divisions as there were exposures made. Some one of these divisions for each star will be found to be blacker and narrower than the others. The corresponding scale reading will represent the focus for that star. It will not be the same for stars in all parts of the field. That should be selected which will give the best definition over the largest portion of the plate without sacrificing the central part.

A number of very interesting photographs have been obtained at Goodsell Observatory with Darlot combination of lenses of 2½ inches aperture and about 7 inches back-focus. The plate accompanying this article gives copies by photogravure of the original negatives. In that of the constellation Orion the principal stars will be easily recognized. The great nebula is shown in the centre of the plate. Just above it is the nebula about *c* Orionis, which seems almost to be a part of the great nebula. A little higher up the three stars, ζ, ε and δ of the belt of Orion are readily recognized. The curious nebula about ζ which was first discovered by photography is plainly shown. On the original negative this nebula seems to extend over the whole belt and downward to the left past the great nebula around ϑ Orionis, beyond the star ν, then makes a great loop to the left and extends upward and to the right as far as the comet-like flaw in the upper part of the plate. The greater part of this enormous extension is so extremely faint that it is doubtful whether it will appear in the photogravure. The hundreds of fainter stars about the belt are many of them, just below the limit of naked eye vision but can be seen with a good opera-glass. Down toward the right is Rigel, surrounded by a large ring. The ring is due to halation or reflection of the light which was so bright as to penetrate through the film to the back of the glass plate. This effect may be avoided by using the nonhalation plates which are now in the market. This picture was taken on the night of Jan. 25, 1892, with an exposure of 3 hours. A beautiful picture of the great nebula of Orion was taken at the same time with the 8-inch photographic telescope to which the camera was attached. The two were guided by the aid of a second telescope through which the observer looked at the brightest star in the trapezium in the nebula and kept it constantly bisected by a pair of cross-wires.

The second picture is of one of the bright patches of the Milky Way, put down on the maps as *Scutum Sobiesii.* The little spot in the center is the splendid telescopic cluster which we all enjoy looking at so much. By the aid of a microscope one may distinguish some of the stars of the cluster. In this picture it is very evident that the light of the Milky Way results from that of a great number of stars which are just beyond the limit of naked-eye vision. Examined closely under the microscope, the whole background of the picture is in places filled with minute stars, while in others, it appears blank. One cannot help being struck by the arrangement of stars in curved lines in many places. This picture was taken Aug. 18, 1893, with an exposure of $1^h\ 50^m$.

In both pictures it will be noticed that the stars, though round at the center, are elongated toward the edges of the plate. This is because the lenses were made for short distance work. With lenses especially constructed for stellar work, good images should be formed over the whole plate.

Mr. J. A. Brashear, of Allegheny City, Pa., is now constructing a stellar camera for Goodsell Observatory. It is to have a combination of four lenses of six inches aperture and the distance from the inner lens to the plate will be 31 inches. Dr. C. S. Hastings calculated the curves of the lenses to suit the particular glass used. It is expected that the definition will be good over the whole of a 10 × 10 plate, which will take in an area of sky over 15° square. We hope before long to let the readers of POPULAR ASTRONOMY see some of the work done by this new camera.

SUGGESTIONS TO AMATEURS.

NEBULÆ AND COMET SEEKING.

LEWIS SWIFT.

With this initial chapter I assume the task of preparation of a monthly series of papers on these and other allied subjects for the new candidate for public favor, the forthcoming POPULAR ASTRONOMY. I undertake this with the understanding that my articles shall be written in as untechnical language as possible, being for the entertainment and instruction of amateur astronomers only, whose observations are limited to the use of telescopes of from three inches to six inches of aperture. It is, perhaps, needless to say that the effort is made a little difficult by reason of the query of how well the objects described will answer the illustrations when seen with the varying instruments—larger or smaller—under different atmospheric conditions, and with practiced or unpracticed eyes.

The number and variety of objects under the head of nebulæ and clusters, found in greater or less profusion in every portion of the sky, is very great, aggregating nearly eight thousand, but of these only a few will come into the list of those within easy, scrutinizing reach of small glasses. As, however, many possessors of such instruments indulge in the pleasant pastime of comet-seeking, some with considerable persistence, it is quite important that the places of all comet-appearing nebulæ be known with, at least, a tolerable degree of exactness, that the observer may arrive at an immediate decision whether the suspect be a comet or not, at which juncture a catalogue of such nebulæ is indispensable, saving all loss of time not only, but preventing the annoyance to himself and others of false notification of the discovery of a comet (of which many have come to me), which, though improbable, I have not thought it right or wise to withhold from general telegraphic announcement when cloudy skies prevented its verification here.

A case in point is the recent finding and immediate telegraphic information to me of the discovery of a naked-eye comet by Mr. Alfred Rordame of Salt Lake City, Utah.

That his claim to priority of discovery may be understood by astronomers and also by the committee of award of the Donohue comet medal, I take, herewith, the opportunity to reproduce his dispatch *verbatim* as received by me at 4 o'clock on the morning of July 9. "Salt Lake City, Utah, July 8; to Lewis Swift, Warner Observatory, Rochester, N. Y. Naked-eye comet; observed 10 o'clock, constellation Lynx; no telescopic observation possible. Alfred Rordame." I had reasonable doubt as to the reality of his find as I had thoroughly searched that region of the heavens but two evenings previous, but still deemed it rash to keep back its transmission and, therefore, telegraphed it to Professor Pickering with the caution "Verify" before it should be cabled abroad.

I am thus particular in transcription and detail because two young men of Alta, Iowa, claim to have seen it on the same evening at 9^h 30^m, which, with the hour's difference of time in their favor, would give them priority of discovery by 1½ hours. Had they made immediate telegraphic notification of the fact to some astronomer they could clearly have received the honor and the medal which will, under existing circumstances, no doubt, now be conferred upon Mr. Rordame. This recital will, I trust, suggest promptness of action in the event of discovery.

Now, when an amateur astronomer, possessing no catalogue of nebulæ, picks up a faint, nebulous object, how is he to determine with the necessary promptitude whether it be a comet or a nebula? Four principal methods are available to the professional astronomer but only the latter two of these to the amateur, viz:

1. Often a first glimpse will decide, a comet, to the practiced eye, appearing unlike any nebula.

2. An absolute knowledge that no nebula is there, which fact not many amateurs could know.

3. Visibility of a tail almost always opposite the Sun.

4 Detection of motion, which, if ascertained beyond a doubt, is a sure sign. This in the case of a rapidly moving comet, may, with a proper appliance in the eyepiece, generally be detected in a few minutes, though often an hour and even longer time is re-

quisite for absolute certainty in this and for the rate of its motion. Though the object move but a hair's breadth, yet that is sufficient to prove it a comet, but here, under the stress of excitement, the eye often plays false. Several stars may, commonly, be seen in the field, many times two in one direction and other two in another, which will range with either the center or some part of the visible surface of the supposed comet. In a little while a very little motion will be suspected when, in all probability, it has not moved at all. To guard against this deception of the eye, I long ago placed in front of the center of the field lens of the eyepiece, a positive (Ramsden), a single horse hair which the luminosity of the sky renders visible without artificial illumination. The eyepiece when rotated will quickly find two stars in each of two directions that the hair (in astronomical parlance termed the wire) will bisect with the object. By this means, a very trifle of motion will declare itself, using, of course, the same comparison stars for each observation. In this manner, there being no opportunity for eye deception, the least motion imaginable and its direction may be estimated with considerable accuracy. If the eyepiece be a negative (Huyghenian) the hair must be attached to the diaphragm between the lenses.

A worker among the nebulæ may chance upon a comet at the outset of his career, or he may seek months and even years and no comet reward his quest, yet for many there is a seductive charm in the work, especially in the study of the resolvable clusters which continually renews enthusiasm and inspires noble and holy thoughts.

In the succeeding numbers of this series, it is my design to illustrate the objects discussed as viewed with my 4½-inch comet-seeker.

WARNER OBSERVATORY,
Rochester, N. Y., Aug. 1, 1893.

A LESSON ON HARVEST MOON.

ELIZA A. BOWEN.

"The full Moon that comes nearest to the autumnal equinox" (coming in 1892 on September 25) "is known as the Harvest Moon: the one next following, as the Hunter's Moon. At that time of the year, the Moon while nearly full, rises for several consecutive nights at nearly the same hour, so that the moonlight evenings last for an unusually long time." The foregoing is Professor C. A. Young's account of Harvest Moon.

Some very simple observations can be made at the time of Harvest Moon which enable us easily to understand its cause. By noting every evening the point of the horizon at which the Moon rises, it becomes evident that the Moon's position is changing northward rapidly.

The Moon rises because the Earth's rotation on its axis brings the horizon down to the Moon; the Moon rises later on consecutive evenings, because she herself revolves round the Earth in the same direction in which the Earth rotates, and having changed place during the rotation of the horizon, it must rotate a little further to overtake her. But the facts stated above show that in September the full moon travels in her orbit, not directly east, but northeast. A path or line directly east from the horizon would be perpendicular to the horizon, a northeast line must be oblique to the horizon.

The September full Moon is traveling on the part of her orbit most oblique to the horizon. It is evident that the moon traveling away from a line will increase its distance from the line more rapidly the more her path approaches a perpendicular. In September, her path being very oblique, she does not get far ahead of the horizon, and consequently the horizon loses little time in overtaking her and the Moon rises nearly at the same hour on consecutive evenings.

In order to secure genuine activity of the student's mind in teaching this, it is best to develop the subject by a series of questions after the Socratic manner. I give an example below.

Is the Sun's rising due to the Sun's motion? What moves? When you say that "the Moon rises," what moves? What line in nature does the rising Moon seem to pass above? Is it the Moon or the horizon that moves? In what direction does the horizon move? Is the Moon wholly at rest, or has she also some motion of her own? In what direction does the Moon revolve round the Earth? Do the horizon rotating with the Earth, and the Moon revolving round the Earth, move in the same or in opposite directions? Would the horizon find the Moon in the same position at the beginning and end of a rotation? Would the Moon at the end, be in advance of her position at the beginning, or behind it? Would the Moon overtake the horizon on consecutive evenings sooner or later? Why then does the Moon rise later every evening?

If the full Moon in September is found further north on every successive evening, can her path lie directly east from the horizon? Since she is found a little further north, and a little further east every evening, what must be the direction of her path in September? Would a northeast line drawn from the horizon be perpendicular or oblique to the horizon? Does the September full Moon move, then, on a path oblique or perpendicular to the horizon?

The student should now draw a horizontal line to represent the eastern horizon. From it he should draw a perpendicular and an oblique line both extending downwards. Then he should take a linear measure of one inch to represent the distance traveled during the twenty-four hours occupied by the horizon in making one rotation. He should begin at the junction of the lines with the horizon, and measure off this distance on both the perpendicular and the oblique line. We may then ask:

On which path, the perpendicular or the oblique, would the Moon reach the greatest distance from the horizon in twenty-four hours? Would the horizon catch up with the Moon sooner when she is traveling on a path perpendicular, or on one oblique to the horizon? Would the Moon rise sooner when traveling on a path oblique or on one perpendicular to the horizon? Why does the full Moon in September rise nearly at the same hour on consecutive nights? What do you see in nature showing that the full Moon in September moves on a path oblique to the horizon?

In practice, it would probably be found necessary to add other questions.

One very great advantage in this method of explaining Harvest Moon is, that the student can at any time of the year, in a class room or anywhere, *visualize* the facts in nature on which the explanation depends. To visualize is to represent in the imagination, to see with the mind's eye. When the proper time comes for seeing what has been visualized by description, he is almost certain to be inspired with a desire to see it.

This visualizing can be carried to a much greater extent in teaching elementary astronomy, and is of great importance. It keeps the student in touch with nature.

SHOOTING STARS.

How to Observe them and What they Teach us.

W. F. DENNING.*

Chapter I. General Remarks.

A very pretty incident, inseparable from the contemplation of the heavens, is afforded by the unexpected and silent flight of a shooting star. On a clear moonless night we cannot view the firmament for any length of time before one of these fugitive sparks will suddenly emerge out of the darkness and, dashing along a considerable space, will then as quickly disappear, leaving the observer in astonishment at the brevity of the spectacle and puzzling how to account for it. Everyone must naturally have

* Bishopston, Bristol, England.

had an experience of this kind and it is one which impresses itself upon the memory. When the observer is alone and the beauty of a starlit sky tempts him to gaze upwards the sudden incursion of a luminous object so utterly dissimilar to the rest, is a little apt to prove startling, besides involving a mystery which sets him thinking. Is it that a distant orb has changed its place in the firmament? Has it lost its stability and hurled itself upon destruction? Or does it simply represent an electric spark or an atmospheric phenomenon originated by the combustion of gases evolved from the Earth? May it not have been a sort of celestial *ignis fatuus* of unhappy omen? Questions like these are often suggested to casual observers of shooting stars, and it is fortunate that they are capable of being answered on the basis of observed truths. The uninformed have sometimes thought that in the momentary gleam of a falling star they have witnessed the death of a world, but science has shown that the event has no such significance.

In the course of these papers we hope to indicate the method of observation usually pursued in recording shooting stars, and we may also have an opportunity of glancing at some of the leading facts in our knowledge of these remarkable bodies. They are not always referred to under the same title, for we find them variously called "shooting stars," "falling stars," "meteors," "meteorolites," "meteorites," etc., but the terms may be regarded as synonymous.

For many generations shooting stars were regarded as atmospheric appearances, not reducible to any well defined laws. Their irregularities and brief existence gave the idea that the study of them would not be productive of any useful lessons and they were entirely neglected. No one seems to have recognized that these bodies possessed a degree of importance far beyond what their visible character implied. It is perhaps a little singular that ancient astronomers did not pay more attention to them, because they form a class of objects eminently suited for naked-eye observation and one on which they might have exercised their patience with much success.

Detached notices of meteors are, it is true, sometimes met with in old writings, but these are general ones and contain nothing but exaggerated outlines of the events observed. Thus in Plutarch's Life of Julius Cæsar it is stated that before the battle between Cæsar and Pompey, "as Cæsar walked the rounds at midnight there appeared a luminous phenomenon in the air like a torch which, as it passed over his camp, flamed out with great brightness and seemed to fall in that of Pompey." It is obvious that descriptions of this character, though interesting to the ordinary reader of history, possess no scientific value.

It may be justly said, even to-day, that there is no branch of astronomy which promises to unfold more significant and wide-reaching facts than that dealing with meteors. Nor is there any description of objects more universal in their operations or more plentiful in numbers than are to be found in meteoric astronomy. Perhaps also we may be safe in saying there is no department of the science capable of furnishing a richer harvest of observations to the persevering student. Large numbers of new showers await discovery, and there are important features relating to some of the oldest and best known systems which have never yet been adequately investigated. Meteors abundantly pervade every region of the Earth's orbit and they probably infest all space in an endless variety of grouping and orbit.

It cannot be too forcibly impressed upon intending observers that the utmost precision in recording meteors is imperative to the value of the results. Professor Herschel has truly said that "great accuracy in observation alone affords the key to the solution of the problem presented by meteors in their nightly flights." These statements may possibly be thought a little inconsistent, for everyone must realize that as the work depends merely on eye estimations it is impossible to eliminate errors; in fact the nature of the research does not admit of absolute accuracy. But there is no doubt that with great care and with the aptitude acquired by long practice a degree of exactness may be ensured that would scarcely have been thought possible in the face of the difficulties to be encountered. These can, however, be successfully overcome by the observer of experience whose eye is well trained to the work, and whose just conception and appreciation of the details enables him to utilize them with advantage.

Before an observer may be considered thoroughly proficient he requires many months of habitual work in watching and registering meteor paths. It is quite impossible for anyone to secure reliable results, except in special cases, until properly qualified in the light of experience. And this department is one where "personal equation" must operate in a considerable degree. One observer, though he may have had no more practice than another, will attain far greater accuracy. It depends in a great measure upon natural ability. We can only look for the best results where this ability and thorough practice are combined.

For the reason that first attempts are generally untrustworthy young observers are recommended not to be premature in the publication of results. It is far better to wait and to feel one's way cautiously. Old observers have sometimes regretted that their early enthusiasm prompted them to record results which failed to stand the tests applied in after years.

Though for many centuries the proper observation of these bodies was neglected, men at length were led to recognize the importance of submitting them to systematic study. But the early observers appear to have been content to record their general positions and directions relatively to the points of the compass. Heis, at length, about 50 years ago, saw the necessity of being more precise and began to register the apparent astronomical positions of their paths amongst the stars. He was followed and imitated by Schmidt and in recent years observers generally have adhered to the same excellent plan. It is certainly far more precise than the indefinite method of our forefathers and its adoption has directly led to the discovery of many important facts concerning meteors.

In this department the observer has not necessarily to wait certain times and seasons, for the fall of meteors is uninterrupted during the year though subject to decided variations. The summer and autumn months are the most prolific in these bodies while a comparative scarcity prevails in the winter and spring. The morning hours are the best in which to look for them, as at this period they are generally about twice as numerous as they are before midnight.

If we attentively watch the heavens for two or three hours on a fine autumn evening, we shall certainly notice many of these shooting stars, and it will soon become apparent that individually they offer some wide distinctions. They show no uniformity in their directions, positions, magnitudes or motions, in fact variety appears to be a leading characteristic. Their discursive flights across the celestial vault would seem to suggest nothing of order amongst them but that they are dispersed indiscriminately. Some of the meteors shoot across the sky with great velocity and lines of phosphorescence are generated along their paths. They are so quickly gone that the eye retains but a very hurried impression of their appearance. Others move with comparative slowness and we are enabled to follow them steadily and to watch their disappearance in a stream of sparks. And it will be remarked that a small proportion of the meteors shoot upwards so that the designation "a falling star" is not always strictly expressive of the effect observed. In brightness too a singular diversity will become obvious. Small meteors, which the eye can but just distinguish, are seen alternately with far brighter objects, and a difference of color is also very striking in many instances. Amid all this dissimilarity and apparent confusion, it would appear impossible to introduce anything like order, but in our next paper we shall hope to show that the complication is really not so intricate as it seems, but that we may readily classify the meteors according to their motions and appearances, and reduce them to well defined systems.

THE FACE OF THE SKY.

The following statements of the appearance of the sky are true for Northfield, Minnesota, at 9 o'clock, Sept. 25th. These statements will be equally serviceable on other nights if it be remembered that for each preceding evening four minutes should be added to the time, and that for each succeeding evening four minutes should be subtracted.

Facing the north, we see to the west the familiar Big Dipper, standing with its base to the horizon, and its handle pointing toward the brilliant Arcturus just disappearing below the horizon (an hour earlier this beautiful star can be better seen): the second star in the handle is a good naked-eye double. Still facing north, we see Cassiopea's chair or the "w" as some prefer to call it. In this region we note a star cluster which to the unaided eye appears as a nebulous spot in the sky; the opera glass resolves it into a beautiful cluster; it may be located by using as pointers γ and δ of Cassiopea (the first star in the back and the one next it in the seat of the chair), following the line of these stars away from the constellation for a space about three times their distance apart, we find the patch of haze. Still to the east and much higher in the heavens is the great Square of Pegasus: Cassiopea is about half way between the northern horizon and the constellation; a line from the northern point of the horizon through the seat of the chair passes through the square. It is possible by the aid of this constellation to locate an important point in the heavens, the Autumnal Equinox, a point which no bright stars mark; by following the line of δ and γ (the two eastern stars of the square) for a distance equal to the distance between them, we come to a point which, if not the exact position of the equinox, is very near to it. Now taking a line from this point through the pole we have the position of the great circle known as the Equinoctial Colure.

Facing the south, Sagittarius is seen disappearing below the western horizon. Much higher in the heavens and about an hour and a half past the meridian is a noticeable line of three stars in the constellation Aquila, the bright Altair in the middle and a fainter star on either side; passing from the lowest of these stars in a south-westerly direction for a distance about equal to the length of the line of three, we come to η of Aquila, an interesting variable star which changes from 3rd to 5th magnitude in a period of 7½ days; during this time it makes four distinct changes of brightness. To the east of Aquila is the little diamond of four stars known as Job's Coffin. Still higher in the heavens is the brilliant, blue Vega (α Lyræ which twelve thousand years hence will be the pole star). Two faint stars near Vega make with it a little equilateral triangle; the farther north of these is ε Lyræ, a difficult naked-eye double; an opera glass brings out the two companions beautifully, while a large telescope shows that each of these is itself double. It is thought that the two stars seen in the opera glass revolve about their common center in something like a million years, and that the stars of each of the lesser pairs are revolving about their respective centers—the one in a period of about two thousand years and the other in half that time.

61 Cygni is a star of much interest in that it is the nearest of all stars visible in our latitude, the nearest and yet believed to be 366,400 times as far from us as is the Sun—a distance over which light travels in 6 years; it is a 5th magnitude star just crossing the meridian, and six degrees south of the zenith; it makes a little right triangle with two somewhat brighter stars.

The point toward which the solar system is moving at a rate, (according to latest authority,) of 14¼ miles a second, is in the constellation Hercules. This point, known as the "Apex of the Sun's way," is very nearly in a line with the two stars, ε Lyræ and Vega; to locate it, follow this line from ε through Vega about seven times their distance apart. Very near the apex are two fourth-magnitude stars, and not far away is one of the third magnitude.

The Milky Way may prove an unending source of interest and profit to the naked-eye observer as truly as to the possessor of a small glass. To the careful, patient observer on moonless nights its extent and interesting detail seem ever increasing. An opera-glass will resolve many of its hazy patches into star clusters of great beauty.

Later issues of POPULAR ASTRONOMY will present star charts to aid in tracing constellations.

PLANET NOTES.

Mercury is morning planet during the first part of September, but rises too near the Sun to be visible to the naked eye. On the 20th Mercury will be at superior conjunction. Toward the end of October the planet will become visible in the evening twilight, just after sunset.

Venus is the bright "evening star" which is so noticeable in the west after sunset at this time. The motions of the Earth and Venus are so related now that Venus appears to recede very slowly from the Sun, and will not be in very favorable position for observation until the latter part of October. Venus will be in conjunction with the Moon, 30′ north, Sept. 12 at 11^h 19^m P. M., central time, and again, 1° 49′ north, Oct. 13, 6^h 40^m A. M. On Oct. 12, at 8^h 39^m P. M., the star δ Scorpii will be seen in the same field of the telescope with Venus, the star being 13′ south of the planet.

Mars will be in conjunction with the Sun Sept. 4 and will not be visible during the following month.

Jupiter is now a very brilliant object in the morning sky. During September and October Jupiter will be in most excellent position for observation, especially during the latter half of the night. The planet is in the constellation Taurus between the Pleiades and Hyades, and is moving very slowly. It is now moving easward, will be stationary Sept. 19, and after that will retrograde slowly. Jupiter will be in conjunction with the Moon Sept. 2 at noon, Sept. 29 at 6^h 31^m P. M., and again Oct. 26 at 11^h 12^m P. M., central time. At all of these conjunctions the Moon will pass from 4° to 5° north of Jupiter.

Saturn will be at conjunction with the Sun Oct. 8, and will therefore be invisible during the months of September and October.

Uranus will be too low in the west in the evening to be well seen. He will be in conjunction with the Moon 2° 14′ north, Sept. 14 at 12^h 55^m A. M., and again 2° 24′ north, Oct. 11 at noon.

Neptune will be at quadrature, 90° west of the Sun on Sept. 5. The position is very favorable for observation especially after midnight. It is in Taurus about 14° east of Jupiter, about 2° west and 32′ south of the 5th magnitude star ι Tauri. On Sept. 15 Neptune will be at the stationary point of his apparent path among the stars and will be very nearly in the same place during the two months of September and October.

Planet Tables.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
		MERCURY.			
Sept. 5	10 11.5	+12 49	4 17 A. M.	11 11.4 A. M.	6 05 P. M.
15	11 22.5	+ 5 56	5 17 "	11 42.8 "	6 09 "
25	12 28.1	− 1 56	6 14 "	12 08.9 P. M.	6 04 "
Oct. 5	13 28.3	− 9 21	7 04 "	12 29.7 "	5 55 "
15	14 25.8	−15 46	7 50 "	12 47.8 "	5 46 "
25	15 21.7	−20 47	8 29 "	1 04.1 "	5 39 "
		VENUS.			
Sept. 5	13 01.9	− 6 16	8 24 A. M.	2 01.3 P. M.	7 39 P. M.
15	13 46.2	−11 13	8 49 "	2 06.2 "	7 21 "
25	14 31.7	−15 46	9 14 "	2 12.2 "	7 10 "
Oct. 5	15 18.8	−19 43	9 40 "	2 19.9 "	7 10 "
15	16 07.6	−22 53	10 04 "	2 29.2 "	6 54 "
25	16 57.8	−25 04	10 26 "	2 39.9 "	6 54 "
		MARS.			
Sept. 5	10 56.2	+ 7 57	5 24 A. M.	11 58.3 A. M.	6 32 P. M.
15	11 19.8	+ 5 26	5 19 "	11 42.5 "	6 06 "
25	11 43.4	+ 2 53	5 13 "	11 26.7 "	5 40 "
Oct. 5	12 07.0	+ 0 16	5 07 "	11 10.9 "	5 14 "
15	12 30.7	− 2 23	5 02 "	10 55.3 "	4 48 "
25	12 54.5	− 4 56	4 57 "	10 39.7 "	4 23 "
		JUPITER.			
Sept. 5	3 57.0	+19 22	9 30 P. M.	4 53.9 A. M.	12 17 P. M.
15	3 58.2	+19 24	8 52 "	4 15.8 "	11 39 A. M.
25	3 58.0	+19 22	8 13 "	3 36.3 "	11 00 "
Oct. 5	3 56.4	+19 17	7 32 "	2 55.4 "	10 18 "
15	3 53.5	+19 08	6 51 "	2 13.2 "	9 35 "
25	3 49.5	+18 55	6 09 "	1 29.9 "	8 51 "
		SATURN.			
Sept. 5	12 47.1	− 2 36	7 54 A. M.	1 46.6 P. M.	7 39 P. M.
15	12 51.4	− 3 04	7 21 "	1 11.5 "	7 02 "
25	12 55.8	− 3 32	6 48 "	12 36.5 "	6 25 "
Oct. 5	13 00.0	− 3 59	6 15 "	12 01.7 "	5 48 "
15	13 04.3	− 4 26	5 42 "	11 26.9 A. M.	5 12 "
25	13 08.8	− 4 53	5 09 "	10 52.1 "	4 35 "
		URANUS.			
Sept. 5	14 22.3	−13 44	10 15 A. M.	3 21.5 P. M.	8 28 P. M
15	14 24.1	−13 53	9 38 "	2 44.0 "	7 50 "
25	14 26.0	−14 03	9 01 "	2 06.6 "	7 12 "
Oct. 5	14 28.2	−14 14	8 25 "	1 29.6 "	6 34 "
15	14 30.5	−14 25	7 48 "	12 52.5 "	5 56 "
25	14 32.9	−14 37	7 12 "	12 15.5 "	5 19 "

NEPTUNE.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5......	4 49.4	+20 55	10 16 P. M.	5 46.1 A. M.	1 17 P. M.
15......	4 49.5	+20 55	9 36 "	5 06.9 "	12 38 "
25......	4 49.4	+20 55	8 57 "	4 27.5 "	11 58 "
Oct. 5......	4 49.0	+20 54	8 17 "	3 47.8 "	11 19 "
15......	4 48.4	+20 52	7 38 "	3 07.9 "	10 38 "
25......	4 47.7	+20 51	6 58 "	2 27.9 "	9 58 "

THE SUN.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Sept. 5......	10 58.6	+ 6 33	5 29 A. M.	11 58.4 A. M.	6 28 P. M.
15.....	11 34.6	+ 2 45	5 41 "	11 54.9 "	6 09 "
25......	12 10.5	− 1 09	5 52 "	11 51.4 "	5 50 "
Oct. 5......	12 46.7	− 5 02	6 04 "	11 48.2 "	5 32 "
15......	13 23.6	− 8 48	6 17 "	11 45.7 "	5 14 "
25.... .	14 01.6	−12 22	6 30 "	11 44.1 "	4 58 "

Minima of Variable Stars of the Algol Type.

U CEPHEI.

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

Sept. 4	9 P. M.
9	8 "
14	8 "
19	8 "
24	7 "
29	7 "
Oct. 4	7 "
9	6 "
12	6 A. M.
14	6 P. M.
17	6 A. M.
19	6 P. M.
22	6 A. M.
27	6 "

ALGOL.

R. A................$3^h\ 1^m\ 1^s$
Decl................+ 40° 32′
Period............2*d* $40^h 49^m$

Sept. 15	3 A. M.
17	midn.
20	9 P. M.
23	6 "
Oct. 5	5 A. M.
8	2 "
Oct. 10	11 P. M.
13	8 "
28	4 A. M.
30	midn.

λ TAURI.

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

Oct. 18	6 A. M.
22	5 "
26	3 A. M.
30	2 "

R. CANIS MAJORIS

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

Sept. 1	4 A. M.
9	3 "
10	6 "
17	2 "
18	5 "
26	4 "
27	7 "
Oct. 4	3 "
5	6 "
12	2 "
13	5 "
21	4 "
Oct. 22	7 A. M.
29	3 "
30	6 "

U CORONÆ.

R. A..............$15^h\ 13^m\ 43^s$
Decl...............+ 32° 03′
Period...........2*d* $10^h\ 51^m$

Sept. 8	midn.
15	10 P. M.
22	7 "
Oct. 23	9 "
30	7 "

U OPHIUCHI.

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

Sept. 1	10 P. M.
2	6 "
6	10 "
7	6 "
11	11 "
12	7 "
17	8 "

U OPHIUCHI, CONT.

22	8 "
27	9 "
Oct. 2	10 "
3	6 "
7	11 "
Oct. 8	7 P. M.
13	8 "
18	8 "
23	9 "
29	10 "
30	6 "

Y CYGNI

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

Sept. 2	3 A. M.
5	3 "
8	3 "
11	3 "
14	3 "
17	3 "
20	3 "
23	2 "
26	2 "
29	2 "
Oct. 2	2 "
5	2 "
8	2 "
11	2 "
14	2 "
17	2 "
20	2 "
23	2 "
26	1 "
29	1 "

Phenomena of Jupiter's Satellites.

Date	h m		Sat.	Phen.
Sept. 1	12 28	A. M.	II	Ec. Re.
	12 58	"	II	Oc. Dis.
	3 15	"	II	Oc. Re.
2	9 23	P. M.	II	Tr. Eg.
3	4 00	A. M.	I	Sh. In.
4	1 11	"	I	Ec. Dis.
	10 29	P. M.	I	Sh. In.
	11 50	"	I	Tr. In.
5	12 41	A. M.	I	Sh. Eg.
	2 01	"	I	Tr. Eg.
	11 09	P. M.	I	Oc. Re.
7	3 06	A. M.	III	Ec. Dis.
8	12 51	"	II	Ec. Dis.
	3 05	"	II	Ec. Re.
	3 30	"	II	Oc. Dis.
9	9 18	P. M.	II	Sh. Eg.
	9 37	"	II	Tr. In.
	11 53	"	II	Tr. Eg.
10	10 42	"	III	Tr. In.
11	12 02	A. M.	III	Tr. Eg.
	3 05	"	I	Ec. Dis.
12	12 22	"	I	Sh. In.
	1 41	"	I	Tr. In.
	2 35	"	I	Sh. Eg.
	3 52	"	I	Tr. Eg.
	9 33	P. M.	I	Ec. Dis.
13	1 00	A. M.	I	Oc. Re.
	9 03	P. M.	I	Sh. Eg.
	10 20	"	I	Tr. Eg.
15	3 27	A. M.	II	Ec. Dis.
16	9 33	P. M.	II	Sh. In.
	11 54	"	II	Sh. Eg.
17	12 06	A. M.	II	Tr. In.
	2 21	"	II	Tr. Eg.
	9 13	P. M.	III	Sh. In.
	10 57	"	III	Sh. Eg.
18	2 28	A. M.	III	Tr. In.
	3 46	"	III	Tr. Eg.
	9 28	P. M.	II	Oc. Re.
19	2 17	A. M.	I	Sh. In.
	3 31	"	I	Tr. In.
	11 27	P. M.	I	Ec. Dis.
20	2 50	A. M.	I	Oc. Re.
	8 45	P. M.	I	Sh. In.
	9 58	"	I	Tr. In.
	10 57	"	I	Sh. Eg.
21	12 09	A. M.	I	Tr. Eg.
	9 17	P. M.	I	Oc. Re.
24	12 09	A. M.	II	Sh. In.
	2 30	"	II	Sh. Eg.
	2 32	"	II	Tr. In.
25	1 13	"	III	Sh. In.
	2 57	"	III	Eg. Sh.
	9 34	P. M.	II	Ec. Re.
	9 38	"	II	Oc. Dis.
	11 53	"	II	Oc. Re.
26	4 11	A. M.	I	Sh. In.
27	1 21	"	I	Ec. Dis.
	10 39	P. M.	I	Sh. In.
	11 47	"	I	Tr. In.
28	12 51	A. M.	I	Sh. Eg.
	1 58	"	I	Tr. Eg.
Sept 28	9 00	P. M.	III	Oc. Re.
	11 06	"	I	Oc. Re.
Oct. 1	2 45	A. M.	II	Sh. In.
2	9 55	P. M.	II	Ec. Dis.
3	2 15	A. M.	II	Oc. Re.
4	8 23	P. M.	II	Tr. Eg.
5	12 33	A. M.	I	Sh. In.
	1 34	"	I	Tr. In.
	2 45	"	I	Sh. Eg.
	3 45	"	I	Tr. Eg.
	8 36	P. M.	II	Ec. Re.
	9 44	"	I	Ec. Dis.
	11 19	"	III	Oc. Dis.
6	12 32	A. M.	III	Oc. Re.
	12 53	"	I	Oc. Re.
	8 01	P. M.	I	Tr. In.
	9 14	"	I	Sh. Eg.
	10 12	"	I	Tr. Eg.
10	12 30	A. M.	II	Ec. Dis.
11	8 29	P. M.	II	Tr. In.
	9 00	"	II	Sh. Eg.
	10 44	"	II	Tr. Eg.
12	2 27	A. M.	I	Sh. In.
	3 21	"	I	Tr. In.
	4 39	"	I	Sh. Eg.
	11 07	P. M.	III	Ec. Dis.
	11 38	"	I	Ec. Dis.
	12 37	"	III	Ec. Re.
13	2 48	A. M.	I	Oc. Re.
	2 48	"	III	Oc. Dis.
	4 00	"	III	Oc. Re.
	8 55	P. M.	I	Sh. In.
	9 47	"	I	Tr. In.
	11 08	"	I	Sh. Eg.
	11 58	"	I	Tr. Eg.
14	9 06	"	I	Oc. Re.
17	3 05	A. M.	II	Ec. Dis.
18	9 17	P. M.	II	Sh. In.
	10 49	"	II	Tr. In.
	11 37	"	II	Sh. Eg.
19	1 04	A. M.	II	Tr. Eg.
	4 21	"	I	Sh. In.
20	1 32	"	I	Ec. Dis.
	3 07	"	III	Ec. Dis.
	4 25	"	I	Oc. Re.
	4 37	"	III	Ec. Re.
	8 02	P. M.	II	Oc. Re.
	10 50	"	I	Sh. In.
	11 33	"	I	Tr. In.
21	1 02	A. M.	I	Sh. Eg.
	1 44	"	I	Tr. Eg.
	8 01	P. M.	I	Ec. Dis.
	10 52	"	I	Oc. Re.
22	7 30	"	I	Sh. Eg.
	8 10	"	I	Tr. Eg.
23	7 00	"	III	Sh. Eg.
	8 07	"	III	Tr. In.
	9 20	"	III	Tr. Eg.
25	11 53	"	II	Sh. In.
26	1 06	A. M.	II	Tr. In.
	2 14	"	II	Sh. Eg.
	1		II	Tr. Eg.

Oct. 27	3 27 "	I	Ec. Dis.		7 12 P. M.	I	Sh. In.
	6 58 P. M.	II	Ec. Dis.		7 43 "	I	Tr. In.
	10 18 "	II	Oc. Re.		9 24 "	I	Sh. Eg.
28	12 44 A. M.	I	Sh. In.		9 54 "	I	Tr. Eg.
	1 17 "	I	Tr. In.	30	7 02 "	I	Oc. Re.
	2 56 "	I	Sh. Eg.		9 14 "	III	Sh. In.
	3 28 "	I	Tr. Eg.		11 00 "	III	Sh. Eg.
	9 55 P. M.	I	Ec. Dis.		11 20 "	III	Tr. In.
29	12 36 A. M.	I	Oc. Re.	31	12 39 A. M.	III	Tr. Eg.

Configuration of Jupiter's Satellites at Midnight Central Time.

Sept.		Sept.		Oct.	
1	1 4 ○ 2 3	22	1 ○ 2 3 4	11	♃ 3 ○ 1 4
2	2 ○ 1 4 3	23	○ 2 1 3 4	12	2 3 1 ○ 4
3	2 1 3 ○ 4	24	2 1 ○ 3 4	13	♃ 4 ○ 2 3
4	3 ○ 1 2 4	25	3 ○ 1 4 ●	14	4 ○ 1 2 3
5	3 ○ 2 4 ●	26	3 1 ○ 4 2	15	4 2 1 ○ 3
6	2 3 1 ○ 4	27	3 4 2 ○ 1	16	4 2 3 ○ 1
7	2 ○ 1 3 4	28	4 2 ○ 1 3	17	4 3 1 ○ 2
8	1 ○ 2 4 3	29	4 1 ○ 2 3	18	4 3 ○ 2 1
9	♃ ○ 4 1 3	30	4 ○ 2 1 3	19	4 2 3 1 ○
10	♃ 2 4 1 ○	Oct.		20	4 ○ 1 2 3
11	4 3 ○ 1 2	1	4 2 1 ○ 3	21	4 ○ 2 3 ●
12	4 3 ○ 2 ●	2	4 3 2 ○ 1	22	2 1 ○ 4 3
13	4 3 2 1 ○	3	3 4 1 ○ 2	23	2 3 ○ 1 4
14	4 2 ○ 1 3	4	3 4 2 ○ 1	24	3 1 ○ 2 4
15	4 1 ○ 2 3	5	2 3 ○ 4 ●	25	3 ○ 2 1 4
16	4 ○ 2 1 3	6	1 ○ 2 3 4	26	2 3 1 ○ 4
17	2 4 1 ○ 3	7	○ 1 2 3 4	27	○ 1 3 4 ●
18	3 ○ 4 2 1	8	2 1 ○ 3 4	28	○ 2 4 3 ●
19	3 1 ○ 2 4	9	3 2 ○ 1 4	29	2 1 ○ 4 3
20	♃ 3 2 ○ 4	10	3 1 ○ 2 4	30	♃ 2 4 ○ 1
21	2 ○ 1 3 4			31	4 3 1 ○ 2

Phases and Aspects of the Moon.

	d	h m
Apogee	Sept. 17	8 18 "
First Quarter	" 17	10 19 P. M.
Full Moon	" 25	2 23 "
Perigee	" 29	9 48 A. M.
Last Quarter	Oct. 2	9 19 "
New Moon	" 9	2 27 P. M.
Apogee	" 15	4 00 A. M.
First Quarter	" 17	5 20 P. M.
Full Moon	" 25	1 28 A. M.
Perigee	" 27	12 30 "
Last Quarter	" 31	4 42 P. M.

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T.	IMMERSION Angle f'm N pt.	EMERSION Washington M. T.	EMERSION Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
Sept. 23	74 Aquarii	6.0	7 39	39	8 52	255	1 13
24	24 Piscium	6.1	16 42	17	16 31	276	0 49
28	δ Arietis	4.0	8 26	63	9 19	243	0 53
28	τ^1 Arietis	5.0	13 32	34	14 41	265	1 09
Oct. 1	49 Aurigæ	5.7	15 17	113	16 28	241	1 11
2	ν Geminorum	4.3	14 03	35	14 39	327	0 36
17	*b* Sagittarii	4.6	5 06	134	5 53	194	0 47
20	56 Aquarii	6.3	5 41	82	6 55	213	1 14
21	ψ^1 Aquarii	4.1	3 58	80	5 01	224	1 03
23	ζ Piscium	4.8	16 42	44	17 33	266	0 51
26	36 Tauri	6.0	15 48	105	16 51	227	1 03

Phenomena of Jupiter's Satellites.

	h m			
Sept. 1	12 28	A. M.	II	Ec. Re.
	12 58	"	II	Oc. Dis.
	3 15	"	II	Oc. Re.
2	9 23	P. M.	II	Tr. Eg.
3	4 00	A. M.	I	Sh. In.
4	1 11	"	I	Ec. Dis.
	10 29	P. M.	I	Sh. In.
	11 50	"	I	Tr. In.
5	12 41	A. M.	I	Sh. Eg.
	2 01	"	I	Tr. Eg.
	11 09	P. M.	I	Oc. Re.
7	3 06	A. M.	III	Ec. Dis.
8	12 51	"	II	Ec. Dis.
	3 05	"	II	Ec. Re.
	3 30	"	II	Oc. Dis.
9	9 18	P. M.	II	Sh. Eg.
	9 37	"	II	Tr. In.
	11 53	"	II	Tr. Eg.
10	10 42	"	III	Tr. In.
11	12 02	A. M.	III	Tr. Eg.
	3 05	"	I	Ec. Dis.
12	12 22	"	I	Sh. In.
	1 41	"	I	Tr. In.
	2 35	"	I	Sh. Eg.
	3 52	"	I	Tr. Eg.
	9 33	P. M.	I	Ec. Dis.
13	1 00	A. M.	I	Oc. Re.
	9 03	P. M.	I	Sh. Eg.
	10 20	"	I	Tr. Eg.
15	3 27	A. M.	II	Ec. Dis.
16	9 33	P. M.	II	Sh. In.
	11 54	"	II	Sh. Eg.
17	12 06	A. M.	II	Tr. In.
	2 21	"	II	Tr. Eg.
	9 13	P. M.	III	Sh. In.
	10 57	"	III	Sh. Eg.
18	2 28	A. M.	III	Tr. In.
	3 46	"	III	Tr. Eg.
	9 28	P. M.	II	Oc. Re.
19	2 17	A. M.	I	Sh. In.
	3 31	"	I	Tr. In.
	11 27	P. M.	I	Ec. Dis.
20	2 50	A. M.	I	Oc. Re.
	8 45	P. M.	I	Sh. In.
	9 58	"	I	Tr. In.
	10 57	"	I	Sh. Eg.
21	12 09	A. M.	I	Tr. Eg.
	9 17	P. M.	I	Oc. Re.
24	12 09	A. M.	II	Sh. In.
	2 30	"	II	Sh. Eg.
	2 32	"	II	Tr. In.
25	1 13	"	III	Sh. In.
	2 57	"	III	Eg. Sh.
	9 34	P. M.	II	Ec. Re.
	9 38	"	II	Oc. Dis.
	11 53	"	II	Oc. Re.
26	4 11	A. M.	I	Sh. In.
27	1 21	"	I	Ec. Dis.
	10 39	P. M.	I	Sh. In.
	11 47	"	I	Tr. In.
28	12 51	A. M.	I	Sh. Eg.
	1 58	"	I	Tr. Eg.
Sept 28	9 00	P. M.	III	Oc. Re.
	11 06	"	I	Oc. Re.
Oct. 1	2 45	A. M.	II	Sh. In.
2	9 55	P. M.	II	Ec. Dis.
3	2 15	A. M.	II	Oc. Re.
4	8 23	P. M.	II	Tr. Eg.
5	12 33	A. M.	I	Sh. In.
	1 34	"	I	Tr. In.
	2 45	"	I	Sh. Eg.
	3 45	"	I	Tr. Eg.
	8 36	P. M.	II	Ec. Re.
	9 44	"	I	Ec. Dis.
	11 19	"	III	Oc. Dis.
6	12 32	A. M.	III	Oc. Re.
	12 53	"	I	Oc. Re.
	8 01	P. M.	I	Tr. In.
	9 14	"	I	Sh. Eg.
	10 12	"	I	Tr. Eg.
10	12 30	A. M.	II	Ec. Dis.
11	8 29	P. M.	II	Tr. In.
	9 00	"	II	Sh. Eg.
	10 44	"	II	Tr. Eg.
12	2 27	A. M.	I	Sh. In.
	3 21	"	I	Tr. In.
	4 39	"	I	Sh. Eg.
	11 07	P. M.	III	Ec. Dis.
	11 38	"	I	Ec. Dis.
	12 37	"	III	Ec. Re.
13	2 48	A. M.	I	Oc. Re.
	2 48	"	III	Oc. Dis.
	4 00	"	III	Oc. Re.
	8 55	P. M.	I	Sh. In.
	9 47	"	I	Tr. In.
	11 08	"	I	Sh. Eg.
	11 58	"	I	Tr. Eg.
14	9 06	"	I	Oc. Re.
17	3 05	A. M.	II	Ec. Dis.
18	9 17	P. M.	II	Sh. In.
	10 49	"	II	Tr. In.
	11 37	"	II	Sh. Eg.
19	1 04	A. M.	II	Tr. Eg.
	4 21	"	I	Sh. In.
20	1 32	"	I	Ec. Dis.
	3 07	"	III	Ec. Dis.
	4 25	"	I	Oc. Re.
	4 37	"	III	Ec. Re.
	8 02	P. M.	II	Oc. Re.
	10 50	"	I	Sh. In.
	11 33	"	I	Tr. In.
21	1 02	A. M.	I	Sh. Eg.
	1 44	"	I	Tr. Eg.
	8 01	P. M.	I	Ec. Dis.
	10 52	"	I	Oc. Re.
22	7 30	"	I	Sh. Eg.
	8 10	"	I	Tr. Eg.
23	7 00	"	III	Sh. Eg.
	8 07	"	III	Tr. In.
	9 20	"	III	Tr. Eg.
25	11 53	"	II	Sh. In.
26	1 06	A. M.	II	Tr. In.
	2 14	"	II	Sh. Eg.
	1		II	Tr. Eg.

Oct. 27	3 27	"	I	Ec. Dis.		7 12	P. M.	I	Sh. In.
	6 58	P. M.	II	Ec. Dis.		7 43	"	I	Tr. In.
	10 18	"	II	Oc. Re.		9 24	"	I	Sh. Eg.
28	12 44	A. M.	I	Sh. In.		9 54	"	I	Tr. Eg.
	1 17	"	I	Tr. In.	30	7 02	"	I	Oc. Re.
	2 56	"	I	Sh. Eg.		9 14	"	III	Sh. In.
	3 28	"	I	Tr. Eg.		11 00	"	III	Sh. Eg.
	9 55	P. M.	I	Ec. Dis.		11 20	"	III	Tr. In.
29	12 36	A. M.	I	Oc. Re.	31	12 39	A. M.	III	Tr. Eg.

Configuration of Jupiter's Satellites at Midnight Central Time.

Sept.		Sept.		Oct.	
1	1 4 O 2 3	22	1 O 2 3 4	11	♃ 3 O 1 4
2	2 O 1 4 3	23	O 2 1 3 4	12	2 3 1 O 4
3	2 1 3 O 4	24	2 1 O 3 4	13	♃ 4 O 2 3
4	3 O 1 2 4	25	3 O 1 4 ●	14	4 O 1 2 3
5	3 O 2 4 ●	26	3 1 O 4 2	15	4 2 1 O 3
6	2 3 1 O 4	27	3 4 2 O 1	16	4 2 3 O 1
7	2 O 1 3 4	28	4 2 O 1 3	17	4 3 1 O 2
8	1 O 2 4 3	29	4 1 O 2 3	18	4 3 O 2 1
9	♃ O 4 1 3	30	4 O 2 1 3	19	4 2 3 1 O
10	♃ 2 4 1 O	Oct.		20	4 O 1 2 3
11	4 3 O 1 2	1	4 2 1 O 3	21	4 O 2 3 ●
12	4 3 O 2 ●	2	4 3 2 O 1	22	2 1 O 4 3
13	4 3 2 1 O	3	3 4 1 O 2	23	2 3 O 1 4
14	4 2 O 1 3	4	3 4 2 O 1	24	3 1 O 2 4
15	4 1 O 2 3	5	2 3 O 4 ●	25	3 O 2 1 4
16	4 O 2 1 3	6	1 O 2 3 4	26	2 3 1 O 4
17	2 4 1 O 3	7	O 1 2 3 4	27	O 1 3 4 ●
18	3 O 4 2 1	8	2 1 O 3 4	28	O 2 4 3 ●
19	3 1 O 2 4	9	3 2 O 1 4	29	2 1 O 4 3
20	♃ 3 2 O 4	10	3 1 O 2 4	30	♃ 2 4 O 1
21	2 O 1 3 4			31	4 3 1 O 2

Phases and Aspects of the Moon.

		d	h m	
Apogee	Sept.	17	8 18	"
First Quarter	"	17	10 19	P. M.
Full Moon	"	25	2 23	"
Perigee	"	29	9 48	A. M.
Last Quarter	Oct.	2	9 19	"
New Moon	"	9	2 27	P. M.
Apogee	"	15	4 00	A. M.
First Quarter	"	17	5 20	P. M.
Full Moon	"	25	1 28	A. M.
Perigee	"	27	12 30	"
Last Quarter	"	31	4 42	P. M.

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T.	IMMERSION Angle f'm N pt.	EMERSION Washington M. T.	EMERSION Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
Sept. 23	74 Aquarii	6.0	7 39	39	8 52	255	1 13
24	24 Piscium	6.1	15 42	17	16 31	276	0 49
28	δ Arietis	4.0	8 26	63	9 19	243	0 53
28	τ^1 Arietis	5.0	13 32	34	14 41	265	1 09
Oct. 1	49 Aurigæ	5.7	15 17	113	16 28	241	1 11
2	ν Geminorum	4.3	14 03	35	14 39	327	0 36
17	b Sagittarii	4.6	5 06	134	5 53	194	0 47
20	56 Aquarii	6.3	5 41	82	6 55	213	1 14
21	ψ^1 Aquarii	4.1	3 58	80	5 01	224	1 03
23	ζ Piscium	4.8	16 42	44	17 33	266	0 51
26	36 Tauri	6.0	15 48	105	16 51	227	1 03

COMET NOTES.

There are no comets known to be visible with small telescopes at the time of this writing, and in fact it is doubtful whether any will be visible in the large telescopes by the time this number of POPULAR ASTRONOMY reaches our readers. The last discovered comet, *b* 1893, commonly named after two independent discoverers, Rordame-Quenisset, is rapidly receding from the Earth and Sun, and at the same time being hidden in the evening twilight.

It is an interesting fact that this comet was observed by Mr. W. E. Sperra, an amateur astronomer of Randolph, Ohio, for over two weeks before it was discovered by Rordame. The former mistook the new comet for Finlay's periodic comet on June 20, when it was in Right Ascension $2^h 43^m$, Declination 17° 30′ N. and observed it on eleven nights before July 8. Not having at hand an ephemeris of Finlay's comet covering that period of time, he did not find out his mistake until it was too late to claim the honor of discovery.

Comet b 1893.—This comet was first noticed at this place by me about 9:30 P. M., July 7th, appearing as a large, hazy star without visible tail, but its true nature was not then suspected. My first telescopic observations were obtained on July 9th, when the comet was a fine object in my 3-inch glass, the coma was large and bright with a strong central condensation; for about 4 or 5 degrees from the "head" the train was fully as bright as the coma and well defined at the edges, from thence it faded gradually but could be traced curving slightly to the N. N. E. for a distance of about 15 degrees; a minute tail was suspected on the east side of the coma close to the main train.

July 10th: The train could be traced for only about 12 degrees to-night, it is wider and less bright and not as well defined at the edges near the head, the coma also does not appear as distinct as on last evening. 11th: Appearance about the same as last night, train could be traced about 17 degrees. 12th: The comet is much more distinct to-night, the coma is brighter and apparently slightly oval, and nucleus quite bright, train about 22 degrees in length. 13th: Train appears much shorter and narrower and is somewhat fainter, coma also appears smaller and the nucleus very stellar, train about 13 degrees. 14th: Train very faint and difficult with the naked eye being visible for only about 5 degrees, coma about the same as on last evening but nucleus seems more stellar. 17th: Train faint about 3 degrees in length. At 11 P. M. a minute condensation of light was detected about ½° from the coma which proved to be a small star when it emerged from behind the tail, it appeared very diffused seen through the tail. 18th: The comet is much brighter to-night than it has been for several nights, the train is more defined for a longer distance even with the strong moonlight. 19th: Coma decreasing, train could be traced only about 1°. 25th: Coma bright with apparently larger nucleus which did not appear stellar. 28th: Coma bright, faint tail only about ½° long, no bright nucleus could be seen. August 3d: Nucleus decidedly stellar, comet is now only about ⅛ degree long, but still a conspicuous object in 3-inch telescope. Aug. 13th: Comet is much smaller and appears somewhat elongated although no train or nucleus could with certainty be seen.

As far as my observations go the comet appeared at its best as regards brightness and distinctness of coma and a portion of train on the evening of July 9th, while the train reached its maximum length, about 22°, on the 12th.

DAVID E. HADDEN.

Alta, Iowa, August 16th, 1893.

GENERAL NOTES.

This number was delayed a few days more than anticipated because the engraving work was behind time. We expect the second number will be mailed on or before October 5th.

The general articles for this issue are largely introductory, but they well suggest the plan of this popular magazine, and, we believe, will tend to bring the scholars and the popular readers of astronomy nearer together in common interest.

This part of our publication will be open to appropriate questions and brief answers. Send them in early each month, so that there shall be time for best answers to queries and comparison of views of competent authority when desirable. Here is an example: "Where is the international date line?" This can best be answered, probably, by a small hemisphere map, showing its position from the Arctic ocean, north of Bhering Straits, in irregular course, till it reaches the Antarctic ocean. We will try to give such a map next time.

Constellation Study.—Professor Winslow Upton, the writer of the first article, is the director of the Ladd Observatory, Brown University, Providence, R. I. He studied practical astronomy at Cincinnati Observatory, was afterwards connected with the government signal service at Washington, and later was called to his present position. Read the introduction to his series of articles on constellation study, and notice every point of suggestion carefully. Interested students will seize this opportunity for self-instruction, and lose nothing through lack of personal and vigorous application in nightly half-hour studies.

The Spectroscope and Some of its Applications.—The spectroscope is now recognized as so indispensible an instrument in the study of modern astronomy, that the average popular reader should understand its elemental principles and its applications. These are so simple that a teacher or student may master them thoroughly in a short time if the needed information is within reach. Professor James E. Keeler, the director of the Observatory at the Western University of Pennsylvania, Allegheny City, has kindly promised to furnish this in a series of articles on the above named topic. He was formerly assistant to Professor S. P. Langley, in that Observatory; was later appointed astronomer at Lick Observatory, where he did work of world-wide fame with the spectroscope, and, finally, he was recalled to the directorship of the Allegheny Observatory. This series of articles will explain the spectroscope and its wonderful work in late years, we are sure, in most admirable way.

Study of the Moon.—Foreign observers are doing more than those in America at present in the study of the Moon. For aid in this work we have asked T. G. Elger and others. Mr. Elger is a Fellow of the Royal Astronomical Society, and the director of the observing section for lunar study of the British Astronomical Association. By this means we hope to present, in clear and satisfactory way, problems now under astronomical study concerning our nearest neighbor. The photogravure copies of photographs shown in our frontispiece will interest readers generally, because the upper plate is by an 8¼-inch telescope, while the other was taken by the aid of the great Lick refractor of 36-inch aperture. Any one who has either Neison, or Nasmyth and Carpenter, on the Moon, will find good exercise in recognizing scores of surface markings plainly shown in both. Try it.

As a simple exercise for the inexperienced try to recognize markings on the Moon's surface by the aid of the naked eye only. How many objects can be *distinctly* seen? Make a picture of what can be seen whether the names are known or not. Try again and see if more can be observed *certainly*. Use an opera glass and notice how many more objects can be added. Why does the observer see more now? Does he see as much more as he ought, considering the diameter of the pupil of the eye as compared with that of the field lens of the opera glass? Many useful easy lessons might be suggested.

Double Star Astronomy.—S. W. Burnham of Chicago, late of the Lick Observatory staff, is, without doubt, the ablest scholar in double star astronomy in the world. It is gratifying to announce that he will write for this magazine on his favorite theme in a way to help those who have small telescopes and want to learn how to do useful work in this most interesting field of research. He will present an article in our next issue.

Making Telescopes and the Care of Them.—We are glad to announce that J. A. Brashear, one of the foremost opticians in the United States, will prepare a series of articles for POPULAR ASTRONOMY on the making of telescopes and how to care for them. Mr. Brashear's reputation fairly authorizes him to write for professional astronomers in such matters, but he now proposes to prepare something for amateurs particularly.

Shooting Stars—How to observe them and what they teach us.—W. F. Denning, Bishopston, Bristol, England, has generously consented to furnish articles for us concerning the Shooting Stars, how to observe them and what they teach us. Mr. Denning's long experience in observing these peculiar phenomena and his thorough study of the radiants of a great number of different streams of meteors, enable him to speak of details for the professional astronomer with recognized authority. Amateurs will certainly find his articles abundantly helpful. They will begin in our next number.

E. E. Barnard of the Lick Observatory will begin in our next, a series of articles on Celestial Photography. He has recently returned from an extended visit to the astronomical observatories of Europe. His photographs of portions of the Milky Way and other celestial objects were exhibited at a meeting of the Royal Astronomical Society of England, June 9 of this year, and by the hearty vote of thanks given him at its close, it is evident that Mr. Barnard's photographic work pleased the distinguished English astronomers present. The more important of these excellent photographs will appear later in one or the other of our astronomical periodicals. The wants of amateurs with small lenses will be kept in mind constantly.

Miss Eliza A. Bowen's excellent article on the Harvest Moon, elsewhere given, is an illustration of how admirably she can put ideas into language. The attention of teachers in the elements of astronomy is called to that paper. Her direct and simple way of putting a matter that often puzzles students, we are sure, will be regarded with favor. Other good things from her ready pen will follow. Those who have seen her popular work entitled "Astronomy by Observation," published by D. Appleton & Co., New York, are already favorably advised of the writer's reputation.

Dr. Lewis Swift will contribute articles on comet-seeking and the nebulæ. It is somewhat generally known that Dr. Swift himself owns one of the best large telescopes in the United States. It is a Clark 16-inch glass and with it he has discovered a very large number of new nebulæ. Dr. Swift's work in discovering comets was done, however, years ago by the aid of a small telescope. He is greatly interested in amateurs and their work. He will probably continue observing work at Rochester, N. Y., for a while yet, although it was decided a few months ago to remove his Observatory to some point on the Rocky Mountains.

Dr. H. C. Wilson of Goodsell Observatory will write on various topics. He has had excellent opportunity for study and observation with the best of American Astronomers. The editorial work done in *Astronomy and Astro-Physics* for the last two years is certainly suggestive of what may be expected for POPULAR ASTRONOMY from Dr. Wilson's pen. He will continue to prepare the planet tables and aid in planet and comet notes. The tables and planet notes are the only matter that will appear unchanged in both magazines. They will consist of four or five pages each month.

Personal Sketches.—Another feature of popular interest is under consideration. It has seemed to us that our readers would be helped, if we could furnish from month to month good half or third page pictures of eminent scholars or observers in astronomy. The sketch to accompany the illustration should be very brief, not to exceed a page of printed matter. The object of this is to familiarize interested readers with the living men and women who lead in opinion and ability in astronomy. Other lines of publication do this creditably, why is this one an exception? Of course every person so represented should see and pass judgment on all that is to be published before it appears, to avoid all error of statement or other unfavorable representation.

Professor George E. Hale, director of the new Yerke's Observatory of the University of Chicago, has promised to write some popular papers on the Sun. His recent wonderful discoveries in regard to photographing the faculæ and solar prominences, so called, place him among the first of American Astronomers in regard to stellar and solar physics. Reference is made to Volumes X and XI of *Astronomy and Astro-Physics* for details of information and beautiful photogravure illustration of both faculæ and prominences, as photographed by Professor Hale's new method. In this our readers will have the newest of the new astronomy in solar studies.

Division of Work.—Text-books, maps, charts and general courses of reading in astronomy are all good and useful in their respective places, but they are by no means all that is necessary or desirable to put a person at his best for acquiring general knowledge in this branch. We have so often seen the good results of division of work and associated study that we are ready to recommend it heartily under proper guidance. Why would it not be a good plan in any small village or in connection with any high school to form a class of half a dozen or more young people for the sake of reading the elements of astronomy and such observational study of the face of the sky as can be done by the naked eye and the opera glass. One of the best maps of the Milky Way we have ever seen was made from naked eye observation alone. A great deal of useful and enjoyable study can be done with the unaided eye, if a person has any interest in such things. We suggest the plan of classified, associate study. For example, those persons who wish to begin the study of the Moon, send us their names indicating what they have done, if anything, whether or not they have any telescope; if so, its size, maker, and attachments, as eyepieces, micrometer, clock, spectroscope, etc. In the same way in regard to the following subjects: Meteors, Star Colors, Variable stars, Jupiter, Sun and others in observational and reading courses. If this is done to any considerable extent, we will undertake the classification and try to secure a competent and experienced guide for each class that can use about the same grade of work on a given topic. We believe work like this is the secret of the interest and success of so many amateur astronomical societies that have recently formed in many parts of the United States. The rapid growth and usefulness of some of these societies is simply phenomenal. This is a part of the great university extension work everywhere so popular. It ought to be extended even more widely. Very general correspondence is solicited concerning this specialized, associated study and observation.

Poole Brothers' Celestial Hand-book is intended as a companion to their Celestial Planisphere, a description of which is found among the advertisements of this issue.

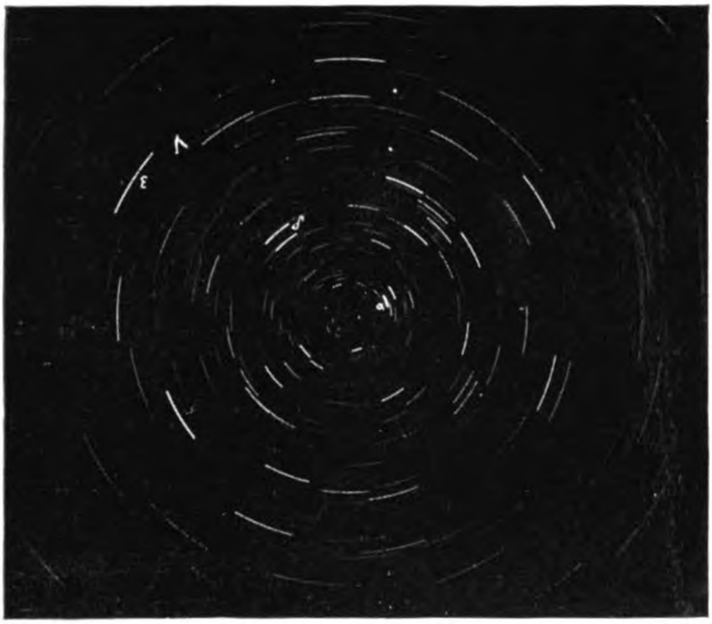
Mr. Jules A. Colas, the editor and compiler of this hand-book, is a scholarly gentleman, and he has taken great pains to collect and arrange within the compass of 110 pages a large amount of material to accompany the planisphere before referred to. We have used the planisphere and hand-book considerably, and have found them both excellent so for as we have been able to examine them carefully. For most of the numerical values given the authority is named, so that it is easy to verify them. The illustration is ample and very good in kind. We notice 140 cuts in the space of the 110 pages. The reading matter is in small type and the printing is superb. We doubt if so much, in so limited space, can be found elsewhere, if we take into the account the amount and variety of illustration. It is a pleasure to call attention to this new work.

Publisher's Notices.—The subscription price for POPULAR ASTRONOMY is $2.50 per year, foreign countries 14 shillings, payable in advance, the annual volume consisting of ten numbers, issued monthly, except for July and August, each containing at least 48 pages of reading matter. Articles for publication may be sent to Wm. W. Payne, Goodsell Observatory, Carleton College, Northfield, Minn., or to Miss C. R. Willard, same address. All remittances for subscription or advertising should be sent to Miss Willard who is in charge of the accounts of the office.

Please take notice that all payments of dues should be made in post office orders or notes, or bank drafts on Chicago, New York, St. Paul or Minneapolis. Personal checks are banked at a discount.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are sole foreign agents.

POPULAR ASTRONOMY No. 2. PLATE III.



Star Trails near the North Pole.

From a Photograph taken at Goodsell Observatory, Sept. 14, 1893, with a 2½ inch camera. Exposure 1 hour.

Photograph of Ursa Minor.

Taken at Goodsell Observatory Sept. 16, 1893, with a 2½ inch camera. Exposure 1 hour.

Popular Astronomy.

Vol. I. OCTOBER, 1893. No. 2

ASTRONOMY WITH THE SMALL CAMERA.

H. C. WILSON.

In my first article on this subject (page 26) I spoke of photographing star trails as a pleasing and useful pastime for the amateur. We are able this month to present an illustration of this work. The upper picture of the frontispiece to this number of POPULAR ASTRONOMY presents a reproduction of a photograph of the north polar region of the sky, taken at Goodsell Observatory on the night of Sept. 14, 1893. The exposure was of just an hour's duration, with a stationary camera of 2½-inches aperture. The camera was directed as nearly as possible toward the true pole of the heavens and it will be noticed at once that there are a few faint stars very near the pole but none exactly at that point. The shortest trail is perhaps three times as long as it is broad. As you go away from the pole the trails of the stars increase in length, but each one is exactly one twenty-fourth part of a circle having the pole for its center. There are many more stars on this plate than can be seen with the naked eye. The brighter stars may be recognized by the thickness of their trails, and we have marked a few of the Greek letters, by which they are known, on the plate. The so-called pole star Polaris, or α Ursæ Minoris, it will readily be seen, is not at the pole but quite a little distance from it. The *Nautical Almanac* gives, its polar distance on Sept. 14 as $1° 15' 40''$. To the left and above the pole is the wide pair of stars δ and at an equal distance farther to the left ε. These three form the tail of the Little Bear or handle of the Little Dipper as the constellation is sometimes called. Near the upper right hand corner of the plate is a very long trail which is really composed of two trails end to end, the two stars having the same declination but differing about an hour in right ascension. In reproducing this picture the original has been copied through a screen, so that the trails are all broken up by the meshes of the screen, but in the original negative they are perfectly smooth and uniform in width.

The second picture of the frontispiece was intended as a companion to the first, showing the appearance of the same stars when the camera is moved by clock-work. The direction of the camera was, however, changed so as to take in the whole constellation of Ursa Minor. The exposure was made of the same duration, the camera being attached to the 8-¼inch equatorial telescope. The observer corrected the irregularities of the driving clock every ten minutes, by looking through the telescope at the star ε Ursa Minoris and adjusting it to the cross-wires of the telescope. The night was not so clear as the one on which the trails were photographed, so that not so many more stars appear in the picture as might have been expected. Nearly all of the minute white spots on the plate represent actual stars. A few are flaws which in most cases may be recognized by their irregular outline when examined with a microscope. We have marked the principal stars with the Greek letters so that the reader will have no trouble in identifying them. The scale of this picture is about twice that of Klein's Atlas and a little greater than that of Heis' Atlas. It will be a good exercise for the student to see how many of the stars shown in this photograph can be identified in the sky with an opera-glass.

CONSTELLATION STUDY.

WINSLOW UPTON.*

II.

In the preceding article of this series, attention was called to the place which a study of the constellations occupies in the science of astronomy. It was stated that astronomers use the constellations to a very limited extent, simply referring to them in star catalogues and maps for the purpose of naming stellar areas within which the stars are situated. It was also stated that it is useful as well as interesting for any one to learn the leading configurations, because such knowledge gives a clearer idea of the effect of the Earth's daily rotation on its axis, and annual revolution about the Sun, than is otherwise obtained. But herein lies the chief difficulty in studying the groups, for they are not found in the same part of the sky at different hours of the night, nor at the same hour on different nights of the year. More than that, as the apparent rotation of the heavens each night is not in the

* Director Ladd Observatory, Brown University, Providence, R. I.

same plane as that on which we seem to be standing, the stellar groups are turned at different angles to the horizon, which materially adds to the difficulty of recognizing them. Groups which rise in the southeast and set in the southwest, like Scorpio and Canis Major as seen in northern latitudes, are affected but little, and so are always recognized when once they are known; but those which rise in the east or northeast, and set in the west or northwest, like Andromeda and Bootes as seen in northern latitudes, are so much affected that the casual observer sometimes fails to recognize that they are the same. And in the case of groups which rise in the northeast the difficulty is increased by the fact that they pass nearly overhead as they move towards the northwest. As no one likes to observe an object when near the zenith, the gradual change in the apparent position of the group is not noted, and there seems to be an abrupt change in its position in the northeast, and later in the northwest. In these northern latitudes the stars which are nearer the pole than the place of observation is north of the equator in latitude do not rise and set, but revolve about the celestial pole, always remaining above the horizon. They therefore appear in all possible positions as is readily seen by watching during one night the movements of the familiar "Dipper" (which is not a recognized constellation, but a part of the large constellation, Ursa Major), and repeating the observation during a night six months later.

The effect of the Earth's annual revolution about the Sun is suggested in the last sentence. As the Earth moves eastward about the Sun, an observer on the Earth sees the Sun projected upon the opposite side of the sky and moving in the same direction of rotation among the stars. Long before it was known that the Earth revolved around the Sun, it was observed that the Sun moved among the stars in an easterly direction nearly 1° a day, and it was very naturally supposed that this apparent movement of the Sun was real, and that the Sun actually did revolve around the Earth. Since the brightness of the Sun prevents us from seeing his movement among the stars, as we can do in the case of the Moon, we detect it by noticing where the same stars are on successive evenings at the same time. The constellations which are in the west at 8 o'clock to-night will be nearer the horizon to-morrow night at the same time, and in a few weeks will be lost in the Sun's brightness. A few weeks later the same stars will rise in the morning before the Sun, showing that the Sun has passed by them moving easterly. Or the same thing may be observed in any other part of the sky. The stars cross the meridian four minutes earlier each night than the preceding night, and those which rise and set, rise and set four minutes earlier for the same reason. The effect of the annual motion of the Earth around the Sun is then to make the constellations appear in different parts of the sky at the same hour in different months of the year. It does slowly in a year what the Earth's axial rotation does each twenty-four hours.

It is worth emphasizing that the change in the constellations due to the daily and annual motion of the Earth is simply one of position in the sky but does not effect their relations to each other. Like the subdivisions of a country, each state has its neighboring states occupying the same relation to it. The same figure may apply too to the individual stars in the constellation, which like the towns of a state retain their relative positions. The figure fails only in the fact that individual stars have movements of their own, but on account of their enormous distances these motions can be detected only with the most refined instruments of modern astronomy, and are quite inappreciable in constellation study. If Abraham, or any other of the Chaldean sages, should look at the heavens to-day, he would notice the same constellations which he saw so many centuries ago.

It follows from the above that the constellations should be learned independent of the time of night and the season of the year. It may be well to begin their study by following the guide of some treatise which says that "at 8 P. M. in October, such and such constellations are overhead, due south, in the east," etc., but when once found, they should be learned with reference to each other, and should be watched at occasional times as long as they are visible in the evening hours, so that they will be recognized ever after whenever they are seen.

Only a passing reference needs to be made to a plan for studying the constellations which was suggested, though perhaps not seriously, many years ago. The names of the constellations were included in doggerel rhymes which one could commit to memory to aid in their recollection. Thus Dr. Watts is said to have treated the zodiacal constellations as follows:

"The *Ram*, the *Bull*, the heavenly *Twins*,
And next the *Crab*, the *Lion* shines,
The *Virgin* and the *Scales*;
The *Scorpion*, *Archer* and *Sea-Goat*,
The *Man* that holds the *Water-Pot*,
And *Fish*, with glittering tails."*

* Burritt's Geography of the Heavens.

And the constellations in the vicinity of Orion are embalmed in the following classic strain:

"The *River's* shining streams beneath him pour,
And angry *Taurus* rages close before;
Behind him *Procyon* barks, and Sirius growls,
While full in front, the monster *Cetus* howls."*

The essential condition for a satisfactory study of the constellations is that the several groups shall be learned without regard to terrestrial objects or to the time of day or year. To know a constellation only when it is over a particular tree is rather awkward in case the tree should be cut down, and it is only a little less foolish to recognize a group when in a particular part of the sky and not wherever the constellation may be found. The remedy for this difficulty is surely to learn the constellations independent of all terrestrial relations and solely by their relative positions. This can be done systematically in some such way as will now be given. It is recommended—

1. That the heavens be divided into four sections, each lune shaped with an angle of 90°,—(just as an orange is peeled into four divisions of this shape.)

2. That these four divisions accord with the system used by astronomers in designating stars by their right ascension and declination.

3. That the boundary lines between the divisions be traced among the stars, and also the celestial equator and ecliptic for reference lines.

4. That the zodiacal consetllations be first learned, and then the other constellations in each of the four divisions.

In northern latitudes, it is advisable to modify this general scheme by taking out of each quarter section the constellations which are north of the zenith, and forming a fifth division of polar constellations.

The first two of these recommendations require explanation for those who are unacquainted with the technical terms there used.

The system of latitude and longitude by which positions on the earth's surface are conveniently designated is familiar to every one. It is constructed in this way: 1st, a great circle on the sphere is drawn. In general, any great circle (a great circle is one whose plane passes through the centre of the globe) may be chosen, but usually some condition will determine its selection. In the latitude-longitude system, the condition is that the great

* Burritt's Geography of the Heavens.

circle shall be perpendicular to the earth's axis of rotation. 2d, a series of circles perpendicular to this circle are drawn, which in the latitude-longitude system are called meridians. They necessarily intersect at the poles and are of indefinite number. 3rd, one of these circles or meridians is selected as a Reference Circle,—in the latitude-longitude system that passing through some place, as Greenwich, is arbitrarily selected. The position of a point on the earth's surface is given by the distance from the equator to the point, measured upon the meridian of that point—its latitude—and by the angle between this meridian and the Reference Meridian—its longitude. In a precisely similar way the positions of the several stars are recorded. There are in fact three or four systems in current use, each having its special uses, but we are concerned now with only one, which corresponds with that of terrestial latitude and longitude in everything but the names employed. We usually look down upon a globe from the outside, and imagine the equator and meridians drawn upon the convex spherical surface. But in studying the stars we must remember that we are within the celestial sphere, and are looking towards the concave spherical surface upon which we may imagine the circles to be drawn. If the earth's axis were prolonged indefinitely, it would seem to pierce the sky at two opposite points, one of which is very near the star often called the Pole Star, or Polaris, and the other invisible in northern latitudes, but as much depressed below the south horizon as the north pole is elevated above it. In passing, it is of interest to note that the celestial pole is at precisely the same height above the observer's horizon as his latitude, and the latitudes of places on the earth's surface are found by measuring indirectly that height. If the plane of the earth's equator is imagined extended until it reaches the sky, it will trace thereon a circle at whose centre we seem to be situated. This circle, the celestial equator, always cuts the horizon at the east and west points exactly, and at its highest point, over the south point of the horizon in northern latitudes, is as high above the horizon as the difference between 90° and the observer's latitude. We therefore see but half of the celestial equator. It always occupies the same position in the sky, and the stars as they move across the sky describe circles which either coincide with it or are parallel with it. The Sun's daily path is upon the equator at the time of the vernal and autumnal equinoxes. The paths of different stars are circles, parallel with it, but smaller and smaller as stars are selected nearer the pole, like the parallels of latitude upon the terrestrial globe.

The circles which are perpendicular to the celestial equator, corresponding with meridians upon the globe, may now be imagined all intersecting at the celestial pole. But they are not called celestial meridians. The term meridian is reserved for the special one which passes through the point directly overhead and consequently through the north and south points of the horizon. The general name for them is declination circles or hour circles and declination corresponds with latitude on the Earth, as the distance from the celestial equator to the star measured upon its declination circle. Two of the declination circles have special names, that which passes through the two points of the equator where the Sun crosses it in March and September each year, called the Equinoctial Colure, and that which passes through the highest northern and lowest southern point which the Sun reaches in June and December respectively, called the Solstitial Colure. These colures are exactly 90° apart.

It will be profitable to notice here the effect which the daily movement of the heavens has upon this imaginary system of circles. The meridian has just been defined as the declination circle which passes through the point directly over the head of the observer—his zenith—and also through the north and south points of the horizon. It therefore seems to be an immovable circle, and is immovable as far as the observer's station is concerned. It is the trace in the sky of the meridian on the Earth which is drawn through the place of observation. By the diurnal motion of the heavens the various declination circles in turn coincide with the celestial meridian, and all the stars upon a given declination circle "cross the meridian" at the instant of the coincidence of the two declination circles. Another way of expressing the same idea is to omit altogether the idea of a fixed meridian and to say that each of the declination circles of the celestial sphere passes in turn directly through the zenith of any observer, and at that instant it is called the celestial meridian because it is in the plane of the observer's terrestial meridian.. It follows from this that any region of the sky, for instance one of the four divisions suggested above, or any special constellation within it, may sometimes be wholly east of the meridian, or west of it, or intersected by the meridian according to the position of the declination circles bounding it at the given time.

It remains to speak of that which corresponds to longitude on the Earth and to the reference meridian, by which it is determined. The latter is arbitrarily chosen; on the Earth that of Greenwich we usually say is agreed upon. There is however no universal agreement among civilized nations on this point, but astronomers of all nations have agreed to adopt the point on the equator where the Sun crosses it each spring as the reference point in the stellar system, and the declination circle passing through it, the equinoctial colure, is therefore the reference circle. The angle between this circle and the declination circle passing through any star is called the right ascension of the star, corresponding therefore with terrestrial longitude. It will be evident that the diurnal motion does not change the right ascension of the star nor its declination, because they are determined by fixed circles in the heavens which turn with it. Right ascension is always reckoned towards the east completely around the sphere and not like longitude on the Earth, both east and west from the primary meridian. It is usually expressed in time, that is hours, minutes and seconds. Declination is reckoned like latitude from the equator towards either the north or south pole, called north and south declination, or + and — declination, respectively. It is always expressed in degrees, minutes and seconds.

We are now ready to consider the first two recommendations for a systematic study of the constellations. The equinoctial and solstitial colures divide the sky into four grand divisions, each 90° or 6^h in width in right ascension, and extending from pole to pole. The division corresponds with the four divisions which might be made on the Earth between the meridian of Greenwich, and those 90°, 180° and 270° east of it.

The Sun crosses the celestial equator in the spring and at that time its right ascension is 0^h. Three months later he has reached the summer solstice, having passed through the first of the four divisions; in the next three months he traverses the second division and so on through the year. The evening sky shows constellations which are in general 60° to 240° east of the Sun, less than this south of the equator and more than this north of it, until in the vicinity of the pole all stars are above the horizon whatever their right ascension. After the autumnal equinox the Sun is in the third division of the heavens until the winter solstice is reached. During these months the fourth division lies west of the meridian and the first division east of it in the early evening.

Let us now carry our thoughts out of doors and try to get a clear idea of the four divisions of the sky, their bounding colures and the celestial equator. Facing the north (assuming that the reader is in north latitude) the "Dipper" and the pole star are first found. In the autumn the Dipper lies northwest of the meridian in the early evening, but it can readily be found whatever its position, as the "seven stars" are so conspicuous. The two stars which form the side of the bowl opposite the handle are nearly in line with the pole star, a bright star rather isolated. They are sometimes called the Pointers from this fact. It will be noticed that the fourth star at the junction of the handle and bowl, is fainter than the others. The equinoctial colure passes very near this star, which is lettered δ Ursæ Majoris and was formerly called Megrez. Imagine the colure to start at the pole star and to run through δ Ursæ Majoris and continue in the same direction to the celestial equator; it will pass through the autumnal equinox. If continued to the south pole it will form the half of the colure which marks 180° or 12^h of right ascension. Near the autumnal equinox itself there is a star, η Virginis, and the circle passes near α Corvi and α Crucis, as will be mentioned later in taking up the constellations in detail. If we prolong the circle in the other direction, we shall find its position marked by three bright stars. The first is in Cassiopeia in the foot of the chair-shaped figure, and is about as far from the pole star as δ Ursæ Majoris. It is lettered β Cassiopeiæ and was formerly called Caph. Continuing the same line, two more stars are reached which form the eastern side of a large quadrilateral, the square of Pegasus. The stars are α Andromedæ and γ Pegasi, and were formerly known as Alpheratz and Algenib respectively. If the line is prolonged beyond the last named star as far as it is itself south of α Andromedæ, the vernal equinox is reached, in a part of the sky where are no bright stars. The five stars thus named mark the equinoctial colure with sufficient precision for the purpose at hand. It may help to recognize different orders of brightness to note that δ Ursæ Majoris and γ Pegasi are third magnitude stars, and the others, α Ursæ Minoris, β Cassiopeiæ, and α Andromedæ are second magnitude stars. δ Ursæ Majoris is about 32° from the pole, and β Cassiopeiæ a little less; α Andromedæ is 30° from β Cassiopeiæ, and γ Pegasi 14° from α Andromedæ. The "pointers" of the Dipper are 5° apart and the northern one is 28° from the pole.

The autumn evenings are specially good for tracing the equinoctial colure, as above described. The vernal equinox is then between the east horizon and the meridian, and the line of bright stars leading to it from the poles is in good position to be viewed. With this colure marked out so prominently in the sky, it is easy to imagine the solstitial colure drawn at right angles to it, but it does not pass near any very conspicuous stars. The 90° or 6^h half passes near η Geminorum which will be later referred to as marking the summer solstice, and passes 4° east of α Orionis, the bright red star in the shoulder of that figure. The 270° or 18^h half passes through the head of Draco, and also near μ Sagittarii which marks the winter solstice.

The position of the celestial equator needs no line of stars to mark it, as it always passes through the east and west points of the horizon and crosses the meridian at a height which is the complement of the observer's latitude. The following, however, mark its position and are here given for future reference when the constellations to which they belong are discussed: The celestial equator passes through the Belt of Orion, 2° south of α Canis Minoris (Procyon), and near η Virginis, γ Virginis and α Aquarii.

The tracing of the ecliptic, which was suggested under the third recommendation, can best be done in connection with the study of the zodiacal constellations, which will be deferred to another paper.

The student of the constellations should learn the Greek alphabet (the small letters only are sufficient) if he wishes to designate the leading stars by their usual names. It was mentioned in the former paper that the usual way of naming the brighter stars is by the Greek letters given by Bayer in the seventeenth century followed by the Latin name of the constellation in the genitive or possessive case. Individual names are nearly obsolete except for the very brightest stars. In these articles both designations will usually be given.

In closing this paper it may be well to suggest that constellation study cannot be carried on successfully by reading, but that there must be constant reference to the heavens. As far as we have gone, we have examined the sky in a general way, divided it into grand divisions and noted the effect of the diurnal and annual motions upon the constellations. This effect will be more evident after a few constellations have been learned, but it is well at this very point to get a general idea of these motions. Let the reader answer the following questions: Do the stars which rise due east pass near the zenith? If not, how far from the zenith are they when they cross the meridian? How many of the stars of the Dipper are always above the horizon? It is a good plan to select a few conspicuous stars in different parts of the sky and watch their movements from night to night for several months; for instance the Pleiades, which in the autumn evenings are in the eastern sky, or the dog star Sirius, which rises in the southeast several hours after the Pleiades. The Dipper and the chair-shaped figure in Cassiopeia are good groups for this purpose in the northern sky. The bright star α Lyræ or Vega, which passes nearly through the zenith as seen in the United States, and in October is west of the meridian in the early evening, is an excellent star to show how far north of the west point a star so situated sets.

The following is a list of the constellations which are visible in northern latitudes, and which will be referred to in the subsequent papers of this series. They embrace the fifty-seven constellations adopted by Argelander and are here arranged according to the four divisions of the sky explained above. The polar constellations are taken out of each division and placed by themselves. The other constellations are arranged in each division from the north toward the south. The zodiacal constellations are in italics; the Roman numerals I, II, III, and IV, refer to the four divisions of the sky bounded by the equinoctial and solstitial colures, and extending from 0^h to 6^h, 6^h to 12^h, 12^h to 18^h, and 18^h to 0^h respectively. An asterisk designates the constellations which are in Ptolemy's list. He also gives two others, Corona Australis and Ara, which are in the southern sky.

CONSTELLATIONS VISIBLE IN NORTHERN LATITUDES.

Constellations North of Zenith.

I	*Cassiopeia	III	*Ursa Minor
I	Camelopardalis	IV	*Draco
II	*Ursa Major	IV	*Cepheus

Constellations of South Zenith.

I.	II.	III.	IV.
*Andromeda	Lynx	Coma Berenicis	*Lyra
*Triangulum	Leo Minor	Canes Venatici	*Cygnus
*Perseus	*_Gemini_	*Bootes	Lacerta
*Auriga	*_Cancer_	*Hercules	*Aquila and Antinous
*_Pisces_	*_Leo_	*Corona Borealis	*Sagitta
*_Aries_	Monoceros	*Ophiuchus	Vulpecula
*_Taurus_	*Canis Minor	*Serpens	*Delphinus
*Cetus	Sextans	*_Virgo_	*Equuleus
*Eridanus	*Hydra	*_Libra_	*Pegasus
*Orion	*Crater	*_Scorpio_	Scutum Sobieski
*Lepus	*Canis Major	*Corvus	*_Sagittarius_
Columba	*Argus	*Centaurus	*_Capricornus_
		*Lupus	*_Aquarius_
			*Piscis Australis

From world to world his couriers fly,
Thought winged and shod with fire;
The angel of the stormy sky
Rides down the sunken wire.

—*Whittier.*

TIME AND TIME SIGNALS.

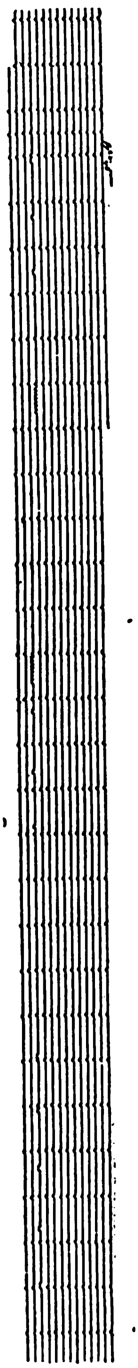
CHARLOTTE R. WILLARD.

From the days when slaves sat under the open heavens watching the movements of the constellations that they might keep a record of time for their masters, or the monk counted the passing hours by repeating Psalms, or the more ingenious man measured his time by the burning out of a candle,—all the way down through the days of noon marks on the kitchen floor and the calling of gatherings at "early candle light,"—do we find men striving to answer the now familiar question, "What time is it?" These laborious efforts, with their varying measure of failure and success, seem to have come to almost perfect fruitage in an age which computes time to the hundredth part of a second, and in which a clock must be regulated to the tenth of a second if it is to hold any place as a standard time piece.

The observatory method of determining time is very simple in principle. The observer turns to his catalogue of stars, and chooses one for his observation, the catalogue giving him the time (to the hundredth of a second) at which that star will be on his meridian; he then turns to the telescope, and at the instant the star crosses the meridian records the time indicated by his clock. The catalogue gives the true time of passage, and unless the clock gives the same it is in error.

This method of clock testing might come into universal use were it not for two practical difficulties. First, the difficulty of determining when a star is on the meridian. Let the attempt be made on any clear night to determine the exact instant when a star passes the meridian, and the difficulty will be obvious—clearly so if it be remembered that the instant of passage must be named with extreme accuracy. This were indeed an easy matter if there were actual meridian lines drawn across the heavens as we see them on spheres; we should then watch the star as it rose in the east, and continued its westward way until the instant that it passed behind the meridian line. Just this effect *is* secured by the Observatory instrument used in making time observations.

The conspicuous part of a meridian circle is a telescope so mounted that it can be turned to any point on the meridian from northern horizon to southern, but cannot be turned upon any other part of the sky. Just back of the eyepiece of this telescope is placed a series of fine wires, one of which is coincident with the



observer's meridian. In observing, these wires seem to be projected as lines upon the sky, and the stars are seen passing behind them; the observer records the clock time of these passages, and has the desired data.

The second practical difficulty in the way of a universal use of this method of clock correcting is that of accurately recording the time. The observatory meets this difficulty by the aid of the chronograph. The chronograph presents a revolving cylinder about which a sheet of paper is clamped; a fountain pen rests upon the sheet, tracing a line as the cylinder revolves; an electric connection with a clock causes the pen to make a break in the line once in two seconds. The observer holds in his hand an electric key connected by wires with this pen; as the star passes a line, a quick pressure on the key makes a record on the chronograph sheet. The accompanying illustration shows a chronograph sheet on which has been recorded the transit of a star. Each line is one minute long, *i. e.*, it took the pen one minute to trace it; the regular dashes are just two seconds apart; the eleven irregular breaks are the records made by the observer as the star passed the lines, the middle or sixth being the record made when it passed the meridian line. It will be noticed that opposite one dash the time is marked—17^h 43^m: from this we may determine the time on any other part of the sheet (as where the star transit is recorded), since progress is made by two-second steps. Such is the method of recording meridian observations at Goodsell Observatory.

The time thus carefully determined is given to the world chiefly through jewelers and railroad companies. From some observatories a constant signal is sent, telegraphing the time day and night; from others, short signals are given at stated hours. The time is telegraphed with extreme accuracy by the clock itself. Wires are run from the telegraph system into the clock, and are so connected with a toothed wheel back of the second hand that the electric current is closed at each even second,—thus producing the sound of the clock tick on all connected instruments. From Goodsell Observatory the time is sent out twice a day,—at ten o'clock in the morning and at nine in the evening. Any one coming into the clock room at three minutes before ten, would hear the operator at the time desk telegraphing the word "time." This call of "time, time, time," continues for just one minute; it is simply a warning to operators all along the line to stop other business, and have their instruments in readiness for the free passage of the signal. At two minutes of ten, by a change of switches at the table, connections are made with the clock, and for two minutes the clock controls the wires, making itself heard for twelve thousand miles. One unfamiliar with the signal will naturally question how the simple sound of the clock tick can be interpreted so as to give the exact time. Those who receive the signal understand that it begins at two minutes of ten, that just before the beat which marks one minute of ten, there will be a short silence, and that just before the ten o'clock beat, there will be a longer silence. In this way, the meaning of the signal is made perfectly clear.

It is indeed impressive to stand in the presence of the great clock as it sends out its message clear and true, knowing that hundreds of men are listening, setting their clocks and running their trains in obedience to the message of a star.

JUPITER'S FAMILY OF COMETS.

W. W. PAYNE.

In the first number of this journal (p. 25) will be found a brief article on the above named topic. A few errors were made in the names of the comets on the plate accompanying that paper. It is the purpose of this further statement to correct those errors, to add a few more orbits of comets belonging to the family, and to give a table of useful data pertaining to all.

That the reader may easily understand the meaning of the table an explanation of terms commonly used by astronomers to define a comet's orbit is subjoined. We know of none better than that given by Professor William Harkness, of the U. S. Naval Observatory, Washington, D. C., and found in full in the December number of the *Sidereal Messenger*, 1887. We use his explanations with some verbal changes.

When a comet is discovered the first question asked about it is, "What are its elements?" To the vast majority of amateurs these elements are almost unintelligible, and even to adepts they often convey but a vague idea of the orbit. The best way to realize their exact import is by making a model;* and by showing how easily that can be done, it is hoped a fruitful source of instruction and amusement will be brought within the reach of every one interested in the subject.

The orbits of all heavenly bodies are conic sections whose size, form and position in space are defined by six quantities called elements which for brevity are usually designated by the following symbols:

T = Instant of the body's perihelion passage. (By perihelion is meant the nearest point to the Sun in its orbit.)

π = Longitude of the perihelion; in the case of the comet, measured along the ecliptic from the vernal equinox to the comet's ascending node, and thence along the comet's orbit to its perihelion; in the case of the Earth measured along the ecliptic from the vernal equinox to the perihelion.

☊ = Longitude of the ascending node; measured on the ecliptic, from the vernal equinox to the ascending node of the orbit.

i = Inclination of the plane of the orbit to the plane of the ecliptic.

e = Eccentricity of the orbit, sometimes given in parts of the radius and sometimes as an angle φ. Parts of the radius are most convenient for our purpose, and seconds of arc may be reduced to that unit by dividing them by 206,265″. When the angle is given $e = \sin\varphi$.

q = Perihelion distance of the body expressed in terms of the mean radius of the Earth's orbit as unity.

Amateurs will notice that for a parabolic orbit e is unity, and in that case the elements are frequently given by stating T, ω, ☊, i, and log q. Here π has been replaced by

$$\omega = \pi - ☊.$$

which is counted in the comet's orbit backward from the perihelion to the ascending node, and the perihelion will lie on the northern or southern side of the ecliptic according as ω is less or greater than 180°.

As π and ☊ are counted from the vernal equinox, and i is meas-

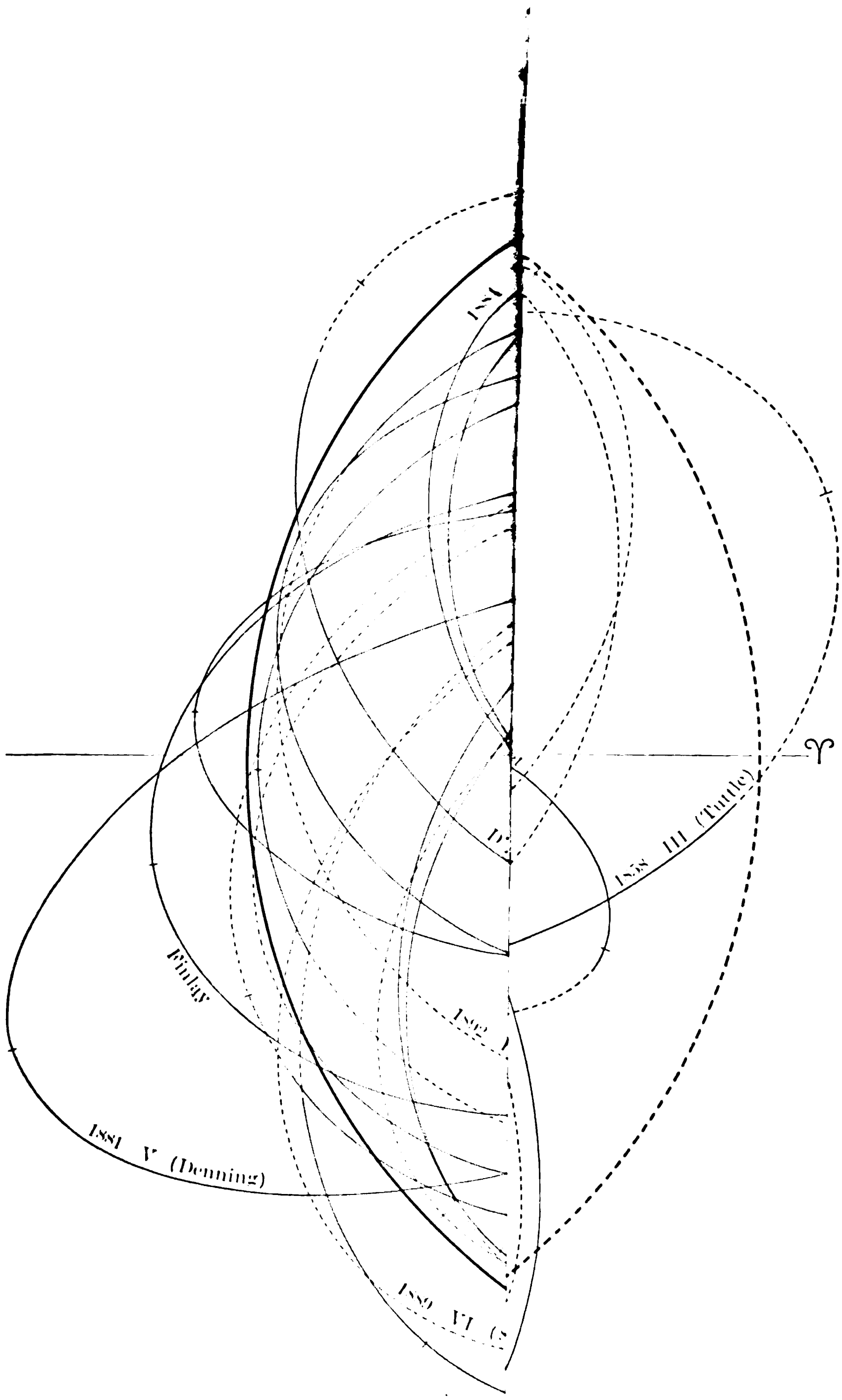
* The mode of doing this is explained in the article referred to.

ured from the plane of the ecliptic, these quantities necessarily refer to a particular equinox which is always specified.

It was long customary to measure longitudes in comet's orbits in the direction of the Earth's motion, to limit i to the first quadrant, and to specify the direction of the comet's motion, whether direct or retrograde; but most astronomers now prefer to follow Gauss in regarding retrograde motion as a result of the inclination passing into the second quadrant, and in accordance with that view they measure a comet's longitude always in the direction of its own motion, and permit i to take any value between 0° and 180°. The circumstance that i is measured at the ascending node limits its range to the first and second quadrants, for if it were to pass into the third or fourth quadrant the ascending node would be converted into a descending one. For a comet having direct motion the numerical values of the elements are the same in the old system as in Gauss' system, but for a comet having retrograde motion they are different, and in that case, if their values according to the old system are designated by a subscript 0, the equations requisite for passing from the old to the Gaussian system are:

$$i = 180° - i_0 \qquad \omega = 360° - \omega_0 = -\omega_0$$
$$\Omega = \Omega_0 \qquad \pi = 2\Omega_0 - \pi_0$$

There is frequently much confusion respecting the angles π and ω, and as no model can be constructed without using the latter it is important to have a clear understanding of its relations to π and Ω. In the old system of elements π is measured from the vernal equinox, along the ecliptic in the direction of the Earth's motion, to the ascending node of the comet, and thence along the comet's orbit, *still in the direction of the Earth's motion*, to the comet's perihelion. In Gauss' system π is measured from the vernal equinox, along the ecliptic in the direction of the Earth's motion, to the ascending node of the comet and thence along the comet's orbit, *in the direction of the comet's motion* to the comet's perihelion. These definitions may perhaps be elucidated by the following statement: Imagine a perpendicular to the plane of the ecliptic erected from the Sun. Then to an observer situated north of the ecliptic in that perpendicular, the motion of the Earth will be counter-clockwise, and longitudes in the Earth's orbit will increase in that direction. Now consider a comet's orbit, imagine a perpendicular affixed to it in such a way that when the inclination of the orbit to the plane of the ecliptic is i the inclination of the perpendicular shall be $(i + 90°)$, and



Jupiter's family of Co

From a drawing by A. O. Sil Observatory,
Nor. Carleton College.

suppose an observer so situated in the perpendicular that when $i = 0°$ he shall be north of the ecliptic. Then, according to the old system of elements, for all possible values of i the observer will remain north of the ecliptic, and the motion of the comet will appear to him as counter-clockwise when direct, and clockwise when retrograde; but according to Gauss' system of elements, he will be north of the ecliptic when i is less than 90°, south of it when i is greater than 90°, and to him the apparent direction of the comet's motion will always be counter-clockwise. Whichever system is adopted, from his point of view π will always increase counter-clockwise, and to find the intersection of the plane of the comet's orbit with the plane of the ecliptic, or in other words, the line of nodes, he must set off ω clockwise from the perihelion of the orbit."

Under q we spoke of the *mean* radius of the Earth's orbit. By referring to the plate the perihelion and aphelion points of the comet orbits will be readily seen by the short cross-lines at respectively the nearest and farthest points from the Sun. The middle point of the line connecting the perihelion and the aphelion is the center of the curve. The distance from the center to the aphelion or perihelion of the comet's path is called its *mean* distance. The nodes of the orbits are called ascending and descending and are easily distinguished. All the bodies whose paths are represented on the plate move contrary to the hands of a watch. The word "Tuttle" (Comet III, 1858) is near the vernal equinox. Below this word will be noticed the cross-line for the aphelion point in Encke's comet. That point nearly marks the ascending node of the comet path shown by the dotted line becoming continuous. About 180° distant the continuous line is broken, which marks the point of the descending node. From these suggestions it would seem that any popular reader could easily follow all that is said before, if it be remembered how the bodies move, and that the dotted portions of their paths are thought of as being below the plane of the ecliptic and the continuous parts above. It is also believed that anyone will readily understand the following table* which is the most complete one we know of, and is brought down to date.

Our readers will be interested to know that the foregoing description of the "Elements" was so well thought of by C. F. Chambers, author of Chambers' Handbook of Astronomy, (English), as to be used by him in the latest edition of his book which is favorably known everywhere as an authority.

At another time we will give Professor Harkness' rules for making a model of the comet's orbit.

* Elements having no reference are taken from *Annuaire* of 1893, Paris.

ELEMENTS OF THE JUPITER FAMILY OF PERIODIC COMETS.

Comets of which more than one apparition has been observed.

Name.	Period in yrs.	Time of Perihelion Passage.	Perihel'n Distance	Aphelion Distance	e	π	☊	i	Mean Equinox	Calculator and Reference.
						° ′ ″	° ′ ″	° ′ ″		
Encke	3.303	1891 Oct. 17.986	0.34047	4.09489	0.84647	158 38 46	334 41 27	12 54 58	1891.0	Backlund, Astr. Gesel. J. 27-1.
Tempel	5.211	1889 Feb. 2.101	1.38660	4.66545	0.55210	306 08 03	121 09 17	12 45 05	1890.0	Schulhof.
Brorsen	5.456	1890 Feb. 4.104	0.58776	5.61038	0.81034	116 23 10	101 27 34	29 23 48	1890.0	E. Lamp, A. N. 2933.
Tempel-Swift	5.534	1891 Nov. 14.083	1.08660	5.17088	0.65270	43 14 16	296 31 15	5 23 14	1891.0	Bossert, Astr. Gesel. J. 27-1.
Winnecke	5.818	1892 June 30.893	0.88642	5.58313	0.72297	276 11 09	104 04 59	14 31 31	1890.0	Haerdtl. A. N. 3062. Astr. Gesel. J. 28, p. 142
Tempel	6.507	1885 Sept 25.734	2.07332	4.89733	0.40513	241 21 50	72 24 09	10 50 27	1880.0	Gautier, A. N. 2656.
Biela {Nucleus 1	6.587	1852 Sept 23.718	0.86016	6.16732	0.75520	109 05 20	245 49 34	12 33 28	1852.0	D'Arrest, A. N. 933
Biela {Nucleus 2	6.629	1852 Sept 22.952	0.86059	6.19687	0.75512	108 58 17	245 58 29	12 33 50		
Finlay	6.627	1893 July 12.176	0.98912	6.06371	0.71951	7 41 34	52 27 43	3 02 02	1893.0	Schulhof, A. N. 3171
D'Arrest	6.691	1890 Sept 17.493	1.32404	5.77776	0.62713	319 14 34	146 16 32	15 42 41	1890.0	Leveau, Astr. Gesel. J. 26-1
Wolf	6.821	1891 Sept 3.473	1.59285	5.60058	0.55714	19 11 38	206 22 29	25 14 33	1891.0	Thraen, A.N. 3050, Berberick, A. J. 253, Astr. Gesel. J. 27-1
Faye	7.566	1881 Jan. 22.671	1.73814	5.97009	0.54902	50 48 47	209 35 25	11 19 40	1880.0	Möller, Berl. Jahrb. 1882

Comets of which only one Apparition has been Observed.

Name.	Period in yrs.	Time of Perihelion Passage.	Perihel'n Distance	Aphelion Distance	e	π	☊	i	Mean Equinox	Calculator and Reference.
1819 IV, (Blanpain)	4.810	1819 Nov. 20.252	0.89256	4.806	0.68675	67 18 48	77 13 57	9 01 16	1819	Encke.
1766 II, (Helfenzrieder)	5.025	1766 Apr. 26.995	0.39898	5.468	0.86400	251 13 00	74 11 00	8 01 45	1766	Burckhardt.
1884 II, (Barnard)	5.398	1884 Aug. 16.483	1.27969	4.872	0.58395	306 11 20	5 08 38	5 27 33	1884.0	Egbert, A. N. 2657
1844 I, (De Vico)	5.459	1844 Sept 2.484	1.18632	5.015	0.61737	342 30 48	63 49 38	2 54 46	1844	Brünnow.
1886 IV, (Brooks)	5.595	1886 June 6.691	1.32772	4.976	0.57874	230 16 51	53 28 57	12 43 26	1886.0	S. Oppenheim.
1770 I, (Lexell)	5.626	1770 Aug. 13.547	0.67431	5.652	0.78684	356 16 27	131 59 34	1 34 31	1770	Le Verrier.
1783 (Pigott)	5.888	1783 Nov. 19.937	1.45929	5.062	0.55246	50 17 25	55 40 30	45 06 54	1783	C. H. F. Peters.
1892 V, (Barnard)	6.309	1892 Dec. 11.05	1.42911	5.396	0.58123	16 52 36	206 38 45	31 12 28	1892.0	Krueger, Astr. Gesel. J. 28 p. 145
1890 VII, (Spitaler)	6.378	1890 Oct. 26.601	1.81791	5.061	0.47144	58 25 58	45 05 52	12 50 44	1890.0	Spitaler, A. N. 3011
1858 III, (Tuttle)	6.609	1858 May 2.974	1.14922	5.894	0.67368	200 46 27	175 04 09	19 30 02	1858.0	Schulhof.
1892 III, (Holmes)	6.909	1892 June 13.238	2.13940	5.116	0.41024	345 53 12	331 42 12	20 47 23	1892.0	Schulhof, A. N. 3140
1889 V, (Brooks)	7.073	1889 Sept 30.012	1.95023	5.419	0.47070	1 26 17	17 58 45	6 04 10	1890.0	Chandler, A. J. 205, A. N. 2952 Astr. Gesel. J. 26-1
1881 V, (Denning)	8.343	1881 Sept 12.834	0.72384	7.503	0.82403	18 10 05	66 09 02	6 53 26	1881.0	Chandler, A. N. 2406
1889 VI, (Swift)	8.534	1889 Nov. 29.572	1.35367	6.998	0.67585	40 15 02	330 36 02	10 14 54	1890.0	Hind, Astr. Gesel. J. 27-1

SHOOTING STARS.

How to Observe Them and What They Teach Us.

W F DENNING.

II. Preliminaries of Observation.

To acquire a reliable knowledge of the phenomena exhibited by any class of objects we must accumulate a great number of observations and discuss them in detail. We cannot, from a general view of a subject, or by a merely superficial acquaintance with its observational features, hope to comprehend its real character or to speak with authority as to its scope and various ramifications. It has been customary, in new departments of science, to prematurely draw conclusions and adopt theories on the basis of imperfect data. Meteoric astronomy is not, it is true, a new branch, but its interesting developments are comparatively recent and the state of our knowledge is such that we still need to tread the path leading to further discoveries with the utmost care and circumspection. The great display of Leonids in 1833 may be justly said to have brought the meteoric branch of astronomy prominently into notice, for it not only awakened considerable interest in the subject, but showed the importance of acquiring systematic observations.

The fundamental and really important object in observing shooting stars is to record their *apparent paths* in the sky with exactness. It is also desirable to ascertain their *durations of flight* as nearly as possible, as this element, in the case of a doubly observed meteor, will give the velocity and enable the form of orbit to be determined. "Personal equation" enters very largely into observations of this kind, for the field is one in which errors of judgment cannot be refined by instrumental measures. Indeed it is doubtful if some observers ever attain to the degree of precision which the work essentially requires. Out of say 50 persons not more than one is likely to excel in an extreme degree, and to possess sufficient natural ability and perseverance to allow him to accumulate results of the high character required. This need not however prove discouraging for there is no reason why the most humble observer, whose small beginnings and inadequate methods give little promise of success, should not, by spurring on in the right direction, attain the necessary precision and perform a vast amount of useful work.

Observations of shooting stars are best pursued out of doors, for the view from a window or opening in an Observatory dome is restricted, and the observer will find that now and then paths are intercepted and lost beyond the limits of his field. Perhaps a flash will suddenly startle him, and although he sees nothing more than that, he realizes having lost a fine meteor. Now this could scarcely have happened had he been observing from an open situation. The writer has often, on seeing a flash, turned in time to catch the end part of the flight, or the streak or train of a brilliant meteor, and has been enabled to record its path satisfactorily though placed in a region of the firmament nearly opposite to that he happened to be watching at the time. In the depth of winter when a starlit sky often means a severe frost, the observer may, however, well be excused for undertaking meteor watches from an open window or some other partially sheltered situation for it is better that he should lose a few paths than relinquish his work entirely owing to the severity of the weather. But it should always be the aim of the observer, if circumstances are propitious, to secure the most commanding place within reach, for the wider the expanse of sky under review the more numerous will meteors appear. It will also be obvious that a good sky must be comparatively free from artificial illumination such as that occasioned by gas or electric light.

A comfortable chair with the back inclined at a suitable angle and with side rests for the arms will be found most convenient for this class of observation. Absolute steadiness and ease in the position of the observer often ensure accuracy in the delicate work of determining the paths. It is the same in this as in some other departments; the more natural and steady the posture of the observer the greater the facility and precision with which the observations will be made. Of course he has to shift to record every meteor seen, but this is not an inconvenience on a cold night, for the frequent movement aids the circulation. In frosty weather I have often found it trying to use the chair at all and generally prefer to pace forward and backward keeping the eyes constantly directed toward the same region in quest of meteors. It is a good plan to lean against a rounded horizontal bar fixed to uprights and about 3½ feet from the ground. This affords a partial rest and enables the observer to maintain his glance upwards for a long time without much inconvenience.

Every meteor that is seen with a fair degree of precision should of course be recorded while all doubtful cases should be rejected. To assist the eye in quickly determining the directions of flight the observer should hold a perfectly straight rod or wand, about 3 feet long, in his hand and project it upon each meteor path as seen, and then, running his eye along the wand, he can readily note the slope of the track relatively to stars both behind and in front of the line of flight and reproduce it upon his globe or chart. If the eye is left entirely to itself in estimating the directions it will be often found to be an untrustworthy guide, and the wand may be regarded as a necessary corrective; in practice it is certainly found a most efficient aid. The line of flight indicated by it represents an arc in the sky which can be readily penciled upon the globe or chart and the R. A. and Decl. of its initial and terminal points read off and catalogued. The swift meteors which leave streaks are registered with great exactness, for though the motion is so rapid that the nucleus of the object is seen very imperfectly, yet the luminous streak, that lingers for a moment upon the track, affords an unfailing guide to the path traversed. Slow meteors are also to be noted with considerable success, as there is often time to place the wand for them to run apparently along its edge when the positions may be easily noted. The quick meteors, leaving neither streaks nor trains, are recorded with greater difficulty as every visible sign of them is gone before the the wand can be applied. In such cases the observer often receives a correct impression as to the direction and, if he is quick to utilize it, will find that after some practice the radiants of these trainless and transient bodies may be as accurately fixed as those of other classes of meteors.

Different observers employ different means in registering the paths. Some are in favor of star charts, specially constructed for the purpose, while others prefer a celestial globe. The writer has invariably used the latter and found it most effective; the most convenient diameter is one of 18 inches. A disadvantage attached to the globe is that it exhibits the stars in reversed positions to that in which they are displayed in the sky; this is sometimes a source of error and is liable to delay identification of stars in particular cases, but these objections virtually disappear after practice. The paths may be laid on the globe with a soft drawing pencil and after a week or two of observation (during the absence of the Moon) the radiants should be determined and the tracks may then be washed off the globe without injury to its surface.

Star charts are sometimes prefered, but to make these suitable for the purpose a special projection is necessary, for it will be obvious that a straight line upon an ordinary star map will not represent an arc (or meteor path) in the sky. With properly prepared maps (such as those formerly issued by the luminous meteor committee of the British Association or those now in course of preparation by Mr. Backhouse) there is necessarily great distortion near the edges and, apart from this, there are other drawbacks, for a meteor may be recorded on one map while its radiant lies on another or a long path may have to come in part on two maps. On the whole the globe is decidedly the best means to be adopted, as it represents the entire star-sphere and will include all the paths and radiants of meteors in whatever part of the sky they are visible, and thus prevents the trouble of the multiple references inseparable from the use of star-charts.

The observer must, of course, post the details of every night's observation into a book ruled suitably for the purpose. There is more than one way of doing this, but the simplest is undoubtedly the best. Certain observers have followed the plan of describing the flights according to the stars near, but this method is not to be recommended for general purposes though it serves admirably to indicate the paths of fire-balls when seen casually by a number of different persons. It is, however, less accurate and less definite than the simple and effective plan of giving the right ascension and declination of the beginning and end points of the path. Moreover the work of deducing the radiants of a number of meteors, roughly noted according to approximate stars, cannot be done with anything like the celerity and precision which the other method affords. Let every habitual observer, therefore, follow a uniform plan and register the R. A. and Decl. of every meteor seen. As an example of a catalogue of such observations I quote the following from my results obtained on a clear night in August last:

Ref. No.	Date 1893	Time.	Mag.	Apparent Path				Length of Path.	Duration.	Notes of appearance	Probable radiant point.
				From		To					
		h m		R. A. °	Dec °	R. A. °	Dec °	°	sec		° °
215	Aug 16......	12 25	2	10	+ 45½	0½	+ 39½	9	0 5	Swift, streak	52 + 57
216	16 . ..	12 34	3	10	+ 14	18½	+ 2½	19	1 3	Swift, sparks	292 + 53
217	16 ...	12 47	4	47½	+ 59	47½	+ 62	3	0 4	Swift, streak	48 + 44
218	16 ...	12 53	4	20	+ 40	13	+ 34	7	0 4	Swift	52 + 57
219	16..	12 56	4	346	+ 54½	328	+ 58	10½	0.8	Swift.	33 + 18
220	16 .	13 5	1	33	+ 26	44	+ 12	17½	1 2	Swift, spark.	292 + 53
221	16.	13 9	3	33¼	+ 25	31	+ 17	8	0 6	Swift, streak.	52 + 57
222	16	13 17	3	21½	+ 21½	15½	+ 13	10	0 7	Swift, streak.	48 + 44
223	16	13 24	3	54	+ 29½	63	+ 32¾	8	0 8	Rather swift.	33 + 18
224	16 ..	13 34	4	19½	+ 40	19¾	+ 45	5	0 5	Swift, streak.	19 + 29
225	16	13 44	3	26	+ 63	10	+ 63½	7	0 6	Swift, streak.	52 + 57

With reference to the *duration* of meteor flights this is an element which, in the majority of cases, defies exact determination. But it should always be ascertained as correctly as the conditions allow, for it is most desirable to learn the rate of velocity at which these bodies are travelling along their paths. In the case of very rapid meteors our efforts in this direction are baffled by the extreme brevity of the apparitions. The duration is, in fact, so short that any attempt to measure it must result in great uncertainty for the visible life of such bodies extends scarcely beyond the fraction of a second. But the slow-moving class often permit estimates of duration approximating the truth. It is a good plan directly a meteor is seen, to begin counting 1, 2, 3, 4, etc., and to continue until the object disappears; then immediately afterwards to repeat the operation at same rate and to the same figure and determine the interval occupied by reference to a good time-piece. Or the letters of the alphabet may be employed to the same end. The writer became pretty reliable, some years ago, in judging short periods of time by getting a friend to discharge arrows from a bow, while he carefully estimated their time of flight, holding at the same time a second or stop-watch in his hand by which he registered the actual times. Frequent comparisons of the estimated and real intervals and continued practice conduced to greater accuracy, and it was found after numerous trials that the estimates of duration of about 2, 3, or 4 seconds were within about 0.25 sec. of error. By experiences of this nature an observer, though he cannot obtain absolute precision, may at least so far approximate the truth as to impart a value to his results. The necessity for practice in judging short intervals is obvious from the discordant times of duration ascribed by different persons to the same meteor. Instances are on record where the duration has been variously estimated from 2 or 3 seconds to 2 or 3 minutes, and it is well known that individual ideas as to these short periods are remarkably diverse and inconsistent. A little preparation of the character alluded to is, therefore, really needed in order that this significant feature in the observation of meteors may be usefully applied in the determination of their velocities. No doubt the rate of speed is not precisely the same when we see a meteor as it was when the body was outside our atmosphere, for the latter acts as a resisting medium and moderates the velocity; indeed some meteors are observed to "slow up" and to come nearly to a standstill at the end of their flights.

DESCRIPTION OF THE FORTY-FOOT TELESCOPE OF THE LICK OBSERVATORY ECLIPSE EXPEDITION.

J. M. SCHAEBERLE.

In response to a request by the editor for a description of the 40-foot telescope used at the eclipse station, the following details are taken from a "Report" on the Eclipse of April 16, 1893, which I am at present preparing.

The objective lens, made by the Clarks, has a diameter of 4.95 inches. The focal length (photographic) I determined with especial care and found it to be 40 ft. 1.2 inches. The lens forms part of the horizontal photo-heliograph of the Lick Observatory.

In deciding upon the method of mounting, it was entirely out of the question to adopt the ordinary equatorial form in which the tube is suspended near the middle of its length, both on account of the great expense attending the completion of such a plan, and for the still more serious reason of its instability in an exposed position at a high altitude where the atmospheric movements were presumably often quite strong.

Any advantage due to the large scale given by such a telescope would, in a great measure, be lost unless great stability of the image on the photographic plate is secured.

It was not deemed advisable to use the horizontal form of telescope in connection with a plane mirror, as the best possible results which could be given by the lens alone could not be obtained if an intermediate reflecting surface were to be introduced, to say nothing of the effects produced in long exposures by a rotation of the image in position angle with a change in the hour angle of the Sun.

Only one plan was considered feasible, and that was to place the object-glass on one fixed pier, and to mount the photographic plate on a slide (the motion to be regulated, by a clock work, so as to give it the same velocity as the Sun's image in the focus), the guides of which being firmly fastened to a second pier, and both piers to be wholly free from contact with the great tube.

In order to obtain, if possible, coronal features at a distance of several diameters from the Sun, it was decided to use 18 × 22 inch plates as the diameter of the Moon's image alone would be more than four and one-half inches.

It was, of course, desirable to test the feasibility of putting up such an instrument by actually constructing and erecting it on Mt. Hamilton before leaving for South America.

Fig. 1. Lick Observatory Eclipse Station,
Mina Bronces, Chile, South America,

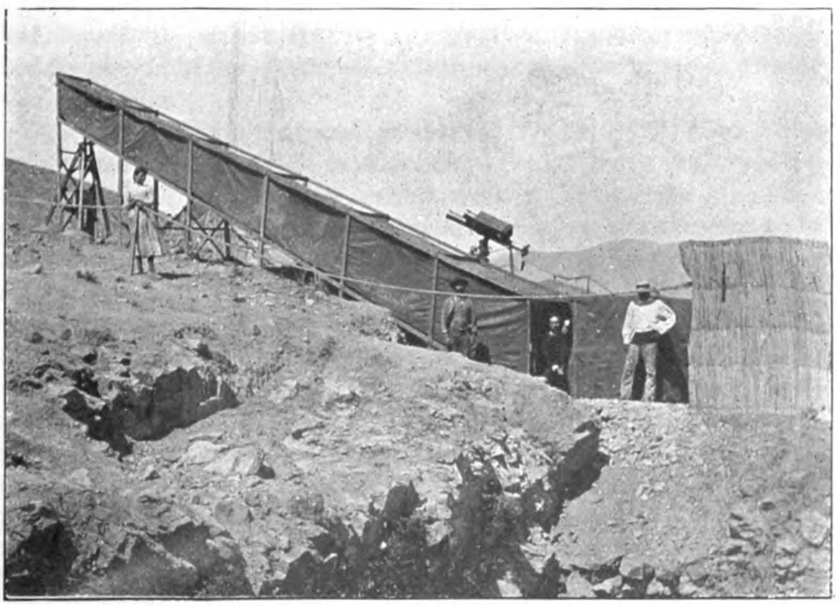


Fig. 2. Lick Observatory Eclipse Expedition. Forty foot Telescope
April 16, 1893.

The services of our Observatory carpenter, Mr. R. P. Frazer, an unusually expert mechanic, were placed at my disposal by Professor Holden, and in the course of a few weeks, one of the slopes near the summit of Mt. Hamilton was graced with the presence of a rather formidable looking structure which successfully withstood the winter storms for several weeks when it was taken apart and neatly packed for shipment. In designing and constructing the parts, it was of course necessary to know beforehand the approximate geographical position of the eclipse station in order to obtain the proper angle of elevation of the inclined portion of the tube. For this purpose a point on the central line and about 50 miles from the coast of Chile was used as a basis for preliminary computations.

I had at first concluded to occupy the station which Professor Obrecht of the Santiago Observatory had selected, and for which he had previously determined the geographical position, and which was eventually occupied by the Harvard College Observatory party under Pickering. Later on, however, I learned through some published information given by Mr. John King, British Consul at Carrizal Bajo, that by going farther into the interior much higher ground and better atmospheric conditions could be reached, the only unknown elements being the geographical locations.

I finally changed my intended plan of going to Vallenar, and, regardless of the increased number of difficulties to be overcome, determined to locate a station at a great altitude on the central line to be found by personal astronomical observations after I reached Chile.

This change of plan necessitated an early start. On my arrival in Carrizal Bajo, just one month before the eclipse, I was met by Mr. King, and together we spent a week in the interior determining, with the aid of a chronometer and sextant, the astronomical locations of various points, and thus gradually approaching the central line. Finally a most desirable location at Mina Bronces, very near the central line, and at an altitude of 6,600 feet, was selected as offering the best possible advantages. To secure an independent check on the longitude we made a special trip back to Carrizal Bajo, a distance of nearly 100 miles, the transportation being by horseback and railroad. I returned to the station alone, having carried the chronometer in my hands the greater part of a distance of nearly 200 miles.

To detect any possible "tripping" of the chronometer it was frequently compared with other time-pieces during the journey on horseback and train.

A spot of ground was now chosen where the slope was such that only a moderate amount of scaffolding would be required to secure the proper elevation of the tube, and from which the first contact could be observed with the 6-inch Clark equatorial.

To avoid any considerable reflection of light from the inside of the canvas tube it was not only painted a dead black, but the dimensions were made unusually large, being 2 ft. × 2 ft. in cross-section at the objective end and tapering to 4 ft. × 4 ft. near the lower end of the inclined tube, where it joined on to a cubical room whose sides were 6 feet. Small iron rings sewed to the edges of the tube at intervals of a few feet served to secure the canvas to the incircling framework made of uprights 3 × 3 inches and 6 feet long, placed at intervals of 6 feet from each other; the longitudinal and cross-bracing consisted of boards 1 × 3 inches cross-section. The uprights were spliced to conform to the slope of the ground.

At the lower end of the telescope the rock was cut away and an excavation of about two feet in depth made to secure greater stability by lowering the whole telescope. The whole framework was securely held to the Earth by strong wire guy ropes fastened to the top of every upright and running to as many separate iron staples driven into the rock.

The object glass was mounted (with three adjusting screws) in a rectangular slide admitting of a lateral motion of several inches in a frame securely fastened to the end of a vertical rod, which, in turn, could be raised and lowered, and clamped to a strongly braced tripod resting directly upon the ground.

The three legs of this tripod (3 × 3 inches) were set in masonry formed of pieces of rock and a species of mortar called "baro" by the natives. The top of the tripod was a few inches below the lower side of the canvas tube through which the rod passed without direct contact, so arranged, however, that no stray light could enter the tube through this aperture.

After the object-glass was in its final position the whole upper end of the tube, with the exception of an aperture for the objective, was made light-proof by sewing several thicknesses of velvet cloth to the sides of the tube directly in front of the adjusting slide. No vibration of the tube could in any way be communicated to the mounting of the lens and the adjustable parts were in turn protected from the wind by the tube itself.

The cubical room at the lower end of the tube was formed by slipping the already patterned canvas over the framework so that the top and three sides of the cube were completely covered, the laps of the opening, 4 × 4 feet on the fourth side, were then tacked to the frame which held the lower end of the inclined tube.

The bottom and sides of the excavated parts of the room were plastered with "baro" to prevent the formation of dust as the observers moved about; at the same time great rigidity was given to the lower end of the tube.

Near the extreme end of the room a rather curiously shaped framework* (for holding the angle-iron guides for the triangular slide carrying the sensitive plates) resting on three legs, was also securely fastened to the ground with a liberal supply of "baro."

The frame was, however, first approximately oriented so that the plane of the slide was normal to the axis of the telescope, and the direction of the guides parallel to motion the Sun's image would have on the day of the eclipse. The final adjustments were made by shifting the iron slides on the frame with suitable adjusting screws. Three carefully made wheels, whose axes were fastened to the triangular slide, served to carry the latter.

The two lower wheels had knife edges working in V groove cut in the upper face of the lower guide, the third wheel simply rolled on the planed face of the upper guide. Directly on top of the highest leg the clock portion of one of our chronographs was mounted. The unwinding of a strong flexible wire wound around a drum on the clock's winding axis served to regulate the velocity of descent of the slide to which one extremity of the wire was fastened. The action of gravity on the slide alone was the motive power for running the regulating clock.

The line joining the supports for the photographic plates was made parallel to the line of motion, so that the longer edges of the plates should be parallel to the equator during the exposures.

To insure greater certainty that no diffused light from the outside should find its way through the canvas the whole interior of the room and about 6 ft. of the inclined portion was lined with an extra sheeting of black cloth.

The night before the eclipse each of the eight plates exposed was placed in its own paste-board box, the cover of which could be quickly removed and replaced for the exposures. These boxes were placed in a pile in one corner of the room; in the adjacent corner was a wooden box into which each paste-board box was placed immediately after the exposure of its plate. During totality I was alone in the telescope and there was not the slightest hitch in the program. I only regret that more plates were not made ready for exposure as a number of very interesting phe-

* See Plate No. 5, Fig. 2.

nomena could have been secured several minutes before the total phase. Inside the tube of the great telescope the image of the visual corona extended far beyond the limits of the 18 × 22 inch plates.

I can not close this descriptive paper without making special mention of the services rendered by Mr. Filip Bray, Captain of the mine, and Mr. R. A. Walker, a mechanical engineer temporarily employed at the mine. During the six weeks of my stay every possible aid was given me by Captain Bray. Mr. Walker was ever eager and ready, day or night, to climb the steep trail to the station, only half a mile away, but 260 feet higher up.

During the first week it became apparent that the best photographic results could not be obtained with the filtered water from the mine; the salts held in solution would become visible as a milky substance when combined with the elements used in making the hydrochinone developer.

On mentioning this fact to Mr. Walker, and stating the disirability of having distilled water, he soon discovered (?) a leak in the boiler near the blow-off valve; and thereafter, drop by drop, a bucketfull of water was obtained daily. As this amount proved insufficient later on, when it was also used for a final washing of the plates, Mr. Walker discovered a more serious leak, near the first, the two together furnishing four pails of distilled water daily.

The work done with the other instruments will be fully described in the forthcoming "Report."

Lick Observatory,
Sept. 11, 1893.

JUPITER'S FIFTH SATELLITE.

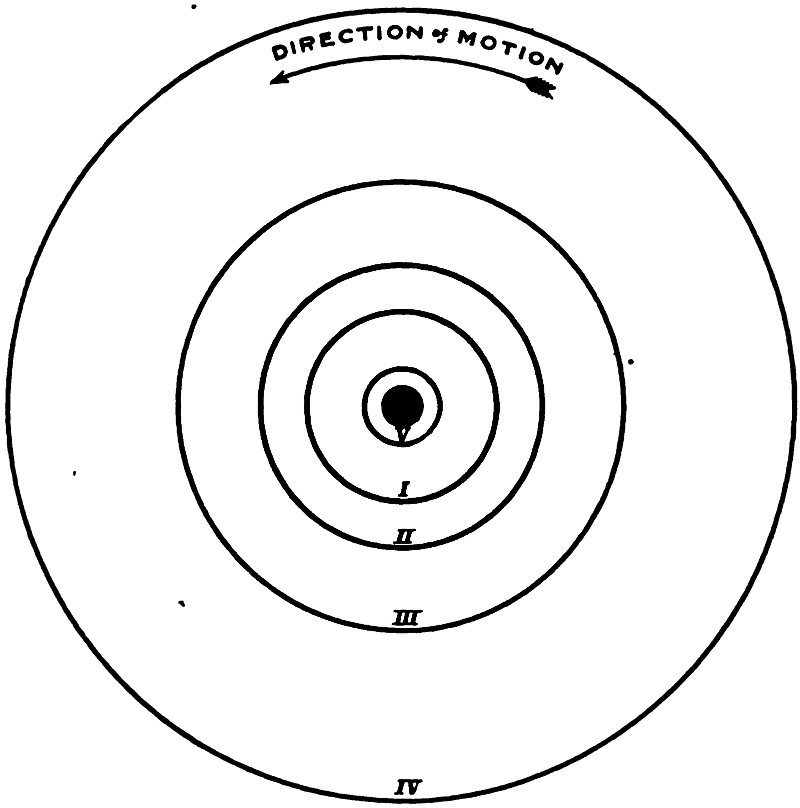
E. E. BARNARD.*

Inasmuch as the discovery of a fifth satellite to the great planet Jupiter on the 9th of September of last year with the large refractor of the Lick Observatory attracted a great deal of popular attention I have thought that now, as this object is again under observation, a little information as to what has become known of it might be of still further interest.

Last winter it was followed with the thirty-six-inch and kept under observation until January 8th, when the increasing distance of Jupiter from us prevented further observation.

* Lick Observatory.

The close coincidence of the satellite period to half a day makes the elongations—the greatest apparent distances of the satellite from the planet, and near which times only is it possible to see it —occur at nearly the same hour of the night for long intervals.



ORBITS OF THE SATELLITE SYSTEM OF JUPITER.

These elongations (on opposite sides of the planet) are six hours apart. In the first part of the summer the western elongation occurred while the planet was yet below or too near the horizon to see a faint object; the other, the eastern, did not occur until after sunrise. These elongations happen essentially five minutes earlier each day. This has gradually brought the morning elongation around so that the satellite can now be seen just before dawn. It was first seen on September 3d, but was too faint to measure satisfactorily. On September 15th, however, it was well seen, and twenty-one measures of its position were obtained. Combining these observations with those of last year it is possible to very closely determine its period of revolution about Jupiter.

From observations covering only three months I had, last year, determined this period to be 11^h, 57^m, 23.06^s. Dr. A. Marth of the Royal Astronomical Society, using the observations obtained here, had made this period 11^h 57^m 21.88^s. The difference between these results may appear insignificant, but when it is known that the little satellite makes two revolutions around Jupiter every day it will be seen that it counts up in the course of a year, and it was necessary to predict its motion that far in advance. This difference would be nearly two and a half seconds a day, and in a year's time would be a very serious quantity indeed. However, from the short time that the satellite was under observation it was, after all, not so great a discrepancy as one might suppose.

Between the observations at the time of discovery in 1892, until those of this year, the satellite had performed 740 revolutions. With such a large divisor as this, any careful observations now ought to give a very satisfactory determination of the periodic time.

I have again carefully computed its period from the observations of 1892, September 10th, and 1893, September 15th, and the result is: Period, 11^h 57^m 22.56^s, which will perhaps be correct to within a tenth of a second of time.

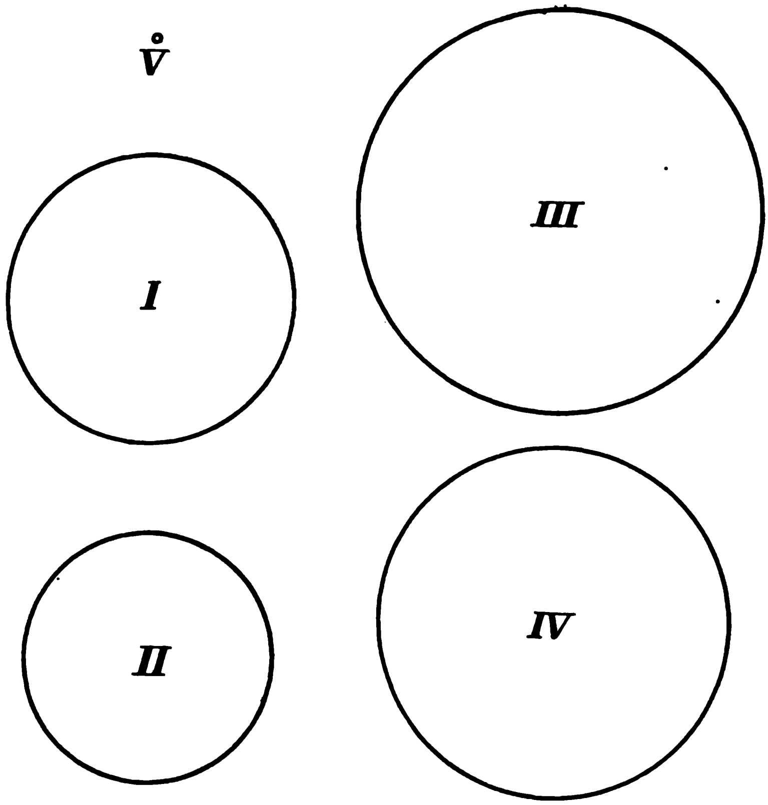
It will be seen that this period is $.50^s$ less than my former determination, and $.68^s$ greater than Marth's result, or almost exactly agreeing with their mean.

From my own measurements I have determined the following facts about the smallest of the Jovian moons:

Its mean distance from the center of Jupiter is 112,000 miles, or about 67,000 miles from the surface of the planet. The orbit seems to be sensibly elliptic, differing somewhat in that respect from the orbits of the other four satellites. This orbit lies in the plane of Jupiter's equator, as do the orbits of the other satellites. The motion of the fifth moon about its primary is 16.4 miles a second, making it the most rapidly revolving satellite known. Though Phobos, the inner satellite of Mars, revolves around that planet in about 7½ hours, yet so great is the circuit of Jupiter's new moon that it actually travels some twelve times swifter than the Martian satellite!

What is its size? This is by far the most difficult thing to determine about it, since it is merely a point and presents no measurable disc. There are, however, several things that tend to limit our maximum estimate of its size.

First—From very careful considerations of the estimate of its brightness I have concluded that if it were seen off on the sky, away from the glare of the planet, it would shine as a star of the thirteenth magnitude. If such is a true estimate of its light, and if its surface has the same reflective capacity as that of Jupiter, it is about one hundred miles in diameter.



RELATIVE SIZES OF JUPITER'S SATELLITES.

Second—Under the most favorable conditions and under the highest magnifying power of the thirty-six inch, it has never shown any sensible disc, but appears as a stellar point, while the other satellites readily expand into veritable moons with ordinary telescopic power. If it were much over one hundred miles in diameter it would show a sensible disc with the great telescope.

Third—the most careful scrutiny has so far failed to show any trace of its shadow on the surface of Jupiter, when it should have been projected on the planet. If the satellite were very much above one hundred miles in diameter this shadow would be seen.

The shadows of the other satellites are visible when crossing the planet as large black drops of ink. Hence there seems to be good reason for believing the new satellite to be not much over one hundred miles in diameter; it may be less.

The smallest telescope will show the four old moons—indeed it has been claimed that one or more of these satellites has been seen with the naked eye. Professor George Davidson, in the clear skies of the Sierras, has seen two of them as one with the naked eye when near each other, and at some distance from the planet. This new satellite, however, is game only for the most powerful instruments. So far, since its discovery, it has been reported as seen with the following telescopes: The two 26-inch telescopes at Washington and the University of Virginia; the 23-inch at Princeton, where Professor Young and his assistant, Mr. Read, saw it before the other large telescopes got any observation of it; the 18.5 inch at Evanston, Ill., where Professor Hough saw it and said it was the most difficult of objects. In England Mr. Common saw it with his great 5-foot mirror. Mr. Newhall with the 25-inch telescope at Cambridge, England, saw it and reported it as being an excessively difficult object. For some reason it was not seen on the continent at all. This, so far as I have been able to learn, is a list of all the telescopes that have yet shown the new satellite.

To give one an idea of the relative size of this new moon, compared with the older satellites, it is only necessary to say that the third satellite, the largest of the four, is over twenty thousand times greater than it in volume.

In the May number of Astronomy and Astro-Physics is an interesting article concerning this satellite by Dr. Wilhelm Meyer, of Berlin, who shows that its proximity to the great planet places it in a very dangerous position. It lies just without what is called "Roche's limit," within which a satellite could not exist, as the enormous attraction of Jupiter would tear it to pieces unless its density was greater than that of any known substance.

In the course of his paper, Dr. Meyer says since the diameter of this object is so small, "it is to be concluded with certainty that a freely movable object on the surface of the new Moon must immediately fly away from it towards Jupiter as soon as the latter rises above the horizon. * * * The probabilities are therefore many thousands to one that the new satellite is not able to hold freely movable objects on its surface."

To those who like to people the planets and satellites with inhabitants this will be interesting, for a resident of this little moon would have to anchor himself pretty fast when Jupiter was visible, or he would very quickly become an inhabitant of the great planet itself!

Dr. Meyer continues: "With the impulse of bodies not held at the surface by molecular forces to fly towards Jupiter will be combined their motion in the orbit of the satellite; the bodies leave the satellite and scatter themselves along the orbit, forming a ring, whose diameter must be less than that of the satellite's orbit and which must resemble in every respect the gauzy, transparent ring which the bright ring of Saturn surrounds. If more and more objects come to it, dust, rock that has crumbled away from the satellite, then the ring will become even denser and finally resemble the bright rings of Saturn. At the outer edge of this ring, the original satellite will continue to revolve and feed the ring with the objects which have deserted it. * * * *. This process of crumbling to pieces, working very slowly to be sure, but incessantly, will constantly reach deeper strata as soon as the upper ones are loosened and all fragments are dispersed over the ring. We can therefore maintain to-day, many thousands to one, that the fifth satellite of Jupiter began long ago to form such a ring, and thus Jupiter possesses, at the present time, just as Saturn does, a ring at the distance of this satellite."

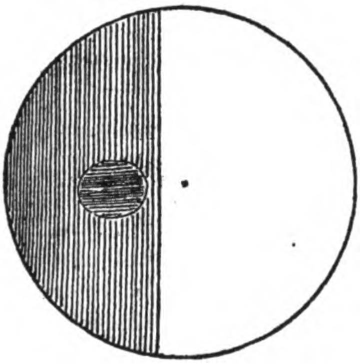
He considers, however, that this ring is probably too faint ever to be detected.

So far this satellite has not received any name, although many names have been suggested for it. Most of these are mythological and have some connection with Jupiter. Columbia, on account of the satellite being found in the Columbian year, and Eureka, because of California, the State in which it was discovered, have been suggested. It would seem, however, almost to have found itself a name—"The Fifth Satellite."

In astronomical literature there is a strong tendency to call it simply "The Fifth Satellite," as it was called in the announcement of discovery. There is some opposition to this, as it might be misleading. The other satellites of the giant planet, besides their mythological names, are also designated as I, II, III, IV, with the Roman numerals, in the order of their distance from Jupiter. If now the new one is called V it would imply that it is the most distant of the satellites, while in reality it is the nearest of all to the planet, and ought by all means, according to this method of numeration, to be Satellite I, which would necessitate a renumbering of the satellite system. I would say, also, in this connection, that the celebrated French astronomer, Camille Flammarion, has written, suggesting the name Amalthea, the nurse of Jupiter (the smallness of the satellite would make this name rather inappropriate), and giving various reasons why it should be so called.

The most that can be said at present is that it is yet nameless, and may so remain. The mythological names of the four older satellites are seldom used. It may be necessary, however, to give it a mythological name to prevent confusion.

As was the case when Professor Hall discovered the satellites of Mars, many theories have been offered to account for the presence of the new body. The asteroid zone between Mars and Jupiter is an endless source of material for such theories. It was suggested in 1877 that the Martian satellites were asteroids captured by Mars from the asteroid zone lying outside his orbit. These same theorizers have not failed to come up again and suggest that the fifth moon of Jupiter is a captured asteroid from the zone of asteroids lying inside the orbit of Jupiter. They never try to account for the satellites of Saturn, Uranus and Neptune this way, because the asteroid mine is too far off; yet they are similar bodies, and undoubtedly had a similar origin. There is no question that this satellite has been there all along, and for infinite ages has performed its revolutions about the planet, undetected until the night of 1892, September 9th.



So great and overpowering is the brilliancy of Jupiter in the great telescope that it is impossible to see the small moon without extraordinary precautions to get rid of the dazzling light of the planet, as ordinarily the eye is so blinded with the glare that the satellite cannot be seen. With an opaque bar across the field of view, the planet may be hidden and the satellite thus separated from it can be seen. But in measuring the position of the small star-like point it is necessary to see both it and Jupiter at the same time. To make this possible a film of mica, carefully darkened by the smoke of a lamp, is stretched across one-half the field of view. The planet is then placed behind this screen where it can be clearly seen, but with its light greatly dulled, while the satellite is visible in the unobscured part of the field, thus making it possible to see both objects at once.

To illustrate graphically the smallness of the new satellite and to show its position in the Jovian system, I append a couple of diagrams. To those who are familiar with the moons of Jupiter this will show what a tiny speck this little object really is. Compared with Jupiter itself, however, it becomes utterly insignificant, for the great planet is nine hundred times greater than it in diameter, while the volume of the satellite becomes infinitesimally small when contrasted with the enormous bulk of Jupiter.

MT. HAMILTON,
September, 1893.

THE FACE OF THE SKY.

CHARLOTTE R. WILLARD.

The following statements are true for Northfield, Minnesota, October 20, 1893, at 9 P. M. They will be equally serviceable for any other night if it be remembered that for each preceding evening four minutes should be added to the time, and that for each succeeding evening four minutes should be subtracted.

The most striking object in the heavens at this time is the planet Jupiter, two and a half hours above the horizon in the northeast, and shining with a brilliancy five or six times that of the brightest fixed star.

There are five first magnitude stars in view. They are here named in the order of their brightness: Vega (α Lyræ), which four and a half hours ago crossed the meridian at a distance of six degrees from the zenith, twenty years ago sent out the light which reaches us to-night—this is true even though "for every breath you draw light travels half a million of miles." Capella (α Aurigæ, which perhaps should be named before Vega), the most northern of first magnitude stars, is seen in the northeast at a distance of twenty-nine light years. Thus the light which reaches us from Capella is nine years older than that which arrives at the same time from Vega. Altair crossed the meridian thirty-six degrees south of the zenith and more than an hour later than Vega; its distance is sixteen and three-tenths light years. The red Aldebaran (α Tauri) rose toward the north an hour and a quarter ago; its distance is twenty-seven light years. The fifth star is Formalhaut (α Piscis Australis) which some authorities do not class as of first magnitude—it is the most southern of first magnitude stars visible in our latitude, and is just crossing the meridian twenty degrees above the horizon.

Returning to the star Aldebaran, we find it in a rich and familiar region, it being the brightest star in Taurus, and one of the five which make up the lesser group Hyades; this group is rich in doubles and is full of interest for the owners of small glasses. Preceding it by about fifty minutes is the well known closely packed little group Pleiades. The Pleiades afford an interesting test of eye-sight —ordinary vision readily finds six stars, many have seen seven, and one observer is recorded as having seen fourteen; the opera glass greatly increases this number a photograph taken at the Paris Observatory shows two thousand three hundred and twenty-six, the plate covering about three square degrees.

Half way between Aldebaran and the seat of Cassiopeia's chair and a little below the line joining their centres, is the variable star Algol. Algol is usually a second magnitude star but once in two days, ~~forty~~ twenty hours and forty-nine ~~seconds~~ minutes it loses about five-sixths of its light passing from maximum to minimum in about four and a half hours; it remains at minimum twenty minutes. To learn the times of change in October see table on page 41, No. 1, Vol. I. which gives the minima to the nearest hour.

The great nebula of Andromeda may be located by taking as pointers $\varkappa$ and α of Cassiopeia (these are two diagonally opposite stars in the seat, neither being adjacent to the back), and following their line south for about fifteen degrees, when we shall come to a hazy spot which is the brightest of all nebulæ. This is in a more convenient position an hour earlier. An opera-glass does good service if one has no telescope, the nebula is, however, clearly visible to the naked eye. In it appeared the sixth magnitude temporary star of 1885 which a few months later was beyond the reach of even the largest telescopes. γ Andromedæ is one of the most beautiful doubles in the heavens, it may be found fifteen degrees from Algol, on the line joining that star and the Great Nebula, for this star the magnitudes 5.5, 6.8 have been thought probable.

PLANET NOTES FOR NOVEMBER.

H. C. WILSON.

Mercury will be "evening star" during the greater part of November, coming to greatest eastern elongation, 23° east from the Sun, on the evening of Nov. 5. It will, however, then be at nearly its greatest southern declination, so that it can be seen by northern observers only at a very low altitude. In the southern hemisphere the position of the planet will be favorable for observation during the first half of the month. On Nov. 26, at 6 A. M. Central time, Mercury will be at inferior conjunction with the Sun. The planet will then be 1° 25′ north of the Sun's center.

Venus will also be evening star during November and will be in splendid position for observation from the southern hemisphere of the Earth, but northern observers must content themselves with views at low altitudes. The phase of Venus will be a little more than half full and gradually decreasing, while the apparent diameter of the disk will increase from 18″, Nov. 1, to 24″, Dec. 1. The crescent Moon will pass Venus about noon Nov. 12, so that on that evening and the preceding the two brilliant objects will be near together.

Mars will be morning planet and may be seen in the morning twilight but at so low an altitude that observations will be useless.

Jupiter is the object of objects to be observed by amateur astronomers during November. The planet comes to opposition Nov. 18. It will therefore be visible during the whole night, and as its declination is between 18° and 19° north of the equator, its meridian passage will be at a high altitude. The diameter of Jupiter's disk during this month will be about 47″, so that not only the belts but many small spots and much fine detail on the planet's surface onght to be visible with telescopes of moderate power. No one can mistake this planet, for his splendid brilliancy outshines any other object in the evening sky, with the exception of the Moon. The latter will pass by Jupiter, about 4° to the north, at about 4 o'clock on the morning of Nov. 23. Jupiter's apparent motion will be westward in the constellation Taurus, a little way south of the Pleiades. For the phenomena of the satellites see the tables which follow these notes.

Saturn has just come out from conjunction with the Sun and cannot yet be seen to advantage.

Uranus will be in conjunction with the Sun at midnight Nov. 2.

Neptune is approaching opposition and is at a high northern declination, so that he may be observed under the most favorable circumstances. The trouble with this planet, for amateurs, is that its disk is so small that it cannot be recognized by that with small telescopes, and its motion is so slow that just now it requires two or three days to make the change of position noticeable. In a photograph taken at Goodsell Observatory on the evening of Sept. 21, with the 2½-inch camera, Neptune is on a direct line between the stars *i* and *ε* of the constellation Taurus and about one fifth of the distance from the former to the latter star. During October and November the planet will move only 1° 23′ west and 11′ south from its present position. There is but one star as bright as Neptune within a radius of a degree, or twice the Moon's diameter, and that star is toward the north from the planet, so that it is now comparatively easy to identify the planet.

Planet Tables for November.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Nov. 5	16 17.2	− 24 10	8 57 A. M.	1 16.3 P. M.	5 36 P. M.
15	16 44.7	− 24 25	8 45 "	1 04.3 "	5 24 "
25	16 15.1	− 20 33	7 18 "	11 55.4 A. M.	4 33 "
			VENUS.		
Nov. 5	17 53.6	− 26 11	10 33 A. M.	2 52.2 P. M.	7 01 P. M.
15	18 43.8	− 25 59	10 53 "	3 03.1 "	7 13 "
25	19 31.8	− 24 41	10 55 "	3 11.6 "	7 28 "
			MARS.		
Nov. 5	13 23.7	− 7 59	4 51 A. M.	10 23.2 A. M.	3 55 P. M.
15	13 48.4	− 10 27	4 47 "	10 08.6 "	3 30 "
25	14 13.7	− 12 48	4 42 "	9 54.4 "	3 06 "
			JUPITER.		
Nov. 5	3 44.0	+ 18 38	5 20 P. M.	12 41.2 A. M.	8 02 A. M.
15	3 38 6	+ 18 20	4 36 "	11 56.4 P. M.	7 17 "
25	3 33.0	+ 18 03	3 53 "	11 11.5 "	6 30 "
			SATURN.		
Nov. 5	13 14.1	− 5 24	4 32 A. M.	10 13.6 A. M.	3 56 P. M.
15	13 18.3	− 5 48	3 58 "	9 38.5 "	3 19 "
25	13 22.2	− 6 10	3 24 "	9 03.2 "	2 24 "
			URANUS.		
Nov. 5	14 35.6	− 14 51	6 32 A. M.	11 34.9 A. M.	4 38 P M.
15	14 38.1	− 15 01	5 56 "	10 58.0 "	4 00 "
25	14 40.4	− 15 12	5 19 "	10 21.1 "	3 23 "
			NEPTUNE.		
Nov. 5	4 46.7	+ 20 48	6 12 P. M.	1 43.6 A. M.	9 15 A. M.
15	4 45.6	+ 20 46	5 32 "	1 03.2 "	8 34 "
25	4 44.4	+ 20 44	4 52 "	12 22.8 "	7 54 "
			THE SUN.		
Nov. 5	14 44.4	− 14 56	6 41 A. M.	11 43.7 A. M.	4 47 P. M.
15	15 25.0	− 18 42	6 59 "	11 44.8 "	4 31 "
25	16 06.9	− 20 55	7 12 "	11 47.3 "	4 13 "

Occultations Visible at Washington

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	Angle f'm N pt. °	EMERSION Washington M. T. h m	Angle f'm N pt. °	Duration. h m
Nov. 14	B.A.C. 7077	6.4	6 22	127	6 56	183	0 34
15	33 Capricorni	5.7	7 05	74	8 19	219	1 14
17	74 Aquarii	6.0	2 14	54	3 23	252	1 09
18	24 Piscium	6.1	11 37	30	12 36	260	0 59
22	τ^2 Arietis	5.3	9 01	125	9 30	173	0 29
24	136 Tauri	5.3	17 51	144	18 30	227	0 39
26	ω^1 Cancri	6.0	13 52	138	14 57	249	1 05

Phenomena of Jupiter's Satellites.

	h m			
Nov. 2	2 31	A. M.	II	Sh. In.
	3 23	"	II	Tr. In.
	4 51	"	II	Sh. Eg.
	5 38	"	II	Tr. Eg.
3	5 21	"	I	Ec. Dis.
	7 54	"	I	Oc. Re.
	9 33	P. M.	II	Ec. Dis.
4	12 32	A. M.	II	Oc. Re.
	2 38	"	I	Sh. In.
	3 01	"	I	Tr. In.
	4 50	"	I	Sh. Eg.
	5 12	"	I	Tr. Eg.
	11 50	P. M.	I	Ec. Dis.
5	2 20	A. M.	I	Oc. Re.
	6 10	P. M.	II	Sh. Eg.
	6 46	"	II	Tr. Eg.
	9 06	"	I	Sh. In.
	9 27	"	I	Tr. In.
	11 18	"	I	Sh. Eg.
	11 38	"	I	Tr. Eg.
6	6 19	"	I	Ec. Dis.
	8 46	"	I	Oc. Re.
7	1 14	A. M.	III	Sh. In.
	2 41	"	III	Tr. In.
	3 01	"	III	Sh. Eg.
	3 56	"	III	Tr. Eg.
	5 47	P. M.	I	Sh. Eg.
	6 04	"	I	Tr. Eg.
9	5 08	A. M.	II	Sh. In.
	5 38	"	II	Tr. In.
	7 29	"	II	Sh. Eg.
	7 54	"	II	Tr. Eg.
10	7 16	A. M.	I	Ec. Dis.
	5 22	P. M.	III	Oc. Re.
11	12 08	A. M.	II	Ec. Dis.
	2 45	"	II	Oc. Re.
	4 32	"	I	Sh. In.
	4 44	"	I	Tr. In.
	6 45	"	I	Sh. Eg.
	6 55	"	I	Tr. Eg.
12	1 45	"	I	Ec. Dis.
	4 02	"	I	Oc. Re.
	6 27	P. M.	II	Sh. In.
	6 46	"	II	Tr. In.
	8 47	"	II	Sh. Eg.
	9 02	"	II	Tr. Eg.
	11 01	"	I	Sh. In.
	11 10	"	I	Tr. In.
13	1 13	A. M.	I	Sh. Eg.
	1 21	"	I	Tr. Eg.
	8 14	P. M.	I	Ec. Dis.
	10 30	"	I	Oc. Re.
14	5 14	A. M.	III	Sh. In.
	5 55	"	III	Tr. In.
	7 01	"	III	Sh. Eg.
Nov.	7 12	A. M.	III	Tr. Eg.
	5 29	P. M.	I	Sh. In.
	5 35	"	I	Tr. In.
	7 42	"	I	Sh. Eg.
	7 46	"	I	Tr. Eg.
15	4 56	"	I	Oc. Re.
17	7 10	"	III	Ec. Dis.
	8 43	"	III	Ec. Re.
18	2 42	A. M.	II	Oc. Dis.
	4 58	"	II	Oc. Re.
	6 27	"	I	Sh. In.
	6 27	"	I	Tr. In.
19	3 37	"	I	Oc. Dis.
	5 48	"	I	Oc. Re.
	9 01	P. M.	II	Tr. In.
	9 04	"	II	Sh. In.
	11 17	"	II	Tr. Eg.
	11 25	"	II	Sh. Eg.
20	12 53	A. M.	I	Tr. In.
	12 55	"	I	Sh. In.
	3 04	"	I	Tr. Eg.
	3 08	"	I	Sh. Eg.
	10 03	P. M.	I	Oc. Dis.
21	12 17	A. M.	I	Ec. Re.
	6 14	P. M.	II	Ec. Re.
	7 19	"	I	Tr. In.
	7 24	"	I	Sh In.
	9 30	"	I	Tr Eg.
	9 36	"	I	Sh. Eg.
22	4 28	"	I	Oc. Re.
	6 45	"	I	Ec. Re.
24	10 34	"	III	Oc. Dis.
25	12 44	A. M.	III	Ec. Re.
	4 55	"	II	Oc. Dis.
26	11 17	P. M.	II	Tr. In.
	11 42	"	II	Sh. In.
27	1 33	A. M.	II	Tr. Eg.
	2 03	"	II	Sh. Eg.
	2 35	"	I	Tr. In.
	2 50	"	I	Sh. In.
	4 47	"	I	Tr. Eg.
	5 02	"	I	Sh. Eg.
	11 47	P. M.	I	Oc. Dis.
28	2 12	A. M.	I	Ec. Re.
	6 01	P. M.	II	Oc. Dis.
	8 50	"	II	Ec. Re.
	9 02	"	I	Tr. In.
	9 18	"	I	Sh. In.
	11 13	"	I	Tr. Eg.
	11 31	"	I	Sh. Eg.
29	6 13	"	I	Oc. Dis.
	8 41	"	I	Ec. Re.
30	5 39	"	I	Tr. Eg.
	5 59	"	I	Sh. Eg.

In. denotes ingress; Eg. egress; Dis., disappearance; Re , reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow. Only the phenomena visible in the United States are given.

Configuration of Jupiter's Satellites, at 10 p. m. Central Time.

Nov.		Nov.		Nov.	
1	4 3 ○ 2 1	11	1 ○ 2 3 4	21	4 3 1 ○ 2
2	4 2 3 1 ○	12	2 ○ 1 3 4	22	3 4 ○ 1 2
3	● 4 ○ 1 3	13	● 2 ○ 3 4	23	3 2 1 4 ○
4	4 1 ○ 2 3	14	3 1 ○ 2 4	24	● 2 ○ 1 4
5	4 2 ○ 3 ♃	15	3 ○ 4 1 2	25	1 ○ 2 3 4
6	2 4 ○ 3 1	16	3 4 2 1 ○	26	○ 2 1 3 4
7	3 1 ○ 4 2	17	4 2 ○ 3 1	27	2 1 ○ 3 4
8	3 ○ 2 1 4	18	4 1 ○ 2 3	28	♃ 3 ○ 2 4
9	2 3 1 ○ 4	19	♃ 4 ○ 1 3	29	3 ○ 1 2 4
10	2 ○ 3 1 4	20	4 2 ○ 3 ●	30	3 2 1 ○ 4

Phases and Aspects of the Moon.

			Central Time.
		d	h m
New Moon	Nov.	8	6 57 A. M.
Apogee	"	11	9 24 P. M.
First Quarter	"	16	11 45 A. M.
Full Moon	"	23	12 08 P. M.
Perigee	"	24	8 00 A. M.
Last Quarter	"	30	3 08 A. M.

Ephemeris of the Fifth Satellite of Jupiter.—We take the following ephemeris by Mr. Marth from the *Monthly Notices* for June, 1893, adapting it to convenient use in the United States. The period of the fifth satellite is assumed to be $11^h\ 57^m\ 21.88^s$, the uncertainty being, according to Mr. Marth, probably within a second of time.

APPROXIMATE TIMES OF GREATEST ELONGATION.

		Greenwich Time.		*Central Time.*	
		East.	West.	West.	East.
Oct.	5	11 44 P. M.	5 43 A. M.	11 43 P. M.	5 41 A. M.
	9	11 22 "	5 21 "	11 21 "	5 20 "
	13	11 00 "	4 59 "	10 59 "	4 58 "
	17	10 38 "	4 37 "	10 37 "	4 35 "
	21	10 15 "	4 14 "	10 14 "	4 13 "
	25	9 53 "	3 52 "	9 52 "	3 51 "
	29	9 31 "	3 30 "	9 30 "	3 29 "
Nov.	2	9 09 "	3 08 "	9 08 "	3 07 "
	6	8 47 "	2 46 "	8 46 "	2 45 "
	10	8 24 "	2 23 "	8 23 "	2 22 "
	14	8 02 "	2 01 "	8 01 "	2 00 "
	18	7 40 "	1 39 "	7 39 "	1 38 "
	22	7 18 "	1 17 "	7 17 "	1 16 "
	26	6 56 "	12 55 "	6 55 "	12 53 "
	30	6 34 "	12 33 "	6 33 "	12 31 "

It will be seen from this ephemeris that the two months of October and November will be very favorable for observations of the satellite, for those who have sufficient optical means. As the times of the satellite's elongations occur at so nearly the same time each night, we have given them only for every fourth night. The others may easily be found by interpolation, the change being five and a third minutes per day. Of course no one will attempt to see this satellite unless he has a telescope of 15 inches or greater aperture.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

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

Nov.	3	5 P. M.
	6	5 A. M.
	8	4 P. M.
	11	4 A. M.
	16	4 "
	21	4 "
	26	3 "

ALGOL.

R. A. .... $3^h\ 1^m\ 1^s$
Decl. .... $+40°\ 32'$
Period .... $2d\ 20^h\ 49^m$

Nov.	2	9 P. M.
	5	6 P. M.
	8	3 "
	17	5 A. M.
	20	2 "
	22	11 P. M.
	25	8 "
	28	5 "

λ TAURI.

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

Nov.	3	1 A. M.
	6	midn.
	10	11 P. M.
	14	10 "
	18	9 "
	22	8 "
	26	6 "
	30	5 "

R. CANIS MAJORIS.

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

Nov.	6	1 A. M.
	7	4 "
	13	midn.
	15	3 A. M.
	16	6 "
	22	2 "
	23	5 "

S CANCRI.

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

Nov.	12	6 P. M.
	22	6 A. M.

S ANTLIÆ.

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

Nov.	9	6 A. M.
	10	5 "
	11	5 "
	12	4 "
	21	6 "
	22	5 "
	23	5 "
	24	4 "

Asteroids of 1893.—The following table includes all asteroids discovered since the beginning of 1893. The first column gives the temporary designation, each being designated by a *permanent* number later, if sufficient observations are obtained to determine the orbit. Those who have discovered asteroids since the beginning of 1893 are M. Charlois, of Nice, M. Wolf, of Heidelberg, A. Borrelly, of Marseilles.

The total number of asteroids discovered up to January, 1893, was 351. The surprisingly large number already recorded for this year is due to the application of photography to this work, all of these having been discovered by this means:

Designation.	Discoverer.	Date.	Mag.	Designation.	Discoverer.	Date.	Mag.
1893 A	Charlois	Jan. 17	9.	1893 V	Charlois	Mar. 21	13.
B	Wolf	12	13.	W	"	21	12.
C	"	16	13.	X	Wolf	21	12.5
D	Charlois	18	12.5	Y	"	Apr. 14	13.
E	"	20	12.5	Z	Charlois	May 19	12.
F	Wolf	16	13.	AA	"	20	11.
G	Charlois	21	11.5	AB	"	20	13.
J	"	Feb. 11	12.5	AC	"	July 14	12.
K	"	Mar. 8	12.5	AD	"	16	11.
L	"	9	9.	AE	Borrelly	5	12.
M	"	10	13.	AF	Charlois	Aug. 11	12.
N	"	11	12.	AG	"	17	11.
O	"	11	12.	AH	"	19	10.
P	"	11	13.	AJ	"	Sept. 15	12.
Q	Wolf	16	12.	AK	"	18	12.
R	Charlois	17	11.	AL	"	18	11.
S	"	17	12.	AM	"	18	12.
T	"	19	13.	AN	"	20	11.5
U	"	19	13.				

1893 H was found to be identical with 1893 G.

Researches upon Comet 1889 V.—In the last two numbers (302 and 303) of the *Astronomical Journal* Mr. C. L. Poor gives a most interesting paper, entitled, "Researches upon Comet 1889 V." It will be remembered that soon after the first accurate orbits of this comet were computed, Mr. S. C. Chandler called attention to its very close approach to the planet Jupiter and consequent great change of orbit in the year 1886. Mr. Chandler also attempted to roughly trace the comet's previous course and came to the conclusion that this might possibly be the lost Lexell's comet of 1770. Mr. Poor has investigated these questions very carefully, going through an immense amount of calculation, and obtains results which, while they do not confirm the suspicion of identity between the two comets, are of very great importance. In his latest calculations, Mr. Poor used the definitive elements of comet 1889 V, obtained by Dr. Bauschinger from all the published observations, extending over a period of over eight months. There is still some uncertainty in the elements, but taking the most probable values, Mr. Poor, after taking into account the perturbations of all the planets which could perceptibly influence the comet's motion, finds that the comet passed very near to the planet Jupiter in July, 1886, so near in fact as to pass through the satellite system. He says:

"Using the elements for July 20, I find for the perijovian distance of the comet the following, in which the semi-diameter of Jupiter is taken as the unit:

$$q = 2.31 + 0.33\nu$$

[ν being the factor of uncertainty of the elements, and being included within the extreme limits of + 40 and — 40].

"That is, the comet not only passed through the system of Jupiter's satellites, but it actually passed within the orbit of the first satellite, whose mean distance is 5.93 radii of the planet. Taking the extreme limits of ν we are safe in saying that the comet passed the center of Jupiter at a distance of not greater than 3.63, and not less than 1.00 radii of the planet. In other words, the center of the comet may have touched the surface of Jupiter, and it certainly approached that surface to within a distance of 2.63 radii of the planet or only 112,300 miles. Even this latter is a very small quantity.

"For the most probable hypothesis, that of $\nu = 0$, the comet was 2.65 days within the system of Jupiter's satellites, and during this time it made nearly a complete circuit about the planet, passing over an arc of 312° of longitude. The comet entered the Jovian system in longitude 118° on July 18.77, passed the planet July 20.10 at a distance of only 2.28 radii, and July 21.43 left the system in longitude 71°. During this time it must have collided with one or more of the satellites."

Meteors.—Two beautiful meteors were observed here on evenings of August 6th and 11th inst., respectively, both were quite large and somewhat pear shaped. That of the 6th was of a bright green color and travelled swiftly from near ζ Bootes about 15° in a S. W. direction exploding before disappearance a few degrees above the horizon, time 11.03 P. M., central time. The meteor of 11th was of a bluish green color and travelled more slowly from near the 3rd magnitude star 12 Canes Venatici to a point about 10° S.W. of Polaris exploding into numerous reddish sparks. It was so brilliant that the whole landscape was lit up as if by a large arc lamp and was noticed by people even in doors. Time 10.06 P. M., central time. DAVID E. HADDEN.

Alta Iowa, August 17, 1893.

GENERAL NOTES.

We have recovered some of our lost time in publishing the September number so late last month. Our next will be issued about the 5th of November.

Professor J. E. Keeler will give the second article in his series on the Spectroscope in our next number.

S. W. Burnham and **J. A. Brashear** will contribute articles respectively on "Double Star Study" and on the "Making and Care of Telescopes" quite soon.

Dr. L. Swift's illustrated paper on "The Great Nebula of Andromeda," in the series titled "Suggestions to Amateurs" is already in hand. It is an instructive one.

H. C. Wilson's article will interest our readers generally. The frontispiece illustration is a unique one. It is a striking illustration of the apparent motion of the sky. Teachers may use it advantageously.

E. E. Barnard's illustrations of Jupiter's satellites will give definite idea of the new, fifth satellite, which he recently discovered. The finding of that tiny object is said to be the most important Astronomical discovery of the present century.

Miss Mary Proctor, the daughter of the late Professor Richard A. Proctor. is making arrangements to give a series of lectures on astronomy for children all over the country during the coming season. The course consists of three lectures for children, entitled: "The Goblins in Starland," "The Stories of the Stars," and "Giant Sun, and His Family." She will also deliver a lecture said to be specially suitable for Normal Schools, on "How to Teach Astronomy to Children." She delivered these lectures at Chicago, during the World's Fair, and met with success.

Astronomy in High Schools.—A business man in a mechanic association in Boston, not long ago wrote as follows:

It seems to me that a concerted effort should be made by all educators who appreciate the importance of the study of Astronomy, to create a public opinion which should lead to a more general and thorough study of the subject in our High Schools, all over the land. Every town of any considerable size, should have one school armed with a small instrument, properly handled, and the rudiments of Solar Astronomy should be taught to every graduate. It is a burning shame that not one man or woman in one hundred can tell the difference between a planet and a fixed star, neither do they know anything of the path of the planets in the heavens, and look upon the celestial bodies with less interest than they do upon a base ball game, or a new bonnet!

It ought not to be so, and it might be changed if our educators would unite in doing missionary work. But I suppose that they will not, and years must elapse before our boys and girls are told the difference between Venus and Sirius. And we boast of our advanced civilization! Three hundred years ago it was excusable, now it is not. A. B.

Remarkable Sun Spot.—On Sept. 15th, I observed near the eastern limb of the Sun, a large spot which promised to be interesting. On the afternoon of the 17th, the air being remarkably clear anu steady, I observed it again. It had increased in size very much since the 15th inst. and in some particulars, is one of the most beautiful and interesting spots I have ever seen. Within an extensive penumbra were nine umbræ intensely black while between two of the largest was an extensive mass of material of a dark red hue, and over a part of another umbra the same reddish matter seemed to be spreading. Between some of the other umbræ the matter was intensely white and brilliant. I thought I detected motion within the spot and watched it closely for some time to assure myself of this fact, but am not satisfied that there was, so as to allege it. I will continue to observe it. The instrument used was my 5-in. Clark refractor with powers of 105 and 200.

It reminds me very much of a spot sketched by Secchi in his *Le Soleil*, in which he shows the red matter or "tail," as he terms it. E. S. MARTIN.

Weighing the Planets.—If we assume the mass of the Earth to be one (1), then the individual and total masses of members of the solar system are as follows:

Sun	= 332,262		Earth	= 1.0
Jupiter	= 317		Venus	= 0 8
Saturn	= 95		Mars	= 0.11
Neptune	= 17.4		Mercury	= 0.06
Uranus	= 14.6		Satellites	= 0 20
			Minor Planets	= 0 25
			Total	332,708.42

For explanation how these results are obtained the reader is referred to Gore's new book entitled *The Visible Universe*, p. 325.

Range of Telescopic Power.—In Young's General Astronomy, page 470 is found a suggestive table showing the relation of the size of telescope to the magnitude of the smallest star visible by its aid. The table follows:

Star Magnitude.	Aperture of Telescope in Inches.	Star Magnitu e.	Aperture of Telescope in Inches
7	0.40	13	6.31
8	0.63	14	10 00
9	1.00	15	15.90
10	1 59	16	25.10
11	2.51	17	39.80
12	3 98	18	63 10

This table assumes that a normal eye and a good telescope, one-inch in aperture will be able to see, as the smallest possible, a ninth magnitude star. On account of the thickness of the largest lenses, the table may fail to give the true relation between aperture and magnitude. Notice how little the gain is in the increase of large apertures so far as magnitude is concerned, but the number of stars in each of these low magnitudes is enormously great. From the above table it also appears that a 20th magnitude star is far beyond any existing telescope.

Variable Stars.—We have been in correspondence with several variable star observers in order to organize a section in this line of observing. Among other letters we have one with a brief working list from Mr. J. A.

Parkhurst of Marengo, Ill. We do not present the list this time, because we wish to accompany it with directions so plain and complete that a beginner may take up the working list and use it regularly. Mr. Parkhurst's letter is so satisfactory that we have asked him to prepare the directions and suggestions that accompany his working lists. All amateurs interested in the observation of variable stars are requested to report to us their names. A description of their telescopes is desired and a statement of work already done, if any.

Miss Mary E. Byrd, Director of the Observatory at Smith College, Northampton, Mass., has prepared and printed a small pamphlet of 39 pages with title, *Questions on the Sky*. It is divided into seven sections with these themes respectively: Sun and Moon; Eclipse of the Moon; Planets for any Year; Planets for the School Year 1893-94; Comets and Shooting Stars; Stars and Milky Way, and Questions for a Telescope with an inch-and-a-half lens.

As introductory the following six rules for observing are given:

1. Begin each night's record on a separate page.
2. Date each page of observations.
3. Record each night the place of observing and the time of beginning and ending.
4. Enter the record in connection with the observation, or immediately afterward.
5. Keep all records of observation in pencil.
6. Make all corrections of the original record and enter copied observations in ink.

In the view of an experienced observer these will seem very common-place directions, and so they are, but no apology is here offered for them because they are elemental in the matter of keeping records. We want to bring just such plain and common sense things to the attention of teachers and young people in the hope that they may gain the benefit of *using* them. Under each section is given a series of questions which form an outline of the theme under consideration, a kind of topical run to guide the student in individual study under the supervision of an instructor. As an illustration we append a few queries from the section on the eclipse of the Moon.

1. Before an eclipse begins can you see any decrease in the brightness of the Moon's limb?
2. At what part of the limb is the shadow first seen?
3. At what instant are you sure that the eclipse has begun?
4. What is the color of the shadow when the moon first enters it?
5. Does the color remain the same throughout the eclipse?
6. An hour after the eclipse has begun what portion of the disc is obscured?
7. At that time what is the shape of the visible Moon?
8. How much does the light of the Moon seen to diminish?
9. What is the form of the line bounding the visible portion of the Moon?
10. Is the bounding line sharp and distinct to the naked eye? Why?

Under the several topics named above the number of questions set range between twenty and one hundred, and the consecutive list above gives a fair idea of the kind of questions chosen. Some such plan as this is very desirable to draw the attention of the student away from a book to the celestial objects themselves whenever this is practicable.

Observatory for Amateurs.—I have read with interest the communications of Messrs. A. E. Douglass (ASTRONOMY AND ASTRO-PHYSICS for March, p. 207), and Charles A. Post (ASTRONOMY AND ASTRO-PHYSICS for May, p. 400), entitled, "The Balance Roof for Telescope Buildings" which has induced me to offer the following description of a modest Observatory I devised and had erected in 1891 to cover my 5-in. Clark refractor. It cost about $80 and has proved secure and very convenient.

The Observatory is built of wood, closely weather boarded, with a stationary roof over one part and a sliding roof over the other part, both covered with tin. Its dimensions are 9 ft. × 12 ft. (the part covered by the sliding roof being 9 ft. × 9 ft.) and 6½ ft. between the floor and cap sills on which the sliding roof rests, the ridge of the roof being 2 ft. above sills. The cap sills on the eastern and western sides of the building project beyond it 4 ft. on the northern and southern sides like arms extended. To the top of each sill is secured, by screws, a semi-circular iron rail ½ in. thick in which the iron wheels, (grooved to fit the rail) travel. Two wheels are secured to each side or gable end of the movable roof on the inside. The wheels (3 in. diameter) and the rails are such as are used for suspending the heavy sliding doors of warehouses and like structures.

The gable ends of the roof, made of solid inch-and-a-half boards, are triangular in shape, 2 ft. in altitude and 9½ ft. base. The upper half of the slant of the roof on each side of the ridge is stationary, being sheathing boards securely fastened to the gable ends and covered with tin. Underneath this part the shutter covering the lower half of the slant of the roof (a light frame covered with tin) slides up, in grooves along the inner side of the gable ends. And in order to have it move easily, small iron rollers or "runners" are placed on the under side of the sliding shutter of the roof and also on the ends as friction rollers.

The shutter being pushed up under the upper part of the roof, as aforesaid, the roof is then rolled by hand pressure to one side until the ridge is vertically over, or beyond the side of the Observatory when an open space is secured ample enough for all movements of the telescope placed in the centre of the building and its declination axis on a level with the cap sills.

To move the roof more easily sash weights (7 lbs. each) are attached to each corner of it by ends moving over pulleys near the ends of cap sills. The roof can be moved towards the north or south, and though rigid and heavy enough not to be affected by strong winds, is yet light enough to be moved with little effort.

The space between the base of the roof and the cap sills on which it moves is covered by a weather strip of wood, extending below the top of the cap sills, which also serves as a guide to keep the roof in position when in motion.

The view around the horizon is unobstructed by the roof, except at a very low altitude above the north or south point, towards which it may be moved. In practice I always roll it towards the north which permits an unobstructed view of the heavens, except a small portion about the northern horizon.

When the roof is to be moved, the telescope is placed in a horizontal position, the declination axis being also horizontal, which permits the roof to pass at a safe distance above it.

In the above sketch details have been ignored and only the main features presented with the hope that it may be understood and at least suggestive.

Wilmington, N. C. E. S. MARTIN.

Occultation of Antares by the Moon.—The occultation of Antares by the Moon was observed here on the night of July 23 and was a most beautiful sight.

The atmosphere was clear and steady and definition remarkably good. The brilliant crimson star touched the Moon at the top of the eastern side, or range of a large crater (near the southern point of the Moon) which appeared as an isolated line of light, separated from the illuminated body of the Moon by a dark space, (the bottom of the crater) and by dark gaps at both ends. Along this uneven line of light Antares glided, its glowing crimson contrasting most beautifully with the brilliant white light of the mountain side, upon which it apparently rested until the star reached a point near its southern end, when it instantly disappeared as if it had plunged into the dark gap. At emersion it as instantly reappeared. The dark limb of the Moon was not seen. The instrument used was a 5-inch (Clark) refractor with power 105. E. S. MARTIN.

Richard A. Proctor's memory in America fell quickly into sad neglect, if the dilapidated condition of his tomb in Greenwood Cemetery, Brooklyn, N. Y., for the last few years is a proper evidence of public forgetfulness of one deservedly so well known previously in the home of his adopted country. It is a blessing to ours, or any country, to have such men in it as George W. Childs of Philadelphia, whose generous impulses are always alert to repair humiliating neglect or public injustice like this which sometimes overtakes the good and the honored of this world. It is doubtless known to most of our readers that Mr. Proctor died of yellow fever in a New York hospital, a day or two after his arrival from Florida, his home. None of his family were present, and because of the fever immediate burial was uncessary, and the place chosen was the vacant lot in Greenwood cemetery owned by the undertaker. Through Mr. Child's thoughtful generosity the mortal remains of this eminent man were given an honorable burial and a simple though beautiful monument in their new resting place. We pay his memory a just tribute in the well chosen words of another:

"While the astronomer was an Englishman, the most active and useful years of his career were passed in America. Original and thorough as were his researches in many fields of science, it was as a lecturer and a writer that he chiefly distinguished himself. It was in America that his talent of scientific exposition was most highly appreciated and developed. It was here that his best work was done as a popular lecturer, with a lucid and animated style and a remarkable power of interesting audiences in his scientific studies. So marked were his usefulness and success here as a public educator that America had become his adopted home. His grave is where it ought to be, in one of the loveliest corners of Greenwood, with many famous men whom he knew in life at rest around him. Henceforth it will not be an unmarked, neglected grave."

Popular Astronomy in Africa.—We are just in receipt of a postal card with the reply card attached asking what will be the expense of postage on this publication to Cape Town, Cape Colony, Africa, from which the card was mailed, as that district is not in the postal union. It is also asked if it is our intention to give the current celestial phenomena for the southern hemisphere as well as those of the northern. Truly the astronomical world is becoming one in its intercourse in many ways.

Queries Pertaining to Astronomical Themes.—We have known for some time that amateurs have desired a general corner, through which to secure information that might be given by questions and answers. We will try hereafter to give attention to requests of this kind and furnish answers to them as fully and promptly as possible. Correspondents and readers are respectfully asked freely to share in this to make the plan generally useful.

1. What months of ASTRONOMY AND ASTRO-PHYSICS have most in them about the Total Solar Eclipse of April 16, 1893? W. W. B.

Answer: February, April and October. The first gives an account of the predictions of the corona made by Professor F. Bigelow, Washington, D. C., according to his magnetic theory, so-called, with a fine frontispiece illustration. The second gives some account of the path of the line of totality across South America and Africa indicating the most available stations on the two continents and some notice where different observing parties were intending to be located. In this number three large cuts are given to show definitely what is described in the text. In the last issue of ASTRONOMY AND ASTRO-PHYSICS will be found two articles by Professor Schaeberle of Lick Observatory. In one he states the preliminary results of his work at the Lick Observatory station in Chile which he thinks fairly accord with his theory of the corona known generally by the name of the "Mechanical Theory," an illustration of which will be found in the January issue, 1893. In the other will be found his reply to the criticisms of astronomers in England and America who claim that the photographs obtained at the different stations along the line of totality do not show a fulfillment of the predictions of his theory. In the October number will be found a beautiful photogravure plate of the Solar Eclipse as observed in South America by Professor Schaeberle. Short exposure only was given to bring out the detail of the inner corona. In the November number of ASTRONOMY AND ASTRO-PHYSICS, 1893, will appear a companion plate showing the corona as it could be photographed by longer exposure to bring out the exterior corona more fully. In another place in this number of *Popular Astronomy* is given an illustration of the 40-foot telescope used in obtaining these pictures and also a general view of the station in South America occupied by Professor Schaeberle to observe this eclipse.

2. Are the rising and the setting of the heavenly bodies the same in Eastern time as in Central? M. B. T. H.

3. In the case of phenomena that do not depend on the rotation of the Earth, as the minima of Algol, is the longitude of the place necessarily considered? M. B. T. H.

4. Given a 4-inch telescope, so good that it will easily resolve α Scorpii, or α Lyræ with a power of 95, and will separate π Aquilæ (1″.7), or ε Arietis (1″.3) with a power of 180 on any good night. If the above aperture be cut down to 2 inches by an annular diaphragm it will resolve Rigel with a power of 95. If a stop be applied cutting out the central 2 inches, the glass will resolve Rigel with difficulty. A central stop cutting out 2¾ inches, but exposing a margin of more than twice the area of the first central 2 inches will fail to resolve Rigel. Do all good objectives suffer in a like degree from uncorrected spherical aberration? The above experiment seems to indicate that the central 2 inches of a 4-inch glass will resolve more than a whole 3-inch objective, especially on a bright object. S. G. S.

5. What are the practical difficulties in the way of better eye-pieces? Do not our expert opticians prefer to temper the objective to the eye-piece rather

than to attack the latter and attempt to improve it? The negative eye-piece is fair, but is it not much behind objectives in perfection? S. G. S.

6. There is a faint star in Cassiopeia not far from κ, the location of Tycho's Nova, as given by Dr. Klein which I have been watching for a week, and can find nothing to correspond with it in Klein's map and D'Arrest's chart. Is it not worth the while of observers to examine it? Its position roughly is 30′ right ascension and 63° 20′ declination. D. F.

BOOK NOTICE.

Elementary Mathematical Astronomy, with Examples and Examination Papers. By C. W. C. Barlow. M. A. B. Sc., and G. H. Bryan, M. A., London. Clive & Co., University Correspondence Press, Warehouse 13 Booksellers Row Strand, W. C., 1893, pp. 493.

On the amateur side of our study there are doubtless many of our readers who desire to know of just such a new book as this which is just received from the publishers. This book, although first published in 1892, has already passed through its second edition. Its introductory chapter is on spherical geometry. Then follows the celestial sphere with the definitions and an explanation of the motions of bodies on it. Thirty pages are given to this theme, followed by twelve examples and an examination paper with ten questions.

The next chapter is devoted to the Observatory in which the principles of the common observatory instruments are explained and fully illustrated, and the work they are intended to do shown. Examples on this theme follow and an examination paper. In the first part of the book there are eleven such chapters. The titles besides those named are The Sun's Apparent Motion in the Ecliptic; Time; Atmospheric Refraction and Twilight; Determination of position on the Earth; The Moon; Eclipses; The Planets; The Distances of the Sun and Stars.

Under the division of Dynamical Astronomy three chapters more are given. The rotation of the Earth; The Law of Universal Gravitation and Future Applications of that Law; then follow a series of useful notes, an appendix, answers to examination questions and a full index.

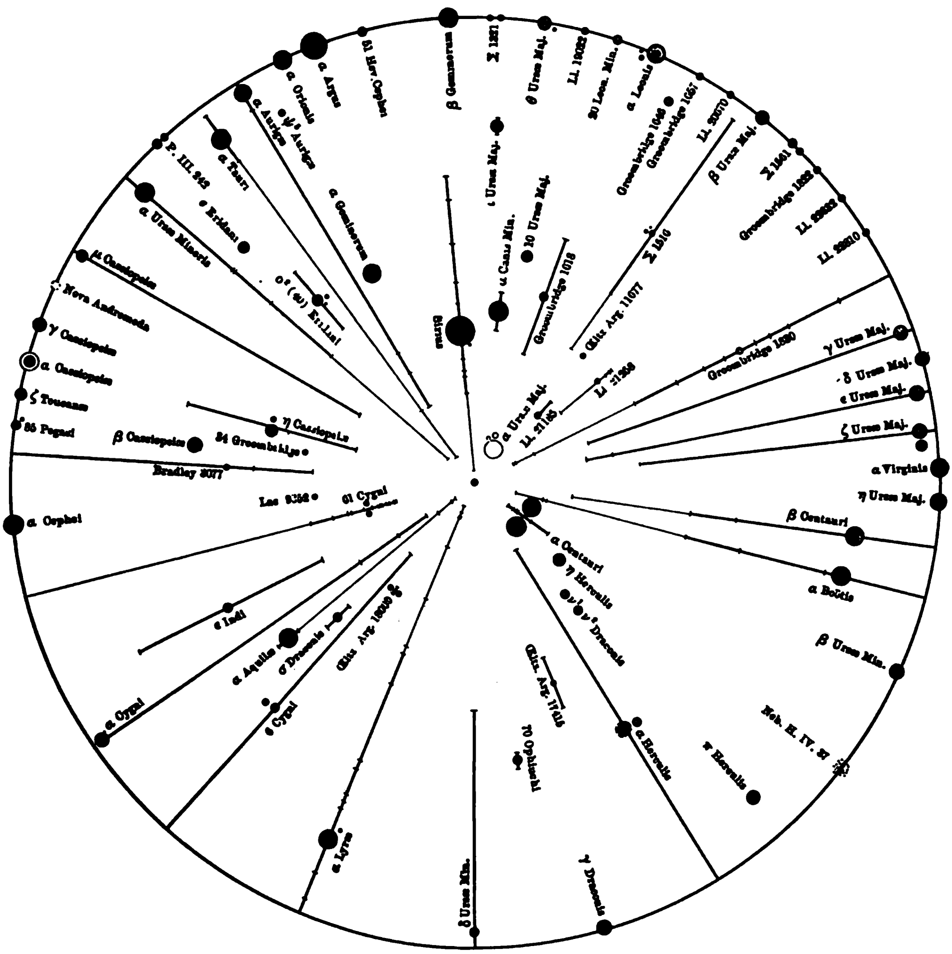
The book is on the plan of the University extension study and is certainly a useful one to give accurate and independent ideas in the study of Astronomy by the aid of elementary mathematics. It is intended for amateurs, and its form is useful for faithful self-instruction, which is part of the plan of a correspondence college. It also furnishes a series of good tests for the student as he advances, by the examples and the examination papers given in connection with each topic.

Publisher's Notices.— The subscription price for POPULAR ASTRONOMY is $2.50 per year, foreign countries 14 shilling, payable in advance, the annual volume consisting of ten numbers, issued monthly, except for July and August, each containing at least 48 pages of reading matter. Articles for publication may be sent to Wm. W. Payne, Goodsell Observatory, Carleton College, Northfield, Minn., or to Miss C. R. Willard, same address. All remittances for subscription or advertising should be sent to Miss Willard who is in charge of the accounts of the office.

Please take notice that all payments of dues should be made in post office orders or notes, or bank drafts on Chicago, New York, St. Paul or Minneapolis. Personal checks are banked at a discount.

Messers. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are sole foreign agents.

PLATE VI



Distances of Stars whose Parallaxes have been determined during the Present Century

Popular Astronomy.

Vol. I. NOVEMBER, 1893. No. 3

SHOOTING STARS.

How to Observe Them and What They Teach Us.

W. F. DENNING, Bristol, England.

Chapter III.—Radiation and Radiant Points.

The observer, having decided to commence observation and attended to the necessary preliminaries, will choose a dark, moonless night and, keeping a sharp watch on the sky, will proceed to register the paths of such meteors as make their appearance. After perhaps two or three hours of work he will imagine that the meteor paths are so irregularly distributed over the celestial vault that they are not to be reduced to any orderly arrangement. But carefully drawing their lines of flight backward he will find that most of them intersect at well defined points. These are called the "radiant-points" and they form a most important feature in the observation of meteor showers. A diagram will perhaps explain the matter more forcibly than mere description and so we subjoin a sketch in which a number of meteors are depicted with their lines of flight produced. Though the directions appear at first sight to be very discursive they resolve themselves into three well defined radiant-points.

It is the principle object of meteor observations to determine the positions of radiant points as exactly as possible and it is on this account that we have previously impressed upon the student the necessity of recording the directions of flight as accurately as possible.

The beginner may naturally feel inquisitive as to the nature of these radiant points. Do they each represent a planetary mass from which are discharged the individual shots seen every now and then? Other explanations may also occur to his mind, so we may as well state here that a radiant does not represent a material object but is produced by the effects of perspective on luminous bodies moving in parallel lines. It seems that meteoric particles (generally consisting of stony matter) exist in extensive shoals or swarms within (and probably without) the solar system, and that they revolve in cometary orbits round the Sun. A number of these meteoric swarms cross the Earth's orbit and plunge into our atmosphere with planetary velocity, but the heat generated by friction immediately renders them incandescent and they are consumed in nearly every case before reaching the

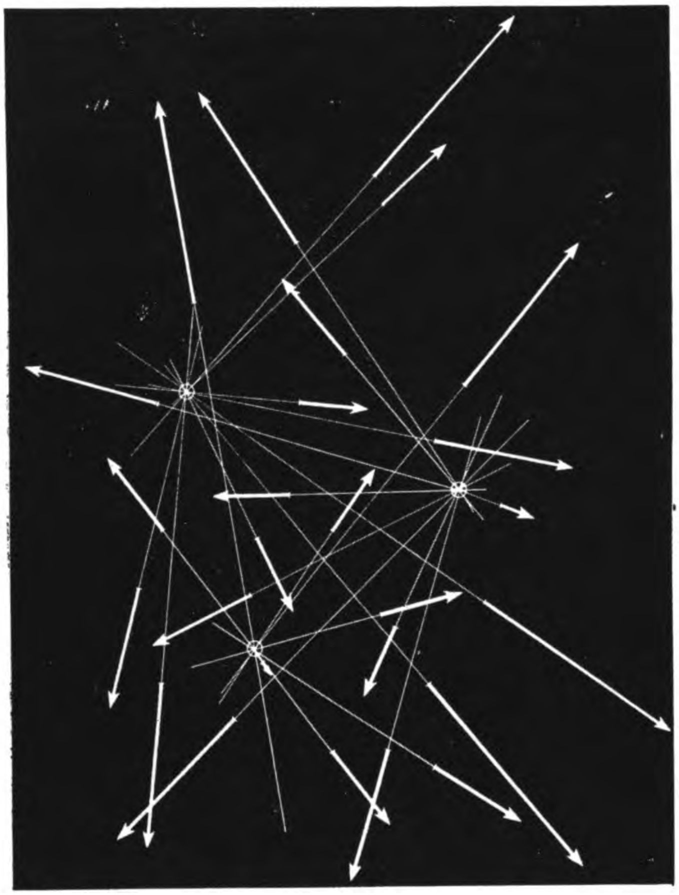


FIG. 1—METEOR PATHS INDICATING MULTIPLE RADIANTS.

ground. We are perpetually suffering bombardment by thousands of these stony visitors and it is fortunate that they are robbed of their harmful character and that their material is exhausted by combustion while still at a considerable height above the Earth's surface.

The foregoing diagram will show how it is that visible meteors as projected on the star sphere, take the form of radiations from a central focus:

Let us suppose the observer to be stationed at D, and that the sky-dome is represented at ABC. Six meteors moving in parallel paths and numbered 1, 2, 3, 4, 5 and 6, are shown and the furred portion of their tracks is intended to represent that observed. At certain points as at 1′ and 5′ they first become visible and disappear at 1″ and 5″. It is clear that the meteors will be apparently projected upon the sky as delineated at *a*, *b*, *c*, *d*, and that the meteor No. 3 will be motionless at the point *a*, which corresponds with the radiant, while No. 5 will have a pretty long path at *c*. In fact the paths will present a series of radiations and will appear to vary in length and speed according to position relatively to the radiant.

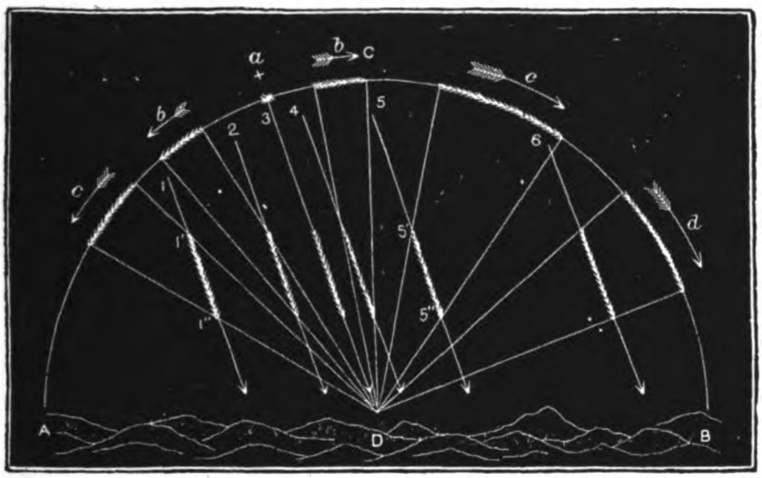


FIG. 2.

It may here be observed that radiant points partake in the diurnal motion of the firmament and are stationary amongst the stars—a fact which sufficiently proves their astronomical character. If they were due to the operations of a body within our atmosphere they would obviously be carried round with the Earth's rotation and make a complete circuit of the heavens once every twenty-four hours.

A grent number of different radiant points are visible on every night of the year and their detection is sometimes a matter of difficulty. On about August 10 when the Perseids are most abundant, there are quite 100 distinct showers in active play.

Some of these are placed within a few degrees from each other, and they are only to be separated by a discriminating and accurate observer. Of course it is easy enough to get the radiant of a prominent display like the Perseids as the meteors are often very numerous and exhibit a good focus with only a few erratic flights. The subjoined diagram will give a good idea of the radiation from a strong shower monopolizing nearly all the meteors recorded.

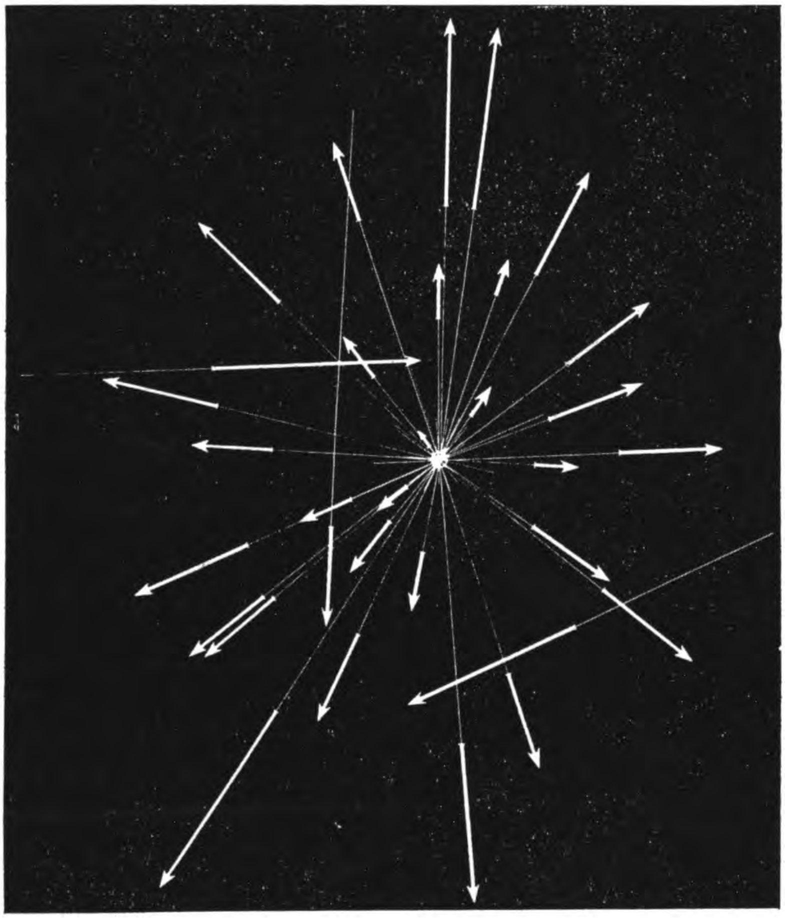


FIG. 3—PATHS FROM A RICH METEOR RADIANT INCLUDING THREE FROM OTHER SHOWERS.

A great difficulty always requiring the exercise of much discretion and care on the part of the observer lies in apportioning meteors to their correct radiants. This cannot be invariably done as a meteor may be directed from several showers in the backward prolongation of its flight. From a single observation we only possess circumstantial or presumptive evidence that a meteor belongs to the radiant to which we have assigned it. We require therefore another "divining rod" beside that afforded by the path-direction. This is often to be found in the physical appearance of a meteor and observers should always, therefore, record the details of aspect presented by each object.

The Earth's motion in her orbit is approximately directed towards a point 90° preceding the Sun along the ecliptic, and this point is known as "the apex of the Earth's way." Meteors from showers in this region and within some 45° of it commonly move with great velocity and generate phosphorescent streaks in their paths These streaks often brighten up after the disappearance of the nuclei, in fact the writer has sometimes seen a streak come out in a spot where nothing was previously observed. Meteors from radiants far from the apex are slow and streakless though sometimes leaving trains of sparks, and the Andromedes of November 23-27 may be mentioned as an example of the slow trained meteors. Whenever a phosphorescent streak is left, we may depend upon it as proving the meteor to come from a radiant in the region of the apex (probably in the eastern sky) while a slow meteor with a train will as certainly have its centre in the region of the anti-apex in the S. or W. sky. The apex rises at about midnight and it will be advisable for the observer to know its position at different hours; this he may readily do by some naked eye star or other means.

A meteor with a long path frequently has its radiant near the horizon, and marked fluctuations of light are cften characteristic of such a body. A radiant near the zenith usually supplies short meteors. A long pathed meteor is always some distance from its center, while a very short, slow meteor will generally be close to it. A very dense streak or train left by a short meteor is a sure sign of foreshortening, as we see the spent material end on, and the radiant will probably be not more than a few degrees distant. A bushy appearance of the nucleus, or a sinuous curved motion, over a short arc are also indications of a foreshortened track. Long, rapid flights afford, on the other hand, clear evidence that the radiant is far away.

Hints like this are not perhaps without their value, but the best teacher, after all, is experience; and the young observer, in order to gain information as to these details, cannot do better than acquire them from nature herself by watching some well known showers, such as the August Perseids and November Leonids, and noting the features of the individual meteors. Practical exercise of this kind is often more effective than any amount of description. The two showers we have mentioned are typical of the swift, streak-leaving meteors, so we would recommend the study of the November Andromedes as well, for they belong to a different class, moving very slowly and casting off trains of yellowish sparks. But the Andromedes do not come every year, nor do the Leonids return in strength except periodically; for this reason the August Perseids offer the best inducement, as they furnish a rich display every year, and are visible certainly from the middle of July to the middle of August.

Meteoric radiation is not always from a point; it sometimes constitutes an area of tolerably large dimensions. Thus during a brilliant exhibition of the Andromedes on November 27, 1885, the radiant was generally noticed to be very diffused. At Bristol the writer estimated its diameter as 7°. But this special shower cannot be accepted as typical of all. There are indeed many radiants which are sharply defined and certainly limited to one or two degrees. It is possible to distinguish such radiants with great precision. Perhaps one or two meteors out of ten will be a little erratic but the great majority of the paths intersect at a point. As a rule very diffuse, scattered radiants, or double radiants for one shower are simply the outcome of inexact observation. The bulk of the radiants determined at Bristol are certainly less than 3° diameter and the probable error in deriving a position is considered to be less than 2°. But a good deal must obviously depend upon circumstances. To get a thoroughly good position for a radiant the observed meteors must be near to it and must include paths nearly at right angles to each other so that both the R. A. and Decl. may be well ascertained.

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

JAMES E KEELER.*

2. *The Wave-length Scale, and the Solar Spectrum.*

In the first number of POPULAR ASTRONOMY, I explained the principles on which a simple form of prism spectroscope is constructed, and showed how a bright-line spectrum is formed when the source of light is a body emitting certain definite kinds of rays. Experiment shows that a bright-line spectrum can be pro-

* Observatory, Allegheny City, Pa.

duced only when the source of light is a gas; thus we see at once that by merely looking at the spectrum of a body we can tell something about its physical condition. Under ordinary circumstances we should not need a spectroscope to tell us whether a body was gaseous or not, but if it were inaccessible,—if it were a nebula, for instance, millions of miles away in space,—even this amount of information might be in the highest degree interesting and valuable.

The particular arrangement, or grouping, of the bright lines, and their relative brightness, depend upon the kind of gas which gives out the light. If we suppose that each elementary substance, when vaporized by heat, has its own characteristic bright-line spectrum, which is the same under all circumstances, the reader will easily understand how the spectroscope can be used to analyze substances whose composition is unknown. It is only necessary to first become thoroughly familiar with the spectra of all the elements in order to recognize them when they occur together. In reality the case is not quite so simple as the one supposed, although near enough to it for the present purposes of illustration.

If a spectroscope like the one I have described, or a small pocket spectroscope, many of which are made by Mr. Browning, is pointed at the Sun or the bright sky near it, a spectrum very different from anything yet mentioned, will be seen. The bright continuous spectrum is crossed by multitudes of fine dark lines. Doubtless other and stronger lines will be seen, running *lengthwise* through the spectrum, but these are comparatively unimportant, being caused by particles of dust in the slit. Any small object, such as the end of a match, or a bit of paper, held in front of the slit, will show at once the origin of these lines. The vertical lines, (or those which are parallel to the slit), are of the greatest importance. If we suppose, as we safely may, that the light when it left the body of the Sun originally contained all possible kinds of rays, it is evident that some particular rays have been stopped on the way to us, or *absorbed*, either by the atmosphere of the Sun or by that of the Earth.

The dark lines in the solar spectrum were discovered by Fraunhofer, or at least their importance was first recognized by him, and the strongest lines are still known by the letters of the alphabet which he gave them for purposes of description. An acquaintance with these lines is indispensable to even the most elementary knowledge of spectroscopy, and hence it seems best to me to begin with a description of the solar spectrum, instead of simpler forms which can afterwards be described more readily by means of the knowledge so gained.

It will first be necessary to explain the system which has been universally adopted for designating the position of a line in the spectrum. So far we have merely mentioned the color of that part of the spectrum in which the line is found, but this evidently gives only a very general idea of its position. To say that a line is in the green does not distinguish it from hundreds of other actual or possible lines. If the observer has a spectroscope provided with a graduated circle, he may measure the minimum deviation of the line, and thus determine its place in the spectrum with much accuracy. If, for instance, the minimum deviation of the line in the green is found to be 48° 45′ 30″, the line cannot be mistaken for any other in the spectrum obtained with that particular prism. The position so determined might be useful to the observer, but it would convey little information to anybody else, as the same line would be differently deviated by different prisms, and hence such a method as this is not suitable for general use. The same objection applies to all scales which are peculiar to the special instruments employed, and it is therefore necessary to find some method of stating the position of a line which is entirely independent of the instrument. The method universally employed is to give the wave-length of the light which is refracted to that part of the spectrum at which the line is found, or more briefly the wave-length of the line. To the beginner this may seem difficult, but in fact he will find the use of the wave-length scale is very simple, as all the hard parts have been done for him by others. It is not even absolutely essential that he should under stand the principles involved in the method, just as a computer could use a table of logarithms without knowing how such a table is constructed, although doubtless he would use it all the better for such knowledge. The principles are not difficult, however, and I will proceed to their explanation, so far as they relate to the ordinary use of the spectroscope.

It is well known that light is an undulatory motion of the luminiferous ether,* a subtle medium assumed to fill all space. The molecules of a heated body are in a state of extremely rapid vibration, and their motion is communicated to the ether and propagated in all directions as light-waves, just as the vibratory motion of the particles of a bell is communicated to the air and propagated as sound waves.

---

* Certain difficulties are avoided by defining light as a sensation, generally caused by external agencies which are here regarded as light itself. The distinction is not often observed and it is entirely unnecessary for our purposes.

In a vacuum light travels at the rate of about 186,000 miles per second. In air the velocity is slightly less, and in glass it is reduced to about two-thirds of its velocity in space. As mentioned in the last article it is the retarding effect of glass that causes light to be deviated from its course by passing through a prism.

The average length of a light-wave is about $\frac{1}{50000}$ of an inch. The waves are not all of the same length, however. The shorter the waves, the more they are retarded by glass, and the more they are deviated from their original course by a prism. Hence it is that the rays of light are spread out by a prism *in the order of their wave-lengths*, the shortest waves going to the upper or violet end of the spectrum, the longest waves to the lower or red end, and other waves to intermediate positions according to a definite law. In the spectra formed by some remarkable substances, this regular sequence of wave-lengths is not found, but such substances are unfit for making prisms.

It is not customary to express the length of light waves in fractions of an inch. The unit in general use is the tenth-meter, which is the ten-millionth part of a millimetre. It is also called an Angström's unit, because it was adopted by Angström in constructing his large map of the solar spectrum. According to this system, the wave-lengths of lines in the visible spectrum range from a little less than 4000 tenth-metres, in the extreme violet, to a little less than 8000 tenth-metres in the extreme red, so that all lines will be indicated by intermediate numbers. The spectrum extends beyond these limits in both directions, but beyond them it is invisible.

The wave-length, of light in a vacuum, or in a medium of constant density are always the same, and it has been proposed to use them as a basis for constructing a practical standard of length; in fact the work of constructing such a standard is now going on in Paris.

The wave-length of a line therefore affords the best possible means of indicating its position, since the wave-length does not change and it is independent of the instrument used. The wave-lengths of all the important lines in the solar spectrum have been determined with extreme precision, not of course by direct measurement, but by indirect methods which are explained in works on optics. It is sufficient for our purpose to accept the results which have been obtained.

It is not necessary to think of the figures given for the position of a line as representing the length of the waves of light at that point; on the contrary, it is more convenient to regard them as the reading of a scale fixed to the edge of the spectrum, and used to read off the positions of lines just as any actual and visible scale would be used. The only difference is that the figures on the wave-length scale have a special meaning, and those on an arbitrary scale have not.

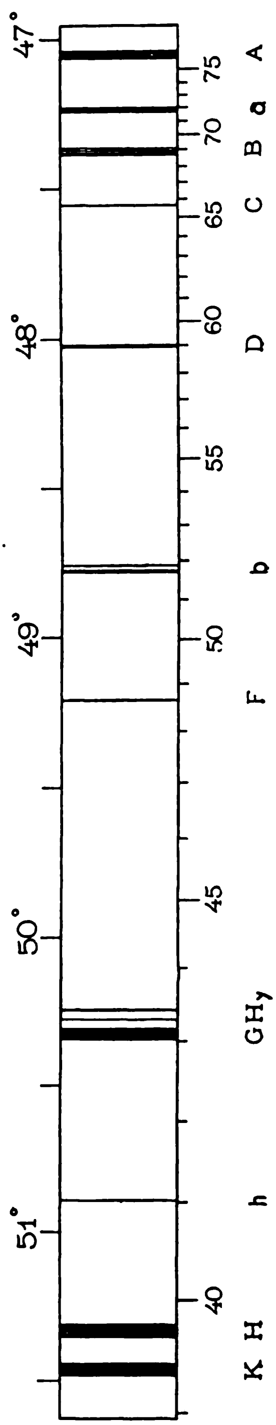
We are now ready to consider the solar lines in somewhat greater detail. The student should familiarize himself with their general appearance and arrangement, so that he can recognize them without difficulty. A rough-and-ready knowledge of the solar lines is like a knowledge of the constellations in studying the stars, while an accurate map of the solar spectrum and a list of the lines with their exact wave-lengths are to the spectroscopist what a star-chart and star-catalogue are to the astronomer. To learn the lines in the spectrum a map is necessary, and quite a number of fine maps have been published;—either original photographs, or engravings made from drawings. The photographic maps are to be preferred. They show us the actual solar spectrum as it is seen in an instrument, whereas in the others we are annoyed by errors which are unavoidable in drawing and printing.

But to the beginner the principal trouble with these maps (leaving aside the question of expense) is that they are on too large a scale, and they show too much. It is not easy to identify lines in a spectrum a few degrees long, seen in a small spectroscope with a low power, with the aid of a map which may be perhaps several feet in length.* To meet this difficulty Dr. Lohse, of the Observatory at Potsdam, published a map on a small scale, showing the lines visible with a small instrument. The student will find this map very convenient. It is in No. 6 of the second volume of the Potsdam Publications.

As all who read this article may not have access to Dr. Lohse's map, I have drawn the accompanying figure, which will perhaps be useful in the same way, although it contains only a few lines. It represents the relation between the principal Fraunhofer lines, their wave-lengths, and their deviations by a 60° glass prism used at the Allegheny Observatory, and it is accurately drawn to scale. The deviations will certainly not be the same for any other prism, and the spacing of the lines will also be slightly dif-

* I find it a time-saving device to color a thin strip along the edge of a map with crayons or water-colors so as to approximately match the tints of the spectrum. When the map is printed on many separate sheets the desired part can be selected at once without looking at the figures. Colors are also useful on a long catalogue of wave-lengths.

ferent; still the figure will represent quite closely the distribution of the same lines in the spectrum given by any small instrument. The degrees of deviation are marked above the spectrum, and they are, of course, of equal length. The wave-lengths are marked below in intervals of 100 tenth-metres, (the last two ciphers being omitted for economy of space), and the reader will notice at once that the intervals are unequal, being much longer in the violet (or left hand) than they are in the red. The distribution of light-waves shown in the figure is characteristic of the prismatic spectrum. It is evidently the result of some law, but the real physical law has never been satisfactorily made out, although an arbitrary formula may be determined for any given prism which will represent the spacing of the wave-lengths with all necessary precision.



If we should draw the wave-length intervals all equal, and plat the Fraunhofer lines in their appropriate places on the scale so obtained, we should have what is called a *normal* spectrum. Such a spectrum can be actually produced, although not by means of prisms. As compared with the normal spectrum, the prismatic spectrum is evidently much compressed in the red and spread out in the violet.

With the aid of the diagram, I will now attempt to describe the principal Fraunhofer lines, so that the reader can recognize them in the actual solar spectrum, which he is supposed to be observing with his small instrument. I shall also give the known origin of the lines, although we have not yet considered the way in which they are determined, and the exact wave-lengths, as they will be useful hereafter.

Perhaps the most easily recognized line in the spectrum is the close double line marked D, and the reader may begin by looking for it. It is in the orange part of the spectrum, just below the yellow, and there are no other strong lines in its vicinity. To see the D line double with his small instrument, the observer may have to direct the collimator to the Sun itself and make the slit very narrow, and also focus the telescope carefully. The D lines are just six tenth-metres apart, their wave-lengths being 5890 and 5896. The lower one (down always meaning toward the red) is called D_1 and the upper one D_2. They are caused by the absorptive action of sodium vapor in the Sun's atmosphere, and if any difficulty is experienced in finding them in the spectrum, the sodium flame described in the last article, when held in front of the slit, will point out their exact places, for it will give two *bright* yellow lines which coincide exactly in position with the dark D lines.

With a more powerful instrument, a fine line can be seen nearly midway between the D lines. It is due to nickel.

Passing down the spectrum, the first strong line we come to is C, in the bright red, or scarlet. It is due to hydrogen, and is an important line in solar spectroscopy. The wave-length of C is 6563.

This is nearly the end of the spectrum if our instrument is pointed to the sky, but if we turn it to the Sun we can see much lower. In the full, deep red we come to B, which looks like a strong dark line with a shade on its lower side. With a very powerful instrument the strong line is resolved into a large number of dark lines, and the dark shading into a most remarkable series of doublets, diminishing in intensity toward the lower end of the spectrum. The B line with its attendant doublets is due to the absorptive action of our own atmosphere, and more specifically to oxygen. No single wave-length can be given for the B line; perhaps the part which would be called its centre with a small instrument is at wave-length 6874.

Below B, at the extreme lower end of the spectrum is the great A line, in appearance much resembling B, although it is darker and stronger, and in a powerful instrument the series of doublets below it is even more remarkable than the corresponding attendants of the B line. The broad dark head is resolvable into a group of lines, the centre of which is at about wave-length 7604. The A line is caused by the absorptive action of oxygen in the Earth's atmosphere.

To see the A line well, the spectrum should be viewed through a piece of deep blue (cobalt) glass, which seems to cut off the diffuse light in the field. It may seem strange at first sight that the blue glass should be preferred to red. The reason is that the blue glass transmits the extreme red of the spectrum (as well as the blue and violet light), and absorbs the yellow rays which cause most of the glare, and which are transmitted by red glass. Drawings of both the A and B groups on a large scale, by Professor Langley will be found in the Proceedings of the American Academy of Science, 1878.

Between A and B are many smaller lines, the most prominent group of which is called *a*. Most of the lines are atmospheric.

Going back to D, and passing up the spectrum, in the bright green we come to *b*, a close group of lines. The strongest lines are designated b_1, b_2, b_3, and b_4 beginning with the lowest one, and their wave-lengths are respectively, 5184, 5173, 5169 and 5167 tenth-meters. A small spectroscope will not separate the lines very well. b_1, b_2 and b_4 are due to magnesium. In a large spectroscope they have hazy borders. b_3 consists of two very close iron lines.

F is a strong line just about on the boundary between the green and the blue. It is a hydrogen line, the second in a regular series which begins with C. Its wave-length is 4861.

Above F the lines become very numerous, and are not always easy to identify. G is the strongest line in a rather wide group, which is only roughly indicated in the figure. Below the group in which G is situated are two rather strong lines; the lower line is Hγ, sometimes called *G* (italic), the third line of the hydrogen series. It is an important line in astronomical spectroscopy, for the reason that it occurs in nearly all star spectra, and it is in the part of the spectrum which most strongly affects the ordinary dry plate used in photography. The wave-length of G is 4308, and that of Hγ is 4341.

Another hydrogen line, *h*, is found at 4102 on the wave-length scale.

H and K are two broad, hazy lines, easily recognized at the extreme violet end of the spectrum, and are best seen with the aid of a piece of blue glass. Both are due to calcium in the Sun's atmosphere. The fourth line of the hydrogen series falls so close to the calcium line in the center of H that it cannot be separately seen. The wave-lengths of H and K (the central calcium lines) are 3969 and 3934.

The lines which have been mentioned take us through the whole range of the visible solar spectrum. The way in which lines in the invisible parts of the spectrum are detected must be left until another time.

It should, perhaps, be mentioned that the tenth-metre is not invariably chosen as the unit of the wave-length scale. Sometimes a unit ten times greater—the millionth of a millimetre—is used, and then the wave-length of the F line would be written 486.1; some writers use the *micron* or thousandth part of a millimetre, and write the wave-length of F, 0.4861. As no line in the visible spectrum has a wave-length ten times greater than that of any other line, no confusion results from this practice. To indicate that a number represents a wave-length, the symbol λ, which always stands for wave-length in optical formulæ, is written before it; as λ 4861.

In closing the subject for the present, I will mention, for the convenience of the reader, some of the more important maps of the solar spectrum that have been published.

Fraunhofer's original map was printed in the *Denkschriften* of the Munich Academy of Sciences, 1814-15. On account of its great historical interest, it is often reproduced in modern text-books; there is a copy, for instance, in Lockyer's "Solar Physics," and another (not showing the whole spectrum, however) in Young's "The Sun".

The original map by Kirchhoff, the discoverer of the natural laws which underlie the phenomena exhibited by the spectroscope, was published in two parts (four plates) in the Transactions of the Berlin Academy, 1861 and 1862. It extends from A to G, inclusive. The accompanying memoirs were translated into English by Professor Roscoe and published with the plates by Macmillan in 1862 and 1863. The instrument with which this great work was executed has four prisms; otherwise it is much like the simple spectroscope described in our last article. It is now in Chicago, in the German educational exhibit of the gallery of the Liberal Arts building. The scale of Kirchhoff's map is an arbitrary one. Lines are still sometimes designated by their place on this scale; as for instance a certain line in the spectrum of the Sun's corona, which is generally known as 1474K. The wave-length of the same line is 5317.

Angström's memoir on the solar spectrum was published at Upsala in 1868. The map, extending from a little below B to K, occupies six plates, and the scale is a *normal* one. Recent researches have shown that the scale readings all need to be increased by just about one division, or tenth-metre. Angström's scale has hitherto been used as a standard in spectroscopic work. A reduced copy of the map is given in a number of text-books, as in Kayser's "Lehrbuch der Spectralanalyse" and Schellen's Spectrum Analysis".

Rutherford's fine photographic map of the normal solar spectrum from *b* to λ 3550 in the ultra-violet was published in 1875, and has been in turn surpassed by Professor Rowland's great map, showing the whole solar spectrum, from below the B line to far in the ultra-violet, on an immense scale. It is mounted on ten separate sheets, and if stretched out so as to form a continuous strip would make a solar spectrum about forty feet long.

Among other maps may be mentioned the following: a magnificently engraved map by M. Thollon, extending from below A to and including the *b* group, left incomplete by the death of the observer, published in Vol. III of the Annals of the Observatory of Nice. The scale is arbitrary; Professor Piazzi Smyth's elaborate and somewhat diagramatic maps, in the Transactions of the Royal Society of Edinburgh; Dr. Becker's map showing the spectrum of the high and of the low Sun, in the same Transactions (Vol. 36, Part I), and Mr. Frank McClean's photographic map on the same plan. Selected portions of a photographic map by Mr. George Higgs of Liverpool, showing wonderful definition, are reproduced in *Knowledge*, Sept. 1, 1890. I am not aware that the complete map has yet been published.

SUGGESTIONS TO AMATEURS, NO 2.

LEWIS SWIFT.

THE GREAT NEBULA IN ANDROMEDA.

When, some 150 years ago, a few nebulous bodies were resolved into stars by the small telescopes then in use, the opinion generally prevailed that, could glasses of sufficient size and power be brought to the work, all would be found resolvable, and, as telescopes were increased in size, and more and more showed themselves to be masses of stars, the idea seemed a not unreasonable one, though, at the same time, a great number were discovered which defied even the mammoth telescopes of Sir William Herschel, so that while but few were added to the list of resolvable nebulæ, a vastly greater number were still unresolvable and the question whether all nebulæ are really star clusters was held in abeyance. It required the invention of an optical instrument entirely unlike the telescope, viz., the spectroscope, which by analysis of their light has settled the matter in a manner both emphatic and unexpected, though it cannot here be described, being alien to the subject I have assumed to discuss.

Only about a half dozen nebulæ are visible to the naked eye. One of the brightest and largest, though by no means the nearest is the great nebula in Andromeda, commonly so called, which though telescopically a nebula is spectroscopically a star cluster, that is to say, the spectroscope shows it to be an aggregation of, probably, countless millions of suns, and yet no telescope has ever resolved it into stars. It may equal or even surpass our Milky Way in grandeur. It has two companions, one a cluster, the other a nebula, both of which are, with large telescopes, superimposed on the face of the principal, though we cannot say whether either belongs to the lucida, or if one or both are between us and it or beyond.

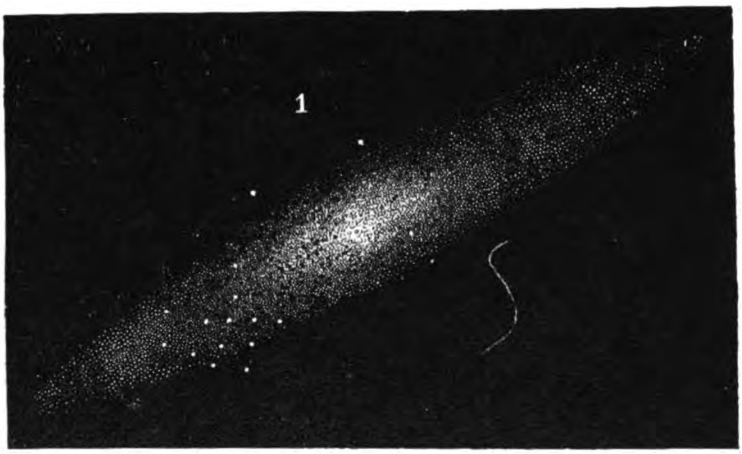


FIG. 1.

Through small and even pretty large telescopes it appears as a long, narrow ellipse of undeviating regularity, but in great instruments the elliptic symmetry is lost.

Its position is right ascension 0^h 36^m 56^s; declination north 40° 41′. It is known as No. 31 of Messier's Catalogue of 103 nebulæ, published in 1781. To the naked eye it presents no particular outline, but seems simply a hazy spot and has often been mistaken for a comet.

To find it, look at Alpha Andromedæ, the pretty bright star forming the northeast corner of the square of Pegasus. Fifteen degrees northeast is another star nearly as bright, and about five degrees north and a little west of the last named is the faint star Nu, (ν) close to which is the nebula.

Under favorable conditions of seeing, my telescope, a 16-inch

PLATE VII.

THE NEBULA IN ANDROMEDA.

Photographed by Mr. Roberts Dec. 30, 1888.

Copied from *Himmel und Erde*.

refractor, shows it extended to four degrees in length and two and one-half in breadth with little symmetry of outline, and having two dark streaks or lanes running lengthwise across its face, which latter a long exposure of the photographic plate shows to be rings, suggesting the rings of Saturn. That it is a double annular cluster seen partly edgewise is in the highest degree probable.

Fig. 1 shows it as it appears through my 4½ inch comet seeker.

Fig. 2 as seen with my 16-inch refractor.

Plate VII. (Opposite) as photographed by Mr. Roberts.

FIG. 2.

The most casual inspection shows a difference so enormous that it is difficult to believe them representations of one and the same object. Unlike most of the illustrations in astronomical text-books these are correct. How difficult it is to make lifelike drawings of nebulæ only those who have attempted their delineation know, and to argue, as has been done, change of physical contour because of dissemblance by different draughtsmen is almost absurd.

The central portion of this nebula is very bright. An examinatian of Fig. 2 will show the two companions which are within the visible boundaries.

The bright points scattered over the plate are stars or self-shining suns like our own, each doubtless, the center of a planetary system where beings like ourselves may dwell. There lies before me as I write a photograph of the nebula and its surroundings by Dr. E. E. Barnard of the Lick Observatory, where sixty-four thousand Suns are distinctly visible. It was not, as might be supposed, taken with the great telescope, but by a photographic camera of five inches aperture lashed to the declination axis of a six-inch telescope, the latter being employed simply to obtain the service of its driving-clock, and, to check the irregularities of its rate, the photographer for 4^h 18^m holding the cross wires of the telescope exactly on a selected star in order that the stars might show as sharp points rather than blurred dots. It is a grand piece of photographic work not merely, but also an example of the unwearied patience of one who but a few years ago belonged to the class I am now addressing, viz., amateur astronomers, but who by untiring energy has achieved a standing which excites the admiration of the world.

This nebula was first discovered of course by the naked eye about a thousand years ago, and as it was then, as now, an inconspicuous object to the unassisted eye, we infer that very little if any change in position or brightness has occurred. In 1885 a new star suddenly shone out from almost the exact center of its brightest portion. When it had attained its maximum brilliancy it was of nearly the sixth magnitude but in a few weeks had so declined as to require a good telescope for its viewing. I well remember on the occasion of my last quest for it, how extremely difficult it was to even glimpse it with my 16-inch glass, though but a few weeks before I had seen it on a single occasion with the naked eye, much extraneous light being shut out by a dense grove of trees. It has not reappeared since nor ever may. By what dire calamity such a torch could be suddenly lighted and so quickly extinguished is only one of the many mysteries of astronomy. And what relation, if any, the star bore to the nebula is also unknown. And though light moves at the rate of 186,300 miles per second, the event must have happened many years before the tidings of the awful disaster of a world on fire reached our planet.

Text-books declare that the late Professor Bond with the 15-inch refractor of Harvard College Observatory saw 1,500 stars on the face of the nebula. With a larger telescope I have been unable to detect so large a number, but, whether they be less or more, they appear to have no connection with the nebulous cluster, but to lie between us and it.

Sir William Herschel is said to have estimated that 100,000 years would be required for the light from the stars of this cluster to reach us, but as its distance is unknown the fallacy of such an argument is apparent, and, I doubt if the distinguished astronomer so averred. But the fact that the spectroscope emphasizes it to be a cluster, while the greatest telescope yet made cannot resolve it, certainly betokens a distance incomprehensible to finite minds.

WARNER OBSERVATORY, Rochester, N. Y.
Sept. 21, 1893.

CONSTELLATION STUDY.

WINSLOW UPTON.

III.

In the preceding article attention was called to the difficulties in learning the constellations which arise from the daily motion of the heavens. Were the stars always in the same part of the sky, it would not be a difficult matter to fix their positions so firmly in the mind that they would be recognized just as we recognize the familiar objects near our homes. But the daily rotation of the Earth on its axis prevents any such recognition, and we are obliged to learn them, if we learn them at all, in their varying positions from night to night. This difficulty is aggravated by the fact that the axis of rotation is inclined to the vertical position in which we stand when looking at the sky, so that the groups seem to turn as they move from east to west. The farther north the constellations lie, the more marked is this change. Thus Scorpio, low in the southern sky, does not change its angle with the horizon so much in moving from southeast to southwest as to render its recognition difficult, but Draco, a winding constellation high in the northern sky, is quite hard to find in its varying positions around the celestial pole. This difficulty, however; soon ceases to be troublesome if the student is persevering and systematic. He must be persevering in order to see a given group in all its positions, for this requires noting it from time to time for several months. He must also be systematic in order to learn the group not as an isolated collection of stars, but as related to neighboring groups; if he is careful in noting these relations he will find it comparatively easy to remember the groups, and he will not be much disturbed by the changes in position from night to night. He will also verify for himself the fact that the heavens turn as a whole, and that in consequence the relative positions of the configurations are unchanged, no matter in what part of the sky they are viewed.

It was suggested in the preceding article that a systematic study of the constellations could be made on the basis of the divisions of the heavens made by professional astronomers in designating the places of stars in star catalogues and charts. The advantages of this plan are sufficiently obvious to need no further discussion, and, as was pointed out, there are certain prominent stars which mark the boundaries of the several subdivisions with sufficient precision for this purpose. This is preeminently true of the stars which mark the position of the equinoctial colure, which corresponds in the celestial system to the meridian of Greenwich on the Earth as a reference circle. It will be remembered that the names *declination* and *right ascension* are used for designating star places, and not latitude and longitude to which they respectively correspond.

It is a good plan to go out into the open air and looking up at the sky imagine the surface of the sphere covered with a system of circles corresponding with those we draw upon the celestial globe. We are accustomed to view the latter from the outside, looking down upon the convex surface. In celestial observation we are within the sphere, at its very center apparently, and look up upon the concave surface of a sphere. On this concave surface imagine the system of circles drawn, corresponding exactly to those on the globe, but with only half of the system visible in the hemisphere above us. Around the north star, or more accurately the north pole, imagine a series of small circles drawn, like the parallels of latitude, larger and larger as one goes south until the horizon cuts off part of the circles imagined. When the circle passing through the east and west points of the horizon is reached, it will be exactly halved by the horizon, just half of it in the visible and half in the invisible hemisphere. It will be noticed that the planes of all these circles are inclined to the horizon because they are all perpendicular to the line joining our eyes with the pole. In consequence, the circle just mentioned, which passes through the east and west points of the sky, does not go through the zenith or point directly overhead, but crosses the meridian at a point as much south of the zenith as the pole is elevated above the north horizon (the latitude of the observer's station). This circle is the celestial equator. Continuing to imagine circles, drawn farther and farther south, it will be seen that more than half of the circles are invisible, and that the portion visible is smaller and smaller until the south point of the horizon is reached. If any difficulty is found in imagining these circles, the daily motion of the heavens will trace them for us. Simply select the Sun, the Moon or any star and look at its place occasionally for a few hours, and it will show just how the circle upon which it is placed lies in the sky. These circles are sometimes called parallels of declination, to correspond with parallels of latitude on the Earth, and sometimes, quite appropriately, diurnal circles for the reason just given.

Continuing the construction of the system of circles on the concave surface of the sphere, we now imagine an indefinite number of circles to diverge from the north pole in all possible directions, like the meridians on the Earth. They will all cross the celestial equator at right angles and then converge, all meeting at the invisible south pole of the heavens. The system is now complete; all that remains is to select one of these circles for a circle of reference—that passing through the points on the celestial equator where the Sun is at the vernal and autumnal equinoxes. This reference circle,—the equinoctial colure,—can be easily traced in the sky, as explained in the last article, by the line of bright stars α Ursæ Minoris, β Cassiopeiæ, α Andromedæ and γ Pegasi leading to the vernal equinox, and α Ursæ Minoris, δ Ursæ Majoris leading to the autumnal equinox.

The reader of these articles, who is following the suggestions made for a first study of the constellations, is advised at this point to recall the definitions of right ascension and declination, and to estimate the right ascension and declination of certain objects in the sky, for instance the planet Jupiter, the Moon, or some star which is already known, as α Lyræ. To do this, first imagine the celestial equator, and then the circle passing from the pole through the object to the equator; then estimate the distance between the equator and the object measured on this circle in degrees, calling the whole distance between the pole and the equator 90°. This is the declination. Next find the line of stars tracing the equinoctial colure, and estimate the angle between this circle and the declination circle just drawn between the pole and the object. This is the right ascension. The angle should be reckoned from the part of the equinoctial colure passing through the *vernal* equinox towards the east until the declination circle of the object is reached. For instance in the autumn evenings the line of stars marking the half of the equinoctial colure which leads to the vernal equinox is high in the sky, coinciding with the meridian at about 9:30 P. M., Nov. 1st., and 7:30 P. M., Dec. 1st. Any object in the eastern sky, as the planet Jupiter this year, has a right ascension less than 90°.

If the object is, however, in the western sky, like α Lyræ, the angle between the equinoctial colure and its declination circle reckoned towards the east will be greater than 90°, in fact greater than 180° or even 270°. A good way in such a case is to reckon backwards or westward from the equinoctial colure and then subtract the estimated angle from 360°. The Moon is an excellent object to make these estimates upon, as it will be found each night about 13° east of its position the preceding night. Its right ascension will therefore increase from night to night until it has completed the whole 360°. At the same time its declination will vary between 28° north and 28° south of the equator. It is the present custom of astronomers to give right ascension in hours, minutes and seconds, like the ordinary time division of 24^h, rather than in degrees, minutes and seconds, but both are in current use. Dividing or multiplying by 15 will evidently change the one method to the other.

There are two difficulties frequently encountered by the student which may here be discussed—that of remembering the groups after they have once been learned, and that of using star maps. The former difficulty is not peculiar to astronomical study. Some one has defined the Memory, as "the faculty by which we forget thiugs." Theorists may tell us that when we once thoroughly understand and learn anything we should never forget it; but practical experience shows that it is necessary to think occasionally upon the subject if it is to be remembered. And so with the constellations. In order to remember them it is necessary to review them occasionally. It is a good plan to form the habit of looking up at the sky frequently on starlight evenings and recall the groups, and if any are seen which are not at first recognized, to look them up upon a star map and thus restore them to their place in the mind. The more frequently this is done the better will the groups be remembered, provided they are thoroughly mastered at the outset.

The other difficulty can be overcome only by practice in the use of star maps, but it is not a serious difficulty except at first. It results from the fact that the star map is necessarily upon a flat surface and so the stars must be located on the map by some one of the various methods of projection of a spherical surface upon a plane. Besides, black stars printed upon a white paper background do not look like white stars seen upon the dark ground of the sky. Some maps have been prepared with white stars upon a blue or black surface to remedy the latter difficulty, but the result has not met with much favor, and maps are to-day usually made with black stars printed upon a whitish paper. This difficulty disappears with a little practice and soon one can readily pass from the map to the stars or from the stars to the map with facility.

There is one way in which the two difficulties just named can be further reduced and which is also an excellent aid in the first learning of the constellations. It is by making star maps one's self as the several groups are learned. This involves some labor but not so much as one might at first think, and it is a labor which in the opinion of some is well spent, for the mere act of plotting upon a page the leading stars of a group tends to fix them the more firmly in the memory, and it accustoms the learner also to the habit of locating points by their relative positions, and at the same time gives facility in using star maps. The rest of this article will therefore be given to an explanation of a method by which students' star maps may be simply constructed as an aid to learning the constellations.

In order to prepare star maps, it is necessary first to have blank maps prepared upon which the stars are to be inserted, and second to have the positions of the stars given with sufficient accuracy for the purpose of plotting them. The blank maps would better be five in number, one for each of the four divisions of the heavens made by the equinoctial and solstitial colures, and the fifth for a polar map made by taking from each of the four the part near the pole. This division is suggested by the ordinary position of the student as he views the heavens. For studying those constellations which lie between his zenith and the southern horizon he faces the south, turning occasionally towards the east or west; the west lies on his right and the east on the left. When he looks at the northern constellations, he faces the north in his average position, and in middle latitudes observes the groups which are usually known as circumpolar groups—those which do not rise and set but are always above the horizon. The polar constellations seem to him to be revolving about the pole in a direction contrary to clock hands. Makers of star maps usually have one or more maps in which the pole is at or near the centre of the map, and others for the parts of the sky lying farther away from the pole corresponding to the view of the sky when the observer faces the south. Let us now note how such maps can be constructed.

1. *The Polar Map.* This should cover that region about the pole in which the stars do not rise or set. For all middle latitudes it is sufficient to select the region which is within 45° of the pole. Select any convenient radius, for instance 6 inches, and describe a circle. Draw two diameters at right angles to each other and let them represent the equinoctial and solstitial colures. Then draw a series of smaller circles concentric with the first one drawn, to represent the parallels of declination.

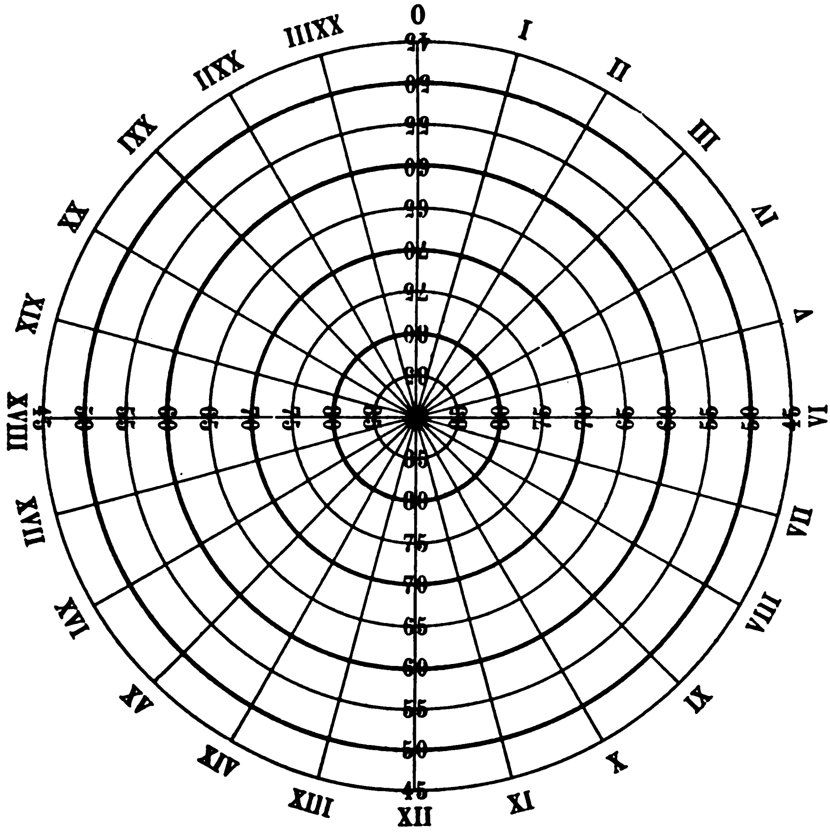


FIG. 1.

For the purpose of plotting the leading stars of the constellations it is advisable to draw these circles for every five degrees of polar distance. Their radii will then be one-ninth, two-ninths, etc., of the original radius. At their intersections with the equinoctial and solstitial colures it is well to write the degrees of declination 85°, 80° and so on to 45°. Then, other diameters should be drawn; if they are placed 15° apart they will accord with declination circles an hour apart in right ascension. They should be numbered from the diameter selected for the equinoctial colure, around the circle in the direction in which the hands of a clock move.

Fig. 1 represents a polar map thus drawn in outline. It was drawn on a scale one-half of that suggested, and has been reduced somewhat in printing. For practical use, a larger size is advisable and the suggested size of 6 inches for the length of the radius is none too large. It requires a sheet of paper somewhat more than 12 inches square. Several minor suggestions in the construction of the map may be made. Contrasts in the heaviness of the lines will make the map easier to use; thus the smaller circles at the even 10° may be made heavier than the others, and the diameters which mark the hours of right ascension may be of different strength. The two colures should be especially prominent so that the division into quarters may be conspicuous. If the size of the sheet admits, it may be well to insert circles or diameters at intervening distances, and these may be made by dotted lines. Experience will show whether the skeleton map prepared as above is more useful without or with more reference lines.

The use of such a map needs but a brief explanation. It is for the insertion of the prominent stars of the polar constellations in their proper positions. Thus a star at 65° declination and 20^h right ascension would be placed at the intersection of the 65° circle with the 20^h declination circle. A star at 73° declination and $5^h\ 40^m$ right ascension would be placed between the 70° and 75° circles and the 5^h and 6^h declination circles at the proper distances. The seven stars of the Dipper have the following positions:

	Right Ascension.		Declination
	h	m	°
α Ursæ Majoris	10	57	62.3
β " "	10	56	56.9
γ " "	11	48	54.3
δ " "	12	10	57.6
ε " "	12	49	56.5
ζ " "	13	20	55.4
η " "	13	43	49.8

When an outline polar map has been constructed, it would be a good plan to insert these stars for practice in its use.

2. *The Equatorial Map.* This map should contain for each of the four divisions of the sky the space south of the boundaries of the polar map (45° in declination if drawn as above suggested), to the limit of the visible heavens. It may be easily constructed on the plan illustrated in Fig. 2, as follows: First two lines at right angles to each other are drawn of the same length, which may well be the diameter of the polar map,—for instance twelve inches. One of these is chosen for the equator and the other for the central declination circle of the section. Parallel lines to the equator are next drawn at distances of every 5° in declination.

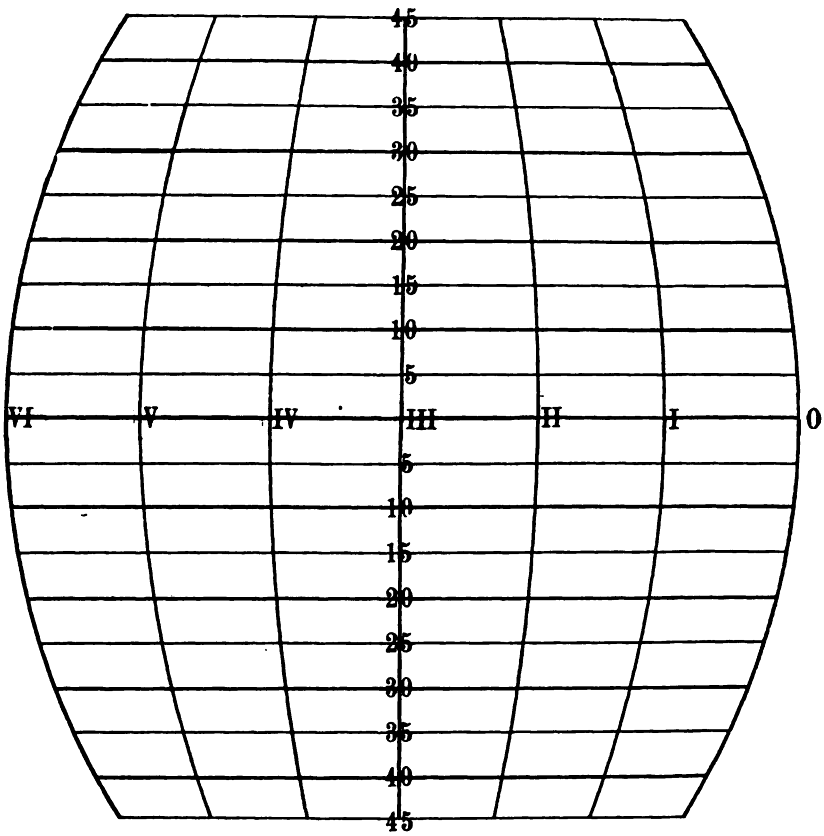


FIG. 2

Their distance apart will be the same as that of the parallels of declination of the polar map. Their length will be shorter and shorter as the distance from the equator increases, according to the values to be given below in a table. These parallels of declination are to be numbered for declinations from the equator north and south. When the lengths of the parallels of declination have been carefully laid off, the right and left boundaries of the map may be drawn by the eye. or they may be drawn by dividers, one leg placed upon the equator at a distance 1.85 times the half length of the line representing the equator. This latter construction will not pass exactly through the terminal points of the parallels of declination, but quite near enough for the purposes of the map. The right and left boundaries thus drawn represent the portions of the equinoctial and solstitial colures included within the map. Intermediate declination circles may be easily inserted; if for each hour of right ascension as in the polar map, the equator and each parallel of latitude will be divided into sixths, and the curves drawn by the eye.

Fig. 2 was drawn on the above plan with the length six inches for the two lines first drawn, and has been somewhat reduced in printing. The double size, 12 inches, is advised for practical use, corresponding with that of the polar map, and requiring paper somewhat over 12 inches square, according to the margin desired. The declination circles for the 0h, 1h, Vh and VIh were drawn with dividers as arcs of circles, those for IIh and IVh were drawn by hand through the points of intersection of the several parallels of declination, each one-third the length of the parallel from the central vertical line. The numbering of the declination circles should be from right to left as in the figure, since right ascensions are reckoned toward the east, which is at the left when the observer faces the south.

The reader familiar with trigonometry will understand that the lengths of the several parallels of declination equal the length of the line representing the portion of the equator multiplied by the cosine of the declination. The curves representing the declination circles should strictly be arcs of ellipses, but if drawn as arcs of circles the error introduced is too slight to be noticed for the purpose at hand.

It will be well to give the lengths of the several parallels of declination in the form of a table. They are calculated on the supposition that the line representing the portion of the equator included in the map is twelve inches in length, that is six inches on either side of the vertical line. One-half of the given values represents the length on either side of the vertical line, and one-sixth represents the distance between the declination circles drawn one hour apart.

Table showing the length of the lines representing the parallels of declination, their half-length, and one-sixth their length, assuming a scale of 12 inches for the equator represented:

Declination.	Length.	One-half length	One-sixth length.
°	in.	in	in
5	11.95	5.98	1.99
10	11.82	5.91	1.97
15	11.59	5.80	1.93
20	11.28	5.64	1.88
25	10.87	5.44	1.81
30	10.39	5.20	1.73
35	9.83	4.91	1.64
40	9.19	4.60	1.53
45	8.48	4.24	1.41

In the above table the fractions of an inch are expressed decimally, but if any one has an ordinary scale in which the fractions are in sixteenths of an inch, the above decimals can be turned into sixteenths before using.

The use of the equatorial map is precisely the same as that of the polar map. Four skeleton maps are to be prepared, one for each of the four divisions of the sky. If the work of preparing these outline maps seems too great, two may be made, *viz.*, the polar and one equatorial, and a test made of their advantages in constellation study before the others are drawn.

A necessary adjunct to the outline maps is a list of stars to be inserted with their right ascensions and declinations. In the following articles of this series the positions of the leading stars in each constellation will be given. In order to make the plotting of the stars aid the memory in retaining the configurations it is advisable not to plot them until the constellation group is learned, and after the leading stars are inserted by their positions, to look at the sky again; if any other stars of the group seem necessary to complete the characteristic figure of the group, these may then be inserted by their relation to those already charted.

The outline maps described above are simplified forms of two well known projections, the stereographic for the polar map and the orthographic for the equatorial map. The construction of maps on the strict principles of these projections would be too difficult and quite unnecessary for the purpose proposed. These maps do not differ materially from those used in Burritt's Geography of the Heavens—a star atlas which did much good service years ago. The projections are not of sufficient accuracy for use in a complete atlas of all stars visible to the eye, but for the purpose of aiding one in learning the groups, they are all that the student requires.

VARIABLE STARS.

J. A. PARKHURST.

There is a fascination about the observation of variable stars that makes the subject well worth the attention of the amateur. When he has once seen such a star play hide and seek with its neighbors, losing three quarters of its light in two or three hours, or perhaps passing from naked eye visibility down beyond the reach of his telescope of three or four inches aperture in a few months, he will find an interest in the subject which will give a new zest to his star studies.

There is an analogy between variable stars and planets. The planet attracts our attention by changing its place among the stars, the variable star interests us by changing the amount of light which it sends us. There are several hundred of such objects scattered over the sky, differing among themselves in many particulars. Some undergo small changes of light; others send us at their maximum more than a thousand times as much light as at their minimum. Some pass through their cycle of change in a few hours, others require more than a year.

What is the cause of these wonderful phenomena? The question has never been completely answered, though some progress has been made in the past few years. Still the question is mainly unanswered, and further knowledge must be founded upon more and careful observations. Who knows what other important facts may be brought to light when we are able to lift the veil which shrouds this mystery?

I doubt whether there is another field in astronomy which offers the amateurs so good a chance to do work which will materially increase the sum of human knowledge. The veteran astronomer, Dr. B. A. Gould, says of variable stars, "The attractiveness and interest of these objects are great, our knowledge of them is limited, observations of them are comparatively easy, while the field for discovery is evidently very large."

Some of these stars may be observed with the naked eye, as Algol and Mira near its maximum. Many more only require an opera or a field glass, while a three-inch telescope will suffice for observing the maxima of nearly all the known variables and will follow many of them through their whole period.

To quote Professor E. C. Pickering, "Those who have not tried it do not realize the growing interest in a systematic research, and the satisfaction in feeling that by one's own labors the sum of human knowledge has been increased."

I shall try in this series of papers to interest amateurs by giving general descriptions of the various classes of variables and to help those who wish to take up the work by giving methods of observing, recording and reducing the observations, ways of avoiding errors, and, as far as possible, answers to questions which may arise in the course of the work. Aids to identifying the variable will also be given and lists of stars selected suited to the capacity of the instruments which the observers possess. I make no claim to originality in the subject matter but only seek to gather and arrange the information needed by the amateur.

The best classification of variable stars seems to be that of Professor E. C. Pickering of Harvard College Observatory. It is as follows:

"I. Temporary stars. Examples: Tycho Brahe's star (in Cassiopeia) of 1572, new star in Corona 1866, [also the new star in Auriga of 1892].

"II. Stars undergoing great variations in light in periods of several months or years. Examples: o Ceti (Mira) and χ Cygni.

"III. Stars undergoing slight changes according to laws as yet unknown. Examples: α Orionis and α Cassiopeiæ.

"IV. Stars whose light is continually changing, but the changes are repeated with great regularity in a period not exceeding a few days. Examples: β Lyræ and δ Cephei.

"V. Stars which every few days undergo for a few hours a remarkable diminution of light, this phenomenon recurring with great regularity. Examples: β Persei (Algol) and S Cancri."

It will be noticed that there are three points of difference in the above classification:

1st. Length of period.

2nd. Amount of variation.

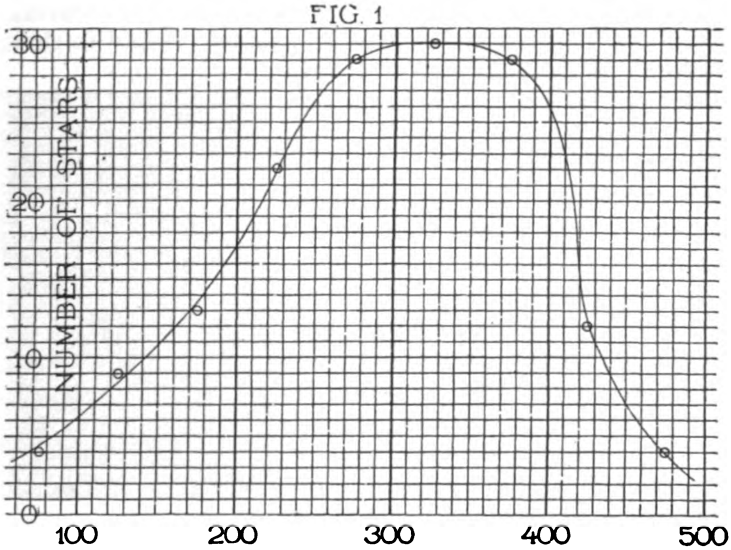
3rd. Character of light curves.

Stars of the class I, temporary stars, are comparatively rare, but often astonishing in the rapidity of their changes. They appear unexpectedly, attain their greatest brilliancy quickly, and fade away slowly. Tycho Brahe's star was the brightest example, being visible at noonday. The new star in Auriga of 1892, has, very naturally, been the most carefully observed, its image being found impressed on photographic plates taken at Harvard College Observatory in December, 1891, about two months before its discovery was announced by Anderson. This star is now

(Oct. 10th, 1893) about the 10th magnitude having remained nearly stationary in light since August, 1892.

No stars of this class have been known to become visible to the naked eye for the second time, so that if they are periodic variables, their periods are very long or very irregular: but there is a wonderful variable, U Geminorum, which seems to form a connecting link between the first and second classes. This star usually is about the 13th magnitude, but occasionally rises in a day or two to the 9th magnitude and then falls more slowly to its original dimness. It repeats these curious antics in irregular periods, averaging about three months. This leads us to think that the "temporary stars" may be doing the same thing on a larger scale and with longer periods. The readers of POPULAR ASTRONOMY will do well to keep watch of these stars. Directions for finding them will be given in a subsequent paper.

FIG. 1



A large part of the variables whose periods are known belong to class II. Dr. S. C. Chandler's Second Catalogue of Variable Stars (*Astronomical Journal*, No. 300), gives 260 known variables. Of this number 155 have periods of more than 50 days, and only 36 less than 50 days, or 81% of the variables of known period belong to class II. The attention of amateurs is especially called to this class of stars, since observations of them are beset with less difficulty than those of classes III, IV and V, while they are more interesting than class I. The length of period of stars of this class varies from 50 days to about 2 years, but the periods are by no means evenly distributed over this interval, the greatest number having periods of a little less than a year. Fig. 1 will represent this distribution to the eye. The periods were divided into groups of from 50 to 100 days, 100 to 150, etc., and a count was made of the number of stars in each group. The horizontal line represents period in days, the vertical line the proportional number of stars.

The range in brightness between the maxima and minima of these stars differs widely, but on the average they are about five magnitudes brighter at maximum than at minimum. This means that at their brightest they send us 100 times as much light as at their faintest. (What if our Sun should act in that way!) But a much greater range is not uncommon, for instance χ Cygni is at some times 7,000 times as bright as at others.

Classes III and IV have less interest for amateurs on account of the difficulties attending their observation, but class V, the "Algol stars," arrests our attention at once. Algol itself is the best example of the class and a description will be of interest. It is in the constellation Perseus which will be found high in the northeast at 9 o'clock on November evenings. The accompanying sketch, Fig. 2, will enable the beginner to identify it. The stars are of the 2d and 3rd magnitudes. Face the northeast and hold the sketch nearly overhead, with the arrow in the direction of the North Star. The distance between the star marked α and Algol is about 10°, (twice the distance apart of the "Pointers"). A table headed "Minima of Variable Stars of the Algol Type" given in each number of Popular Astronomy. From this table we learn that a minimum of Algol will occur about 11 P. M. Nov. 22d, and 8 P. M. Nov. 25th. Let us begin our observations on one of these evenings three or four hours before the time indicated. We will find Algol nearly as bright as α, and much brighter than δ or ρ. As the evening passes on we will find Algol fainter till it finally is less than δ and not much brighter than ρ. As the hour for the minimum passes it will grow brighter till it attains its usual magnitude three or four hours after the indicated time. For the rest of the 2 days and 20 hours its light remains unchanged. No wonder such strange behavior gave it

the name Algol, the demon. It was long ago surmised, and the spectroscope has lately proved that this diminution of light is caused by partial eclipses of the principal star by a close, darker companion, the two revolving around their common center of gravity in 2 days, 20 hours, 49 minutes.

Any amateur who once observes a minimum of Algol will want to do more in this interesting field. To aid in this work I will give in my next paper the means used for designating the variables, the methods of observing and recording the observations, and helps to identify the stars.

Let any reader who wishes to engage in this work communicate with me either directly or through the editor, giving description of the instruments he possesses, and what experience he has had with them, also what star-charts or catalogues he has, and telling whether he can find an object whose right ascension and declination are given.

MARENGO OBSERVATORY, Marengo, Ill.,
1893, Oct. 20.

THE DISTANCES OF THE STARS.

WM. W. PAYNE.

When any person untaught in astronomy is told that the many stars he sees, on any clear and moonless night, are suns, like our own, scattered through space, the next question likely to be asked is, How far are the stars away? Though scholars have thought on this question for centuries, astronomy cannot answer it very well, chiefly because the instruments now in use are too coarse to make the measures needed to determine accurately the very small quantities that enter into the computation of the star distances. This is not so in regard to the dimensions of the solar system; great as they are, the distances of the planets from the Sun are known quite accurately, even in terrestrial units, as miles, and our knowledge extends to much in detail about their sizes, masses, densities and other physical qualities; but when we try to sound the star depths of the universe far beyond the planet realm, with any measuring line now known to science, the task at once becomes enormously great. It will however be profitable to give a brief outline of the efforts that have been put forth to solve it, in order to know how hard the problem is, and to learn what views astronomers now hold in regard to the distances of the stars.

As early as 1610 Tycho Brahe refused to accept the Copernican theory because, with fine instruments, he could not observe an annual change in the relative places of the stars which should appear if that theory was true. He thought his measures were correct to a third of a second of arc, but we now know that his probable error in star places was nearly 200 times greater than he supposed. He reasoned well, but his instruments misled him.

Galileo favored the Copernican theory and suggested the observation of stars near together to decide whether or not relative change of places do occur annually. But Sir William Herschel, whose astronomical work was done between the years 1768 and 1822, was the first to give anything like a rational idea of the extent of the starry universe. The question of its magnitude seemed to be almost constantly in his mind, and it is certain that he tried all means of observation he knew most assiduously to obtain some direct answer to it, but without success. Failing in his favorite way of study, he sought to gain some general idea of the scale on which the universe is built by indirect reasoning. An example of this is, his use of the law of distance as related to stellar brightness. He knew that if any one of the brightest stars were removed from us into space ten times its present distance, it would barely be seen by the naked eye. If the same star were removed 100 times as far away as at first, it could still be seen in a small telescope; but if carried 1,000 times its original distance, then only the great telescopes of the world could reach it, because so far away and so very faint. From such facts as these Herschel reasoned that the brightest stars as a *class* are nearer to us, and that the fainter stars as a *class* are farther away, and that these faint stars may be 1,000 times more distant than the bright ones called the first magnitude. While this asssumption of distance and varying brightness is reasonable for classes of stars, Herschel knew that it would not necessarily hold good when applied to single stars, for, if true, it would follow that all stars must be equal in size, or light-giving power, or both, and such knowledge no one could then affirm. This was as far as indirect reasoning would lead one of the most able and earnest thinkers of his times, and so the problem of individual star distances remained unsolved for many years after his death.

About the year 1839 the distinguished Bessel turned his attention to the problem of stellar distances, by the aid of a new instrument called the heliometer which was designed to measure very small angles. This instrument differs from an ordinary telescope in having its object-glass cut into halves, and so arranged in the tube that one-half is fixed and the other has motion in a line perpendicular to the axis of the telescope. By this device* and the apparatus connected with it, the observer can measure very accurately the distance between two stars in the same field of view in the telescope. It is to Bessel that we are to give the imperishable honor of first proving unmistakably that the distance of a star is a measurable quantity. The manner in which this result was secured, as well as a description of some other later methods will be given, soon, in an illustrated article concerning distance and parallax.†

We are now more concerned in trying to show just what has been done during the present century in finding the distances of the stars. For this purpose we have copied portions of a drawing which accompanies an excellent article by Mr. A. C. Ranyard "On the Distances of the Fixed Stars," found in *Knowledge* (English) for February, 1890. We have omitted from the plate (which is the frontispiece to this number), the names of the observers, dates, and parallaxes obtained by each, and reduced the original about one-half, our object being to show, at a glance, nearly all the stars whose parallaxes have been studied during the present century, and to indicate their distances from the Sun and the degree of certainty of present knowledge concerning the same.

Our Sun is supposed to be in the center of the figure. One-tenth of the distance from the center to the circumference in any direction represents the distance of stars whose parallax is one second of arc; two-tenths, stars having a parallax of half a second, and so on. For stars on the circumference the distance would correspond to a parallax of one-tenth of a second, and, in some cases, to what is called *negative* parallax, which is about equivalent to saying that the observer's work in such cases was unsatisfactory. If a star has a parallax of one second of arc (none known is so great as that) its distance is ~~60,000~~ times as great as that of the Earth from the Sun, or nearly ~~6 millions~~ of miles. It would take light traveling at the rate of 186,000 miles per second 3.26 years to reach us from a star at such a distance. A convenient unit of measure for star distances is the light-year, or the distance that light travels in one year, and this mode of estimate is now commonly used. From statements already made, it is easy for any one to find the distance of any star in light-years on the plate, by the following simple formula:

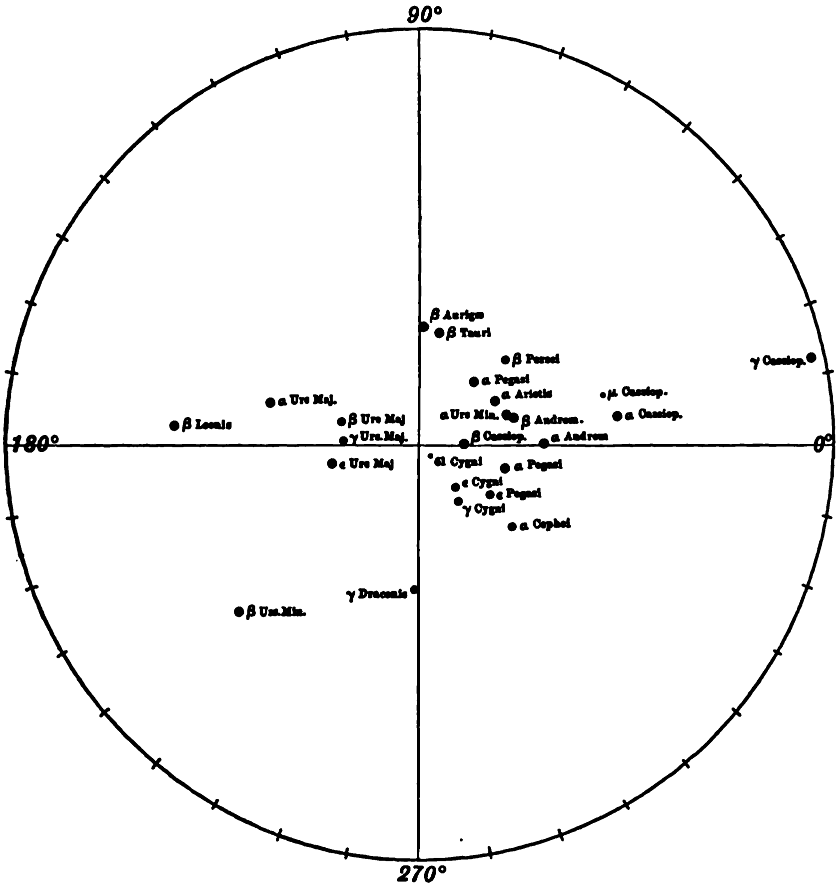
* An illustration of the divided glass, and a description of the way it is used may be found in *Young's General Astronomy*, ~~page~~ 677.

† *Young's General Astronomy*, page 461.

$$\text{Light-years} = \frac{3.26}{p''},$$

p meaning the parallax in seconds of arc. If the star is on the circumference of the circle,

$$\text{Light-years} = \frac{3.26}{0''.1} = 32.6.$$



DISTANCES OF 29 STARS OBTAINED BY THE AID OF PHOTOGRAPHY BY PROFESSOR PRITCHARD.

The following table will be plain if we say the first column is tenths of distance from the center to the circumference, second column is parallax corresponding to adjacent tenths of radius, and last column is light-years:

Tenths.	p''	L.-Y.	Tenths.	p''	L.-Y.
.1	1.00	3.26	.6	0.16	19.56
.2	0.50	6.52	.7	0.14	22.82
.3	0.33	9.78	.8	0.12	26.08
.4	0.25	13 04	.9	0.11	29.34
.5	0.20	16.30	1.0	0.10	32.60

If this table were extended to include faint stars, the remote ones are probably so far away that the journey of their light in reaching us would require many thousands of years.

Another impressive feature of the plate, of a different kind, is the *uncertainty* of our knowledge of the distances of the stars represented. This is shown by the varying lengths of the radial lines drawn through the stars. These lines are intended to connect points which represent respectively the different distances found by different observers. The places given to the stars on the radial lines are the most probable mean values of all the observations.*

The uncertainty in value in these results arises in part from the fact that observers are trying to measure quantities smaller than they can see. Professor Young's illustration is an apt one. Suppose Polaris has a parallax of 0''.08, with an error of observation amounting to $\frac{1}{50}$ of a second (which is a favorable assumption for the observer), that error would be one-fourth of the whole value, and to determine it would be like trying to measure $\frac{1}{16}$ of an inch at a distance of ten miles. Such an attempt by any methods of measurement now known to us would be next to impossible. This point will be enlarged upon in the paper to follow already referred to.

The accompanying figure is an illustration of the distance of 29 stars obtained by the aid of photography by the late Rev. Chas. Pritchard at Oxford University Observatory, England, during the years 1887—1890, and published in the *Vierteljahrsschrift der Astronomischen Gesellschaft* (German), 1893, p. 117. This is some of the latest published work we know of by this method. The figure is on the same plan as that of the frontispiece and the distances of its stars may be determined in the same way.

JUPITER AT OPPOSITION. A NAKED-EYE STUDY.

ELIZA A. BOWEN.

The opposition of Jupiter or Saturn gives an opportunity to make our acquaintance with a superior planet's motions a genuine study of nature. It is important to teachers to know how this may be done, but also to all persons who have only a book knowledge of astronomy.

* For the right ascension, declination, parallax, dates, instruments, observers, etc., of all these stars, amounting in all to over 70, see a useful table by Mr. Herbert Sadler, *Knowledge*, February, 1890, page 63.

The opposition of Jupiter comes on November 18, 1893, and I propose in this paper to give a plan for observation study.

The "opposition" of Jupiter means that Jupiter and the Sun are seen by us against opposite points of the heavens, points 180° apart on the celestial sphere, and the proper object of the observer is first to have as much testimony of his own eyes as is possible, to the truth of this statement. Both the Earth and Jupiter are moving, and the exact instant of opposition does not come at sunset, but the movement is so slow that the situation is little altered for a day or two to an observer without measuring instruments. At sunset we can see the point of the celestial horizon 180° from the Sun, and Jupiter is just above it, and very soon, as light lessens, we see Jupiter against, or in, the constellation Taurus.

The observer should answer the following questions:

Did the Sun set north or south of the west point of the horizon? How many degrees separate the east and west points of the horizon? If the Sun has set south of the west point, would a point 180° from the Sun at sunset be north or south of the east point of the horizon? Is Jupiter north of the east point? Does what you see go to confirm or to disprove the statement that Jupiter is 180° from the Sun? Do the three bodies, the Sun, the Earth and Jupiter appear to be in a straight line? Which is in the middle? Which is nearer to the Sun, the Earth, or Jupiter?

The Earth is not exactly on a straight line extending through the centres of the Sun and Jupiter, but is only so near it that we say practically that the Earth at opposition crosses the line between Jupiter and the Sun. A line through the centres of Earth and Sun would, if extended, pass through the circle of the ecliptic on the celestial sphere. It is easy to see that Jupiter is not on that circle, but very near it.

At midnight the observer can again test the statement that the Earth is crossing a line between the centres of Jupiter and the Sun. He should answer these questions:

Is the Sun now north or south of the Earth's equator? When the Sun is on the meridian below the horizon, would a point of that meridian 180° from the Sun be north or south of the Earth's equator and the equator of the heavens? Does Jupiter appear to be in that position?

Our knowledge of the chief motion of Jupiter is based on seeing the planet when we cross the line between it and the Sun. I will show how it leads us to certain conclusions. What I say will be worthless unless it is followed step by step by observation.

It is now desirable for the observer to go out again at sunset, and as the situation changes so slowly, the evening of November 19 will do.

There appears to be a great sphere or dome above us and the Sun seems to be on one side of it, but this is merely the result of perspective, and we must try to get rid of this idea. We must think of the Sun as being the centre of the heavens (for us). The stars on all sides of the Sun are at an immense distance from him.

At every sunset, the path which the Earth has traveled for the previous six months in revolving round the Sun, lies in the space above us. In November, the Sun at sunset lies southwest of us, and if we imagine a line beginning far southwest of the Sun and coming in a great semi-circle northwest of the Sun and passing down through the centre of the Earth, it would represent, with sufficient accuracy for our purpose, the path which the Earth's centre has traveled for six months. Last May, the Earth was on the southwestern end of that semi-circle, and during last June, July, August, September, October, she has traveled northeast round that path, and now she has brought us to the northeast end of the semi-circle.

This path could be more definitely represented if we could see the stars at sunset, but they are there. Scorpio is southwest of the Sun on the celestial horizon, but far beyond the Sun. Coming northeast, there are Sagittarius, Capricornus, Aquarius, Pisces, Aries, and finally Taurus, which lies northeast of us.

The student must now stop until dark, and just as soon as the stars come out, look at these constellations. Taurus is now above, not on, the horizon, and the Sun and Scorpio are below the western horizon but the change is not great. The line across the base of that semi-circle is, on the west, inclined a very little downward, but you can imagine it.

Let us add that every year, from May to November, the Earth's centre travels round this semi-circle. The corresponding semi-circle, which is the Earth's path from November to May, lies below the horizon at sunset.

If the reader has this semi-circle round the Sun well fixed in his imagination when, just at dark, he looks at Jupiter and the stars, he is prepared to understand some facts that I will describe, seen by myself and other eyewitnessesss when the Earth was traveling eastward on that path in the years 1888, 1889, 1890, 1891, 1892.

In May, 1888, the Earth was on the other side of the Sun, beginning her six months' journey round that semi-circle, and on May 22, she crossed the line joining Jupiter and the Sun, and I and all other eyewitnesses saw Jupiter in Scorpio, just as you now see the planet in Taurus. Jupiter was then as now on our right when we face north, for we have unconsciously been turned upside down since then, in consequence of the Earth's revolution round the Sun. After crossing that line, the Earth continued her journey round the semi-circle and, finally, round the other semi-circle now below the horizon.

Finally in May, 1889, she again began to travel round the semi-circle now above us and on June 25, 1889, the Earth again crossed a line extending from Jupiter to the Sun and I and the other eyewitnesses saw Jupiter in the constellation Sagittarius. Then the Earth continued her journey round the Sun.

Again in May, 1890, she entered on the semi-circle above us and on July 30, 1890, she again crossed a line extending from Jupiter to the Sun. I and the other eyewitnesses saw Jupiter near the western boundary of Aquarius. After that the Earth made another revolution round the Sun on these semi-circles.

Next, in May, 1891, the Earth began her journey on the semi-circle above us and as she traveled round, on September 5, she crossed a line joining the centres of Jupiter and the Sun. We then saw Jupiter in Pisces. After that, the Earth completed her revolution round the Sun.

In May, 1892, the Earth again began her path round the semi-circle above us, and on October 12, 1892, she crossed a line extending from Jupiter to the Sun. I and other eyewitnesses saw Jupiter in or against Aries. Then the Earth finished her revolution.

Finally, last May, the Earth began her last journey round the semi-circle (until 1894) and as you know, and can partly see for yourself, on November 18, the Earth again crosses a line extending from Jupiter to the Sun. This is six years and nearly six months since I saw Jupiter in Scorpio at the planet's opposition of 1888. This sixth revolution of the Earth will not be completed until next May.*

It is only when we are crossing the line between Jupiter and the Sun, that we see the planet where it would be seen by an observer at the Sun. Point in succession to all the constellations named, and answer the following questions:

If Jupiter was seen successively against, or in. those star groups, would a motion of Jupiter account for those changes of position? Does Jupiter move on a curved or a straight line? Does Jupiter move eastward or westward? Do Jupiter and the Earth move in the same or in contrary directions? Around what centre does Jupiter revolve? Is the path or orbit of Jupiter within or without the Earth's orbit? How long does it take the Earth to travel round this semi-circle? How long has it taken Jupiter? The Earth on November 18 is crossing a line extending from the Sun through Jupiter to Taurus. can you (roughly) estimate how long it will take Jupiter to revolve round the Sun and again reach the line it is on at the precise moment of opposition? This is a sidereal revolution of Jupiter. What fraction of a sidereal revolution has Jupiter made since May 22, 1888? How many oppositions have been seen since? From one opposition to the next is called a synodical period. How many synodical periods (or revolutions) have taken place while Jupiter has revolved half way round the Sun?

---

* Perhaps some teachers will think that a diagram would aid in making this clear. For a teacher who gives an oral lesson on it, pointing to the constellations and revolving the finger in a circle, there will be no need whatever of a diagram to make it clear. If students see a diagram first they will always, whenever they think of the subject, see with their "mind's eye" a diagram and not objects in nature.

Of course the Earth's path is an ellipse, not a circle; but it is an ellipse which cannot be distinguished from a circle except by accurate measurement. The imagination of ordinary students more easily represents a semi-circle in nature than half of an ellipse.

TO BE CONTINUED.

THE FACE OF THE SKY.

CHARLOTTE R. WILLARD

The present season affords sights of rare beauty to the naked-eye observer of the heavens. As soon as twilight comes on Venus is seen in the west, while Jupiter is well up in the east; because of their surpassing brilliancy these two planets are unmistakable. To one unfamiliar with the heavens, this is perhaps the best time of year for beginning study, as the evenings are now long and the most striking constellations of the northern hemisphere pass before us between the hours of seven and ten. Much can be gained by any one who without chart or guide will observe the stars and their varying positions during the hours named—perhaps such unaided work is the best possible preparation for the later use of charts and other helps.

We will make a brief statement of the heavens as they will appear in our latitude (44° N.) on the evening of December first.

Facing the north the Big Dipper is seen with its base no longer parallel to the horizon, but having moved so far in its progress around the pole that the extreme star in the handle is now near the horizon. Cassiopeia is seen just crossing the meridian and only fifteen degrees from the zenith; while the Little Dipper lies between these two constellations and to the west, having its bowl perpendicular to the horizon. Two first magnitude stars are visible in the west; the more northern of these is Vega which locates for us Lyra; the other star is Altair (α Aquilæ). Southeast of Vega is a noticeable group of four stars which mark the constellation Cygnus: these stars are so situated that they make a nearly isosceles triangle, having three stars in the base; the central star of the base (γ Cygni) is about twenty-five degrees from Vega; if the line from the star at the vertex (α) through γ be continued for about twenty degrees, β is found; this star marks the head of Cygnus. High in the heavens is the great Square of Pegasus. The Great Nebula of Andromeda is just past the meridian and very near the zenith. To the east we find the familiar group Pleiades followed by the Hyades (a V-shaped group of five stars including the red first magnitude star Aldebaran). Still farther to the east and only a little above the horizon is Orion; much farther north and rising at the same time with Orion is the zodiac constellation Gemini clearly marked by the two bright stars Castor and Pollux; Castor rises first, the two are about four and a half degrees apart. The first magnitude star Capella makes a nearly equilateral triangle with Pollux and Betelgeuse (the most northern first magnitude star of Orion).

The evening of December first will be free from moon light and if perfectly clear will show much of interest in the Milky Way, although the presence of Jupiter's light will be a disadvantage. At first glance there may seem to be little to notice in this cloud-like path across the sky; but when the eye becomes accustomed to the dim light, marvelous changes are wrought in its appearance. Its apparent extent increases as one is able to detect the fainter parts; the study of its position on the celestial sphere becomes most interesting; a division is noticed from Cygnus down to the western horizon; a question arises as to the relative number of naked-eye stars in the Milky Way and in the rest of the heavens; the parts are seen to differ much in brightness, possibly suggesting that we are nearer to some parts than to others; details at first unsuspected are seen as the eye becomes more sensitive and can detect "the fringes, rifts, vacuities, rings, sprays and streams of stars" in countless variety; the dark, seemingly starless vacuities excite wonder and conjecture; the borderland of the Milky Way suggests much.

Probably the best drawings ever made of the Milky Way as a whole, are those of Dr. Boeddicker. In preparing his maps Dr. Boeddicker took his observations while lying on the ground under the open heavens; after careful study of a section, the drawings were made from memory.

An opera-glass adds greatly to the interest of Milky Way study: it resolves much that is cloud-like to the naked eye, into multitudes of clearly shining stars.

We will briefly state some of the conclusions which have been reached from a study of the Milky Way.

It covers more than one-tenth of the visible heavens.

The central line of the Milky Way differs very little from a great circle of the celestial sphere—a fact which leads to the conclusion that whatever this great band may be, whatever its wonderful structure and relation to the rest of the universe, our Earth must be in or close to its central plane.

The stars visible to the naked eye are more numerous on the Milky Way than elsewhere. "The Milky Way is made up almost wholly of small stars from the eighth magnitude down. It contains also a large number of star clusters but very few true nebulæ."—Professor C. A. Young. Professor Pickering's spectroscopic work seems to indicate that the Milky Way forms a system separate from the rest of the siderial Universe.

"There can at least be very little doubt that galactic stars are in general fully the equal of our Sun in real lustre."—Agnes Clerke.

"What is unmistakable is that the entire formation whether single or compound, is no isolated phenomenon. All the contents of the firmament are arranged with reference to it. It is a large part of a larger scheme exceeding the compass of finite minds to grasp in its entirety."—Agnes Clerke.

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be morning planet during December and will be visible to the unaided eye during the middle of the month. One must look toward the southeast about an hour before sunrise in order to see it. Mercury will be at greatest elongation, west from the Sun 21° 23′, Dec. 14 at noon.

Venus will be evening planet during December setting in the southwest between seven and eight P. M. Although so brilliant to the eye it will not, on account of its low altitude, be in good position for telescopic observation in northern latitudes. Venus will be at greatest elongation, east from the Sun 47° 29′, Dec. 6 at 3^h 36^m P. M. In the southern hemisphere this will be a very favorable opportunity to study the surface markings of Venus and it is to be hoped that Professor W. H. Pickering and his assistants at Arequipa will be able to add much to our knowledge of this subject and of the rotation of the planet.

Mars will be morning planet, but is getting farther south all the time so that its position will be unfavorable for northern observers. In the southern hemisphere the conditions will be much better. There will be quite a close conjunction of *Mars* and *Uranus* Dec. 6 at 4^h 09^m central time, when the former will be only 8′ north of the latter. Observers in Australia and Japan should be able to see the two planets in the same field of view of the telescope. The ruddy color of Mars and the green hue of Uranus will present a striking contrast. Eighteen hours later Mars will pass close to the wide double star α Libræ, the components of which Webb puts as third magnitude, pale yellow, and sixth magnitude light grey. Mars will pass 11′ north of the brighter star.

Jupiter, having but just passed opposition, will be in excellent position for observation during December. We have had a few good views of the planet this year when much of fine detail was seen upon the surface, notably a large number of very small dark red spots. The "great red spot" was seen by us with the 16-inch telescope on the night of Oct. 31. Its center was on the central meridian of Jupiter at 11^h 31^m, central time, as near as we could estimate. This time agrees closely with that predicted by Mr. Marth. The spot was seen without difficulty although the color was quite faint. The color was exactly the same as that of the belt just to the south of it and the two objects merged into one another without the slightest change in intensity of color. The outline of the spot seems to be the same as in past years, except as stated above, that its southern edge is merged into the belt. There seemed to be two white clouds over the central portions of the spot, the following of the two being the larger. We give among the tables in this number a portion of Marth's ephemeris of the spot so that our readers may know just when it may be seen. The apparent diameter of Jupiter during December diminishes from 46″ to 44″. His brilliancy will be greater than that of any other object in the evening sky, excepting the Moon, so that none can mistake him. His course is slowly westward in Taurus.

Saturn will be visible in the morning, but at a low altitude, so that for northern observers there will be no satisfactory observations. Saturn is in the constellation Virgo just a little north and east of the star Spica. The planet is the brighter of the two. The rings of Saturn are pretty well opened now, the angle of their plane to the line of sight being now about 12°, and increasing to 14° at the end of December. Saturn and the Moon will be in conjunction Dec. 3 at 3^h 20^m P. M. and Dec. 31 at 1^h 41^m A. M. Saturn will be about 3° north of the Moon in both instances.

Uranus is in Libra very close to the star α, referred to above in the note on Mars. At 5^h 32^m on the morning of Dec. 16, Uranus will be in conjunction with the star, only 3′ north. The conjunction with Mars has already been mentioned.

Neptune will be at opposition Dec. 3 and therefore in best position for observation during December. Its motion during the month will be 53′ west and 6′ south. The position Dec. 1 will be one third of the distance on a straight line from ι to ϵ Tauri. A photograph taken at Goodsell Observatory, Oct. 18, shows no star as bright as Neptune within 1° of this position.

Planet Tables for December.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
1893.	h m	° ′	h m	h m	h m
			MERCURY.		
Dec. 5	15 40.2	−16 47	5 47 A. M.	10 41.3 A. M.	3 36 P. M.
15	16 04.5	−18 38	5 40 "	10 26.3 "	3 13 "
25	16 56.8	−21 50	6 08 "	10 39.1 "	3 10 "
			VENUS		
Dec. 5	20 16.5	−22 24	10 48 A. M.	3 17.0 P. M.	7 46 P. M.
15	20 56.8	−19 20	10 35 "	3 17.7 "	8 01 "
25	21 31.5	−15 47	10 14 "	3 13.0 "	8 12 "
			MARS.		
Dec. 5	14 39.7	−15 00	4 38 A. M.	9 41.0 A. M.	2 44 P. M.
15	15 06.1	−17 01	4 34 "	9 28.2 "	2 22 "
25	15 33.4	−18 50	4 31 "	9 16.1 "	2 01 "
			JUPITER.		
Dec. 5	3 27.8	+17 46	3 10 P. M.	10 27.0 P. M.	5 44 A. M.
15	3 23 4	+17 32	2 27 "	9 43.3 "	4 59 "
25	3 19.9	+17 22	1 45 "	9 00.6 "	4 16 "
			SATURN.		
Dec. 5	13 25.9	− 6 30	2 50 A. M.	8 27.4 A. M.	2 05 P. M.
15	13 29.1	− 6 47	2 15 "	7 51.4 "	1 28 "
25	13 31.8	− 7 11	1 39 "	7 14.8 "	12 50 "
			URANUS.		
Dec. 5	14 42.7	−15 22	4 43 A. M.	9 44.1 A. M.	2 45 P M.
15	14 44.8	−15 32	4 07 "	9 06.8 "	2 07 "
25	14 46.7	−15 40	3 30 "	8 29.5 "	1 29 "
			NEPTUNE.		
Dec. 5	4 43.2	+20 42	4 11 P. M.	11 42.2 P. M.	7 13 A. M.
15	4 42.0	+20 40	3 31 "	11 01.7 "	6 32 "
25	4 40.9	+20 38	2 51 "	10 21.3 "	5 52 "
			THE SUN.		
Dec. 5	16 50.1	−22 29	7 23 A. M.	11 51.0 A. M.	4 19 P. M.
15	17 34.1	−23 19	7 32 "	11 55.6 "	4 20 "
25	18 18.5	−23 23	7 37 "	12 00.6 "	4 24 "

Phases and Aspects of the Moon.

		d	*Central Time.* h m
New Moon	Dec.	8	1 40 A. M.
Apogee	"	9	5 24 A. M.
First Quarter	"	16	4 21 A. M.
Perigee	"	22	9 18 P. M.
Full Moon	"	22	10 37 P. M.
Last Quarter	"	29	5 18 P. M.

Phenomena of Jupiter's Satellites.

	h m			
Dec. 2	1 48	A. M.	III	Oc. Dis.
	4 46	"	III	Ec. Re.
4	1 34	"	II	Tr. In.
	2 20	"	II	Sh. In.
	3 51	"	II	Tr. Eg.
	4 20	"	I	Tr. In.
	4 41	"	II	Sh. Eg.
	4 44	"	I	Sh. In.
5	1 31	"	I	Oc. Dis.
	4 07	"	I	Ec. Re.
	3 37	P. M.	III	Tr. In.
	5 06	"	III	Tr. Eg.
	5 17	"	III	Sh. In.
	7 06	"	III	Sh. Eg.
	8 15	"	II	Oc. Dis.
	10 46	"	I	Tr. In.
	11 13	"	I	Sh. In.
	11 25	"	II	Ec. Re.
6	12 57	A. M.	I	Tr. Eg.
	1 25	"	I	Sh. Eg.
	7 57	P. M.	I	Oc. Dis.
	10 36	"	I	Ec. Re.
7	3 39	"	II	Sh. In.
	5 00	"	II	Tr. Eg.
	5 12	"	I	Tr. In.
	5 41	"	I	Sh. In.
	6 00	"	II	Sh. Eg.
	7 23	"	I	Tr. Eg.
	7 54	"	I	Sh. Eg.
8	5 05	"	I	Ec. Re.
11	3 51	A. M.	II	Tr. In.
	4 58	"	II	Sh. In.
12	3 16	"	I	Oc. Dis.
	6 55	P. M.	III	Tr. In.
	8 28	"	III	Tr. Eg.
	9 18	"	III	Sh. In.
	10 30	"	II	Oc. Dis.
	11 07	"	III	Sh. Eg.
13	12 31	A. M.	I	Tr. In.
	1 08	"	I	Sh. In.
	2 00	"	II	Ec. Re.
	2 42	"	I	Tr. Eg.
	3 20	"	I	Sh. Eg.
	9 42	P. M.	I	Oc. Dis.
14	12 31	A. M.	I	Ec. Re.
	5 00	P. M.	II	Tr. In.
	6 18	"	II	Sh. In.
	6 57	"	I	Tr. In.
	7 18	"	II	Tr. Eg.
	7 37	"	I	Sh. In.
	8 39	"	II	Sh. Eg.
	9 09	"	I	Tr. Eg.
	9 49	"	I	Sh. Eg.
15	4 09	"	I	Oc. Dis.
	7 00	"	I	Ec. Re.
Dec. 16	3 18	P. M.	II	Ec. Re.
	3 35	"	I	Tr. Eg.
	4 18	"	I	Sh. Eg.
19	10 26	"	III	Tr. In.
	11 53	"	III	Tr. Eg.
20	12 46	A. M.	II	Oc. Dis.
	1 18	"	III	Sh. In.
	2 16	"	I	Tr. In.
	3 03	"	I	Sh. In.
	3 08	"	III	Sh. Eg.
	11 29	P. M.	I	Oc. Dis.
21	2 27	A. M.	I	Ec. Re.
	7 21	P. M.	II	Tr. In.
	8 43	"	I	Tr. In.
	8 56	"	II	Sh. In.
	9 31	"	I	Sh. In.
	9 41	"	II	Tr. Eg.
	10 55	"	I	Tr. Eg.
	11 17	"	II	Sh. Eg.
	11 44	"	I	Sh. Eg.
22	5 56	"	I	Oc. Dis.
	8 56	"	I	Ec. Re.
23	1 56	"	II	Oc. Dis.
	3 10	"	I	Tr. In.
	3 15	"	III	Ec. Dis.
	4 00	"	I	Sh. In.
	4 52	"	III	Ec. Re.
	5 22	"	I	Tr. Eg.
	5 54	"	II	Ec. Re.
	6 13	"	I	Sh. Eg.
24	3 25	"	I	Ec. Re.
27	1 40	A. M.	III	Tr. In.
28	1 16	"	I	Oc. Dis.
	9 43	P. M.	II	Tr. In.
	10 30	"	I	Tr. In.
	11 26	"	I	Sh. In.
	11 35	"	II	Sh. In.
29	12 03	A. M.	II	Tr. In.
	12 42	"	I	Tr. Eg.
	1 39	"	I	Sh. Eg.
	1 56	"	II	Sh. Eg.
	7 43	P. M.	I	Oc. Dis.
	10 52	"	I	Ec. Re.
30	3 15	"	III	Oc. Dis.
	4 16	"	II	Oc. Dis.
	4 57	"	I	Tr. In.
	5 00	"	III	Oc. Re.
	5 55	"	I	Sh. In.
	7 09	"	I	Tr. Eg.
	7 17	"	III	Ec. Dis.
	8 08	"	I	Sh. Eg.
	8 29	"	II	Ec. Re.
	8 54	"	III	Ec. Re.
31	2 11	"	I	Oc. Dis.
	5 20	"	I	Ec. Re.

In. denotes ingress; Eg. egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow. Only the phenomena visible in the United States are given. The times are Central Standard.

☞ **E. E. Barnard** of Lick Observatory has contributed an illustrated article concerning the new Brook's comet. It comes to hand too late for this issue. Something good is promised about the freaks of the tail of this comet learned from the photographs of it taken at the Lick Observatory.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

Date	h m
Nov. 15	8 58 P. M.
16	4 49 "
17	2 44 A. M.
17	10 36 "
18	6 27 P. M.
19	4 22 A. M.
20	12 14 "
20	10 05 P. M.
21	3 56 "
22	1 52 A. M.
22	9 43 P. M.
23	5 34 "
24	3 29 A. M.
24	11 21 P. M.
25	7 12 "
26	5 07 A. M.
26	3 03 P. M.
27	12 59 A. M.
27	8 50 P. M.
28	4 41 "
29	2 31 A. M.
29	10 28 P. M.
30	6 19 "
Dec. 1	4 09 A. M.
Dec. 2	12 06 A. M.
2	7 57 P. M.
3	5 52 A. M.
3	3 48 P. M.
4	1 44 A. M.
4	9 35 P. M.
5	5 26 "
6	3 21 A. M.
6	11 13 P. M.
7	7 05 "
8	5 00 A. M.
9	12 51 "
9	8 43 P. M.
10	4 34 "
11	2 30 A. M.
11	10 21 P. M.
12	6 02 "
13	3 57 A. M.
13	11 59 P. M.
14	7 50 "
15	5 45 A. M.
15	3 42 P. M.
16	1 37 A. M.
16	9 29 P. M.
Dec. 17	5 20 "
18	3 15 A. M.
18	11 07 P. M.
19	6 58 "
20	4 53 A. M.
21	12 45 "
21	8 36 P. M.
22	4 28 "
23	2 24 A. M.
23	10 15 P. M.
24	6 06 "
25	4 01 A. M.
25	11 53 P. M.
26	7 44 "
27	5 39 A. M.
27	3 36 P. M.
28	1 32 A. M.
28	9 23 P. M.
29	5 14 "
30	3 09 A. M.
30	11 01 P. M.
31	6 53 "

Configuration of Jupiter's Satellites, at 9:30 p. m. Central Time for an Inverting Telescope.

Dec.	
1	2 3 O 1 4
2	1 4 O 2 3
3	4 O 2 1 3
4	4 2 1 O 3
5	4 3 O 1 ●
6	4 3 O 2 ●
7	4 3 2 1 O
8	4 2 3 O 1
9	4 1 O 2 3
10	● O 2 1 3
11	2 1 O 3 4
12	3 2 O 1 4
13	3 1 O 2 4
14	3 2 1 O 4
15	2 3 O 1 4
16	1 O 2 3 4
17	O 2 1 4 3
18	2 1 O 4 3
19	4 2 O 1 ♃
20	4 3 1 O 2
21	4 3 O ♃ ♃
22	4 2 3 O 1
23	4 1 O 2 3
24	4 O 1 2 3
25	4 2 1 O 3
26	4 2 O 3 1
27	3 1 O 4 2
28	♃ 3 O 1 4
29	3 2 O 4 ●
30	1 O 2 3 4
31	O 1 2 3 4

Elongations of the Satellites of Saturn.

(The western elongations will be found approximately half way between the eastern and other positions may be easily interpolated.)

MIMAS

Date	h		
Dec. 9	4.9	A. M.	E
10	3.5	"	E
11	2.1	"	E
12	12.7	"	E
12	11.3	P. M.	E
13	9 9	"	E
14	8.6	"	E
15	7.3	"	E
16	5.9	"	E
17	4.5	"	E
18	3.1	"	E
19	1.7	"	E
20	12.3	"	E

MIMAS Cont.

Date	h		
Dec. 21	10.9	A. M.	E
22	9.5	"	E
23	8.1	"	E
24	6.8	"	E
25	5.5	"	E
26	4.1	"	E
27	2.7	"	E
28	1.3	"	E
28	11.9	P. M.	E
29	10.5	"	E
30	9.1	"	E
31	7.8	"	E

ENCELADUS

Date	h		
Dec. 15	6.6	A. M.	E
16	3.5	P. M.	E
18	12.4	A. M.	E
19	9.3	"	E
20	6.2	P. M.	E
22	3.1	A. M.	E
23	11.9	"	E
24	8.8	P. M.	E
26	5.7	A. M.	E
27	2.6	P. M.	E
28	11.6	"	E
30	8.4	A. M.	E
31	5.3	P. M.	E

TETHYS

		h	
Dec.	13	5.3 A. M.	E
	15	2.6 "	E
	16	11.9 P. M.	E
	18	9.3 "	E
	20	6.6 "	E
	22	3.9 "	E
	24	1.2 "	E
	26	10.5 A. M.	E
	28	7.8 "	E
	30	5.1 "	E

DIONE

Dec.	14	8.8 A. M.	E
	17	2.5 "	E

DIONE CONT.

		h	
Dec.	19	8.2 P. M.	E
	22	1.9 "	E
	25	7.6 A. M.	E
	28	1.3 "	E
	30	7.0 P. M.	E

RHEA

Dec.	6	1.8 P. M.	E
	11	2.4 A. M.	E
	15	2.9 P. M.	E
	20	3.4 A. M.	E
	24	3.9 P. M.	E
	29	4.4 A. M.	E

TITAN

		h	
Dec.	14	6.9 P. M.	W
	22	4.3 "	E
	30	6.1 "	W

HYPERION

Dec.	15	8.4 P. M.	E
	27	2.2 "	W

JAPETUS

Dec.	10	6.2 A. M.	W
	30	4.5 P. M.	S

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

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

Dec.	6	3 A. M.
	11	2 "
	16	2 "
	21	2 "
	26	1 "
	31	1 "

ALGOL.

R. A...............$3^h\ 1^m\ 1^s$
Decl................+ 40° 32′
Period............$2d\ 20^h 49^m$

Dec.	10	4 A. M.
	13	1 "
	15	9 P. M.
	18	6 "
	30	6 A. M.

λ TAURI.

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

Dec.	4	4 P. M.
	8	3 P. .M

R. CANIS MAJORIS.

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

Dec.	6	5 P. M.
	7	8 "
	8	11 "
	10	3 A. M.
	11	6 "
	14	4 P. M.
	15	8 "
	16	11 "
	18	2 A. M.
	19	6 "

R. CANIS MAJ. CONT.

Dec.	23	6 P. M.
	24	10 "
	26	1 A. M.
	27	4 "

S CANCRI.

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

Dec.	1	5 P. M.
	10	5 A. M.
	19	5 P. M.
	29	4 A. M.

S ANTLIÆ.

R. A.............. $9^h\ 27^m\ 30^s$
Decl...............— 28° 09′
Period........... $0d\ 7^h\ 47^m$

Dec.	1	10 P. M.
	2	6 A. M.
		9 P. M.
	3	5 A. M.
		9 P. M.
	4	5 A. M.
		8 P. M.
	5	4 A. M.
		7 P. M.
	6	3 A. M.
		6 P. M.
	7	3 A. M.
		6 P. M.
	8	2 A. M.
	9	1 "
		midn.
	10	midn.
	11	11 P. M.
	12	10 "
	13	6 A. M.
		9 P. M.
	14	6 A. M.

S. ANTLIÆ CONT.

Dec.	14	9 P. M.
	15	5 A. M.
		8 P. M.
	16	4 A. M.
		7 P. M.
	17	4 A. M.
		7 P. M.
	18	3 A. M
		6 P. M.
	19	3 A. M.
		6 P. M.
	20	2 A. M.
	21	1 A. M.
	22	1 A. M.
		midn.
	23	midn.
	24	11 P. M.
	25	10 "
	26	6 A. M.
		9 P. M.
	27	6 A. M.
		8 P. M.
	28	5 A. M.
		8 P. M.
	29	4 A. M.
		7 P. M.
	30	3 A. M.
		6 P. M.
	31	3 A. M.
		6 P. M.

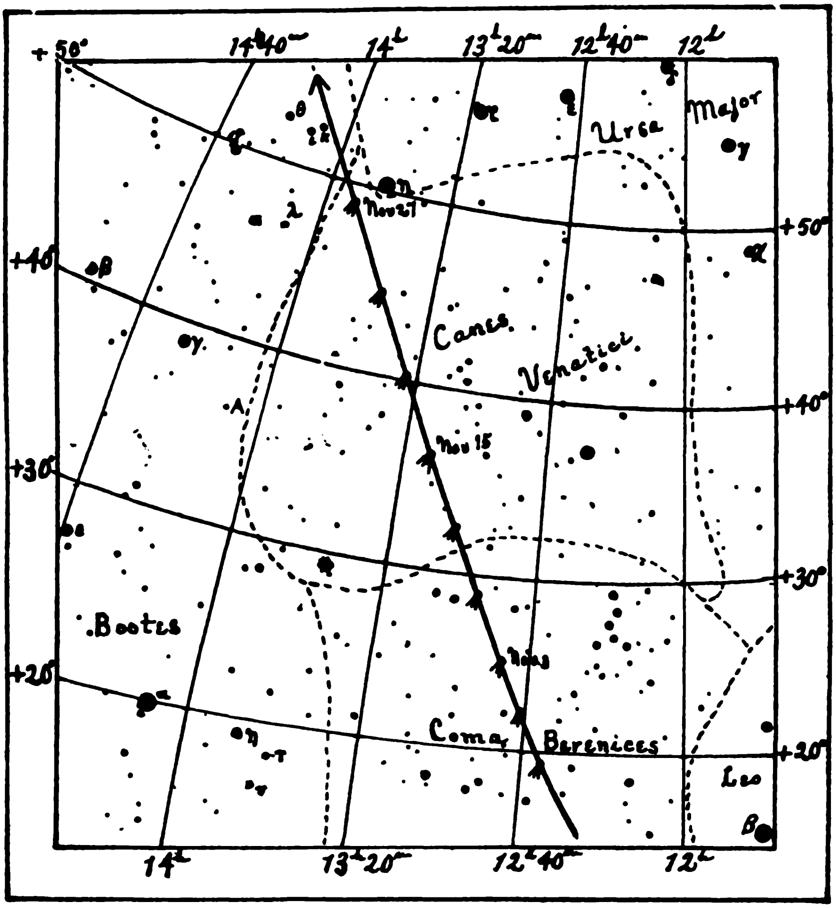
U. CORONÆ.

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

Dec.	11	5 A. M.
	18	3 "
	24	midn.

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T.	IMMERSION Angle f'm N pt.	EMERSION Washington M. T.	EMERSION Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
Dec. 10	B.A.C. 6628	5.9	5 21	110	6 25	211	1 04
17	ζ Piscium	4.8	13 18	99	14 04	213	0 56
19	40 Arietis	6.3	6 32	359	7 08	294	0 36
20	36 Tauri	6.0	14 12	97	15 11	245	0 59
23	47 Geminorum	6.0	5 43	102	6 31	254	0 48
24	λ Cancri	5.7	6 43	106	7 33	266	0 50
30	86 Virginis	5.9	16 57	89	17 59	351	1 02



PATH OF COMET *c* 1893 (BROOKS) THROUGH THE CONSTELLATIONS.

Comet *c* 1893 (Brooks).—The third comet of this year was discovered on the morning of Oct. 17 by Mr. W. R. Brooks of Smith Observatory, Geneva, N. Y. It was a telescopic comet, about as bright as a star of the seventh magnitude, with a distinct nucleus and a tail about 3° long. At Northfield, owing to bad weather and moonlight, we were unable to see the comet until the morning of Nov. 3 when its description was essentially the same as at the time of discovery. Professor Porter at the Cincinnati Observatory was able to get observations of its position

Oct. 18, 19, 21 and 23 and from these has computed the following elements and ephemeris, which have been printed in *Astronomical Journal* No. 306. These indicate that the comet passed perihelion Sept. 20 and is now receding from the Sun; but that it is approaching the Earth and will continue to approach us during November. Its theoretical brightness will slowly decrease during this time.

The course of the comet during November will be northeastward (celestial) through the constellations Coma Berenices, Canes Venatici and Boötes. This is shown in the accompanying diagram, in which the reader will be able to recognize the principal stars. During the latter part of the month the comet will be visible all night. On the 27th it will be quite near the last star (η) in the tail of the Great Bear.

Dr. B. A. Gould calls attention to the fact that the elements of this comet bear a striking resemblance to those of the first comet of 1864. It is too early yet to determine whether there is any possibility of their identity.

Prof. E. E. Barnard succeeded in photographing the comet on the morning of Oct. 19 with the 6-inch portrait lens of Lick Observatory. "The picture, although the exposure was short, and the comet very poorly placed, is a very successful one, and shows this object to possess characteristic features similar to those shown in the photographs of Swift's comet 1892 I.

The plate shows the tail to a distance of 3½°. This tail irregularly divides into two slightly divergent branches. There are two narrow straight rays springing out from the head on opposite sides and nearly symmetrical with the main tail. The north ray, which seems to leave the region of the nucleus, is inclined to the body of the comet by about 45°; the southern, which leaves the comet 10′ or 15′ minutes back of the head, is inclined about 30°. They are both about ½° long. There are faint evidences of several other rays from the southern side of the comet.

ELEMENTS OF COMET *c* 1893 (BROOKS) BY J. G. PORTER.

$$T = 1893 \text{ Sept. } 20.552 \text{ Berlin M. T.}$$

$$\left.\begin{array}{l}\omega = 350^\circ\ 40'.2\\ \Omega = 175\ \ 19\ .3\\ i = 130\ \ 13\ .7\end{array}\right\}1893.0$$

$$\log q = 9.91968 \quad q = 0.83115$$

EPHEMERIS FOR BERLIN MIDNIGHT.

	R. A. h m s	Decl. ° ′	log Δ	log r.
Nov. 7	12 55 03	+28 48.9	0.1729	0.0806
11	13 03 19	32 24.0	.1597	.0982
15	13 12 35	36 14.3	.1470	.1155
19	13 23 08	40 19.9	.1353	.1324
23	13 35 20	44 39.9	.1250	.1468
27	13 49 42	+49 11.7	0.1169	0.1647

GENERAL NOTES.

Some of our enthusiastic readers say "Give us more illustration if you can." Haven't we done pretty well this time? Send us more subscribers and see what we will do.

The high commendation that we received from some very prominent astronomers in England in relation to the character of the first two numbers of this publication are gratifying indeed. Messrs. Wesley & Son of London recently ordered for seventeen annual subscribers.

Our space is much crowded this time and consequently our paragraph subjects are greatly limited in number. We have also been obliged to omit some useful comet notes and tables.

Naked-Eye Sun Spot.—Mr. O. R. Loomis of Bound Brook, N. J., writes that he saw a large sun spot with the naked eye October 25. He verified the observation with a 3-inch telescope. Examining our solar photographs of about the same date a large group of sun spots is noticed which were well defined and prominent between Oct. 21 and Oct. 27. The diameter of the group was more than 43,000 miles and covered the largest solar area about October 21.

PLATE VIII.

THE YERKES TELESCOPE.

CLEAR APERTURE OF OBJECTIVE 40 INCHES.

Photographed by S. W. Burnham at Columbian Exposition.

Popular Astronomy.

Vol. I. DECEMBER, 1893. No. 4

PHOTOGRAPHS OF BROOKS' COMET (OCT. 17, 1893).

E. E. BARNARD

On the morning of the 17th of October W. R. Brooks, of Geneva, N. Y., discovered a small comet in the constellation Virgo, some ten degrees west of the star Epsilon. The comet was very low on the eastern horizon, and though not visible to the naked eye, it was quite bright as a telescopic object. It had a small nucleus and a short tail, but presented no features essentially different from the average telescopic comet.

The writer, having been engaged since the absence of the September moon in photographing the Milky Way, was prepared to photograph this new comet if possible.

On the morning following its announcement the position of the comet was carefully measured with the twelve-inch equatorial for the benefit of the early computers of its orbit. There was nothing, as seen in this telescope, to suggest any special results in photographing it, especially as the comet could only be seen for about half an hour and was badly obscured by the dense atmosphere near the horizon. However, on the morning of the 19th it was decided to try a plate, and an exposure of half an hour was given—from the time the comet could first be seen above the horizon until dawn cut it out.

The resulting photograph was highly satisfactory, as it showed features not seen in the twelve-inch. The comet presented a straight tail, nearly four degrees long, with two minor rays springing out from each side of the head for a short distance and making a considerable angle with the main tail.

The next morning was cloudy, but on the morning of the 21st another exposure of half an hour was given. Nothing new was shown on this picture, but the features were all more strongly marked, especially the ray from the northern side of the head, which now appeared as a short, broad tail. The main tail was straight and presented a rather graceful appearance.

On the morning of the 22d the twelve-inch showed that some disturbance had occurred, as the tail near the head was distorted. The customary exposure of half an hour was given with the Willard lens. To say the least the resulting picture was astonishing.

It presented the comet's tail as no comet's tail was ever seen before. The graceful symmetry was destroyed; the tail was shattered. It was bent, distorted and deflected, while the larger part of it was broken up into knots and masses of nebulosity, the whole appearance giving the idea of a torch flickering and streaming irregularly in the wind. The short northern tail was swept entirely away and the comet itself was much brighter.

The very appearance at once suggested an explanation which is probably the true one. If the comet's tail in its flight through space had suddenly encountered a resisting medium which had passed through the tail near the middle, we should have precisely the appearance presented by the comet. It is not necessary that the medium should be a solid body; if it possessed only the feeblest of ethereal lightness it would deflect, distort and shatter the tail. What makes this explanation all the more probable is that the disturbance was produced from the side of the tail that was advancing through space. But there is no known body or bodies in that part of the heavens. If, therefore, the explanation is the true one, this comet points out the existence of a hitherto unknown body or substance in the neighborhood of the sun—a swarm of meteors, a mass of exceedingly attenuated cosmical matter. It cannot be of much density, or it would have shown on the plate. Such matter is not an unreasonable supposition since it has long been suspected that some unknown influence of this kind exists near the Sun and disturbs the motion of the perihelion of Mercury.

I am speaking of this comet as if it were near the sun. This is an assumption that may be wholly erroneous. It is apparently near the sun, but in reality may be a vast distance beyond, although that is hardly probable. However, this does not affect the explanation of the phenomenon; it only locates the disturbing influence in a more improbable region.

With these thoughts paramount it was with considerable anxiety that the developments of the next morning were awaited. It was cloudy, but the clouds were breaking and flying in the face of almost a hurricane. The comet was finally got into the guiding telescope and another exposure began. The flying clouds occasionally permitted the image of the comet to fall on the plate. The little observatory rocked in the wind and the dome threatened every moment to fly away in the direction of San Francisco. A broken half hour's exposure was thus secured, and the resulting picture amply confirmed the disturbance of the previous morning. The tail was broken and seemed to hang in irregular cloud masses, deflected out of line with the stem of the tail near the head. A portion of the end of the tail was completely detached and was drifting off as an independent comet. This fragment was some four or five degrees from the head and a degree from the nearest part of the tail. Unless this portion dissipates into space it will be an independent comet traveling in quite a different path from the original. Its exact position was right ascension, 12 hours, 20 minutes; north declination, 20 degrees; October 22d, 16 hours 40 minutes, Mount Hamilton mean time. The next morning was cloudy and the full moon now blots out the comet and its phenomena.

The orbit of this object is not yet known, so that it is not possible to say whether it will become a naked-eye comet or not. If it has not yet passed perihelion it will certainly become visible to the naked eye, as it is now but little below that and is getting into a better position for observing. If the comet gets brighter and again presents freaks of the kind described it will be evident that the suggested explanation is at fault and that the comet is possessed of phenomena totally unheard of before. If it does not repeat these changes then the explanation of an encounter with a resisting medium is the only one that will hold, and it will consequently prove of the highest importance to astronomy.

It will be seen, I think, that the theory is at least a good working one, and I trust the reader will see how the subtle photographic plate may reveal to us wonders of a very startling nature where the unaided eye looks upon a blank space only.

It is altogether probable that no other photographs have been made of this comet yet, as it is such an unpromising subject, and that this history of it is recorded only on the Lick observatory photographs.

MOUNT HAMILTON, OCT. 25.

SHOOTING STARS.

How to Observe them and what they Teach us.

W. F. DENNING.

IV. THE OBSERVATION OF METEOR SHOWERS—DIFFERENCES AMONG THEM.

The observation of a rich meteor shower, to be complete, must be undertaken by two observers acting in concert. While one of them watches the sky continuously and counts the total number of meteors visible and also notes the proportion belonging to the special shower in progress, the other will register the paths, determine the position of the radiant, and record other details not absolutely requiring uninterrupted attention. If one observer only is employed in the work he cannot reckon the number of meteors and register the paths as well, for the latter occasions breaks in the watch which ought to be continuous. He can make allowances, it is true, for the time his attention is withdrawn from the sky, but this is not nearly so satisfactory as counting the actual numbers. The capacity possessed by a single observer is, however, often sufficient to give a good idea as to the character of a shower. When, say, the Perseids are being observed, he should tabulate his results for each evening; he can then, by comparison afterwards, see what changes affect the place of the radiant and the intensity of the shower. As an example of such a table, I give the results of my observations of the Perseids in August last:

Date 1893.	Time of Watch.	Duration.	All meteors seen.	Perseids.	Meteors registered.	Radiant of Perseids.	Weather.
	h m h m	h				° °	
Aug. 5	10 15 to 10 45	1½	13	4	7	39+55	Partly cloudy
8	10 50 to 12 50	2	36	12	14	41+56	Sky clear.
9	11 30 to 14 0	2½	45	20	25	43+57	A few clouds, frequent lightning.
10	10 50 to 11 50	1	21	14	9	45+57	Many clouds.
12	11 30 to 13 0	1½	24	7	11	48+58	Partly cloudy.
13	10 15 to 15 15	3½	43	8	29	48+58	Pretty clear.
14	10 15 to 14 30	4	56	7	36	49+67	Very clear.
15	11 10 to 14 30	3	35	1	22	....	Very clear.
16	10 15 to 15 15	4½	41	4	29	52+57	Very clear.
5 — 16	10 15 — 15 15	23½	314	77	182	39+55 to 52+57	

Really brilliant showers, like the Andromedes (= Biela's comet) of November 27, 1885, are more fugitive and their great intensity is generally limited to a few hours. In counting the meteors during such a display, the observer should group his observations into short periods of say 5 or 10 minutes and state total number seen during each interval. The time of maximum may then be deduced from the records. The radiant should also be determined, say once during each hour of the shower's progress, for there may be a considerable displacement in the course of a single night. The radiant of the Andromedes is at about 19° + 45½° at 6 P. M., but 12 hours later (viz. at about 6 A. M.) it is at $31° + 51°$ according to theory.

When observations are pursued on ordinary nights solely for the purpose of finding radiant points it is not nearly so important to record the *lengths* of the meteor paths observed as to note the exact *directions* of their flights. The latter feature is in fact all-important, for with accurate materials of this character the radiants become well defined in certain positions. Of course, when observations are undertaken at two or more stations for the express purpose of getting duplicate records of the same meteors with a view to the computation of their real paths in the atmosphere, it then becomes important to note the beginning and end points of the courses with great precision or the observations will exhibit discordances. It is most unfortunate that proper regard is not given to this circumstance by observers generally so that the published accounts of the numerous fireballs which appear unexpectedly might be of real value to those engaged in their investigation. It sometimes happens that a fireball is so generally observed that scores of descriptions of it are printed, but these are usually so rough and unreliable that it is rarely possible to deduce satisfactory results from them. The suddenness of the apparitions and the inexperience of many of the observers doubtless furnish the causes of the errors commonly vitiating the observations.

There is probably no class of phenomena in which more diversity exists than in that comprehended under the title of meteoric astronomy. The number of showers not only appears to be infinite but an endless variety is displayed amongst them; in fact, it would be difficult to find two streams perfectly alike in all respects. The more prominent features in which dissimilarity exists are as follows:

In richness of display.
" periodic time.
" character of radiation.
" duration of activity.
" nature of orbit, etc., etc.

Perhaps it may be as well to say something on these points separately.

In "richness of display" every observer must have quickly recognized the wide distinction that is apparent. There are showers which like the Leonids of 1799, 1833 and 1866 and the Andromedes of 1872 and 1885 are capable of supplying many thousands of meteors in an hour to one observer, while on the other hand there is a host of feeble systems some of which yield no more than 5 or 6 meteors during watches on several successive nights covering in the aggregate 30 or 40 hours! There are in fact a considerable number of streams of such extreme tenuity that a single observer, though he may watch the sky during an entire night in winter, will only succeed in noting about one meteor from each of them. Yet though so feeble such showers are to be accurately detected and their radiant points correctly assigned by the observer who perseveres in watching for long intervals and who registers the individual tracks with the necessary precision. It might be supposed that such exhausted systems are scarcely worthy of notice and must certainly be very doubtful, but in point of fact their very feebleness makes them interesting and the difficulty of securing them adds a zest to the efforts of the observer. It would be unwise to disregard the weaker streams, for some of the attenuated showers of to-day may form the most brilliant displays of a future time or they may possibly represent the nearly extinct relics of fine showers in past ages. In any case they are worthy of careful observation. Mr. Greg entertained a contrary opinion and his method was to average the positions of a number of radiants lying near together and to consider them as forming one shower, but the writer regards this as a most erroneous practice. We might as well take the mean place of the stars in the Pleiades and catalogue the position as that of a single bright star! The method would simplify matters by reducing the number of objects, but it would not be true to Nature and therefore meets its own condemnation. If the number of showers is so great and the proximity and feebleness of their radiants such that complications arise in dealing with them we must nevertheless face the matter as it stands and endeavour by long and careful study to remove the difficulties. The necessity for generalizing may be felt but it will never do to adopt a sweeping method palpably inconsistent with the direct issues of observation.

With regard to "periodic returns" of showers we find differences similar to that affecting cometary returns. The Leonids furnish us with beautiful displays every 33 years and though the real maximum is confined to a single year yet in the few years preceding and following the maximum fine showers are usually presented. Thus in 1864, 1865, 1867, etc., there occurred conspicuous displays near the great shower of 1866. At the close of the present century we shall doubtless witness some brilliant revivals of this remarkable meteor-system for its parent comet

(I, 1866 Tempel) will revisit us in 1899. The Andromedes of Biela's comet seen in very great abundance on Nov. 27, 1872, and 1885 and more recently on Nov. 23, 1892, furnish an instance of a short period meteor shower and it will probably return in its greatest magnificence in 1898 or 1899. The Andromedes and Leonids constitute the best known and most definite instances of periodical meteor showers. The Lyrids of April, the Perseids of August, the Orionids of October and some other well known systems probably have longer periods which are not yet exactly ascertained. The Perseids and Orionids apparently partake more of a regular annual display without developing periodical outbursts and this appears to be the prevailing feature of the great majority of meteoric systems. They recur every year without special intensity and probably form complete ellipses throughout which the particles are pretty evenly distributed. Undoubtedly a proportion of the known streams have definite peroids of recurring activity, but observation has not yet succeeded in determining many such showers. The writer noticed a rich display of Draconids on Aug. 21-25, 1879 which has not returned since that year, but the inference is that it forms a periodical shower which will reappear at some future time. It is highly probable that condensed meteor groups with periodical maxima, become, in time, distended into complete elliptic streams of annual recurrence. Every particle of such a group would have a slight difference of orbit and period with the effect that after many revolutions the meteors are distributed along the entire orbit.

In our next chapter we hope to refer to differences in the radiation and duration of activity of various systems.

ORBITS OF COMET 1889 V.

H. C. WILSON

This comet was discovered by Mr. W. R. Brooks, then of Phelps, N. Y., July 6, 1889. It was a rather faint telescopic object and would not have attracted very much attention, but for the fact that it was moving in a short ellipse with a period of about 7 years, and that in the year 1886 it must have passed very close to the planet Jupiter and its orbit must then have been very greatly changed. This was pointed out by Mr. S. C. Chandler, in No. 204 of the *Astronomical Journal.* In a later paper (*Astr. Jour.* No. 205) Mr. Chandler gave the results of a rough calculation of the principal perturbations by Jupiter, that is from Jan. 24 to Sept. 14, 1886, and attempted to trace the course of the comet backward from that time. He found that the encounter with Jupiter in 1886 effected a complete tranformation of the comet's orbit. Instead of the present small seven-year ellipse, it was previously moving in a large one of about 27 years' period, whose aphelion lay outside of Saturn's orbit, and whose perihelion was almost exactly at the present aphelion distance. The direction of the lines of apsides and the nodes were reversed and turned through an angle of about twenty degrees. The plane of the orbit was also tilted about fourteen degrees.

Furthermore, tracing back the course of the comet with the elements of the twenty-seven year ellipse, Mr. Chandler found that the comet must have been very near Jupiter in the year 1779, the very time when the lost comet of Lexell 1770 was in the immediate vicinity of the planet and suffered the notable disturbauce which was supposed to have taken it out of our reach. This coincidence of time and place afforded a strong presumption of the identity of the two comets. Later computations do not confirm this presumption but there remains the very interesting and difficult problem of determining exactly the course of a comet when under the preponderating influence of a great planet.

In recent numbers (302 and 303) of the *Astronomical Journal*, Mr. C. L. Poor has given the results of his investigations in regard to Comet 1889 V. He used as the basis of his work the definitive elements of the comet's orbit computed by Dr. Julius Bauschinger from all the published observations, the latter extending over a period of over eight months. There is still some uncertainty expressed by the factor ν, in these elements, not due to the computations but to the inaccuracies of the observations. Mr. Poor finds that ν is probably within the limits -40 and $+40$. This uncertainty is very slight but enough to affect, to some extent, the character of the calculated approach of the comet to Jupiter. Taking the most probable values of the elements and calculating the perturbations by all of the planets, which could preceptibly influence the comet's motion, back to 1886, Mr. Poor finds that the approach was closer than Mr. Chandler had supposed. The nucleus of the comet passed within the orbit of the first satellite and may have almost grazed the surface of the planet itself.

In calculating the path of the comet when very near to Jupiter Mr. Poor followed the method of transforming the elements of the ellipse around the Sun into those of a hyperbola around Jupiter, regarding the Sun as a disturbing body. This transformation was made at the date Oct. 26.5, 1786. After tracing the movement of the comet back around Jupiter for six months the elements were again referred to the Sun as a center at the date March 24.5, 1886, and it was found that the orbit had so greatly changed that the period was then 41.87 years. For several months before that time, however, the perturbations by Jupiter had been large and when these were calculated back to March 14.5, 1884, the elements were found to give a period of 31.38 years, with the perihelion passage July 20, 1886. Mr. Poor thinks that the uncertainty of this period is within two years.

Instead of giving the numerical element of the comet's orbit at the various stages of its transformation* we have attempted to represent them graphically by means of the diagrams, Figures 1 and 2. In Fig. 1, the four elliptic orbits are shown together with the orbits of Earth, Jupiter, Saturn and Uranus. The four ellipses of the comet's path all meet near that point of Jupiter's orbit which is opposite the vernal equinox. For two of them this is the most distant part of the orbit (aphelion), for the other two it is the nearest part (perihelion). One can see at a glance what a tremendous change in the path of the comet occurred between March and October, 1886.

Interpreting the elements with the aid of the figure they tell us that the comet previous to 1884 was moving in a large ellipse the nearest point of which to the Sun lay very close to Jupiter's path, and the farthest point about half way between the orbits of Saturn and Uranus. The plane of the orbit was inclined at an angle of about 7° to ecliptic and the orbit crossed the latter from south to north in longitude 186°, very near the path of Jupiter. This orbit is represented in Fig. 1 by the line marked "Orbit of Comet 1889 V in March, 1884." The comet was describing this path at the rate of a revolution in about 31.38 years. Had it not been influenced by Jupiter it would have gone around this orbit again and again and never have been seen from the Earth. As it happened to come to perihelion at the same time that Jupiter was in that vicinity, it was drawn at first very gradually, then more rapidly, from the large, smooth curve of Figure 1 into the larger dotted curve, then into the smaller dotted curve, and finally and gradually into the slightly larger smooth curve. This last curve, "Orbit of Comet 1889 V in 1889," it will continue to follow for several revolutions of seven years' period

* These elements are given in *Astronomy and Astro-Physics*, Nov. 1893, p. 795.

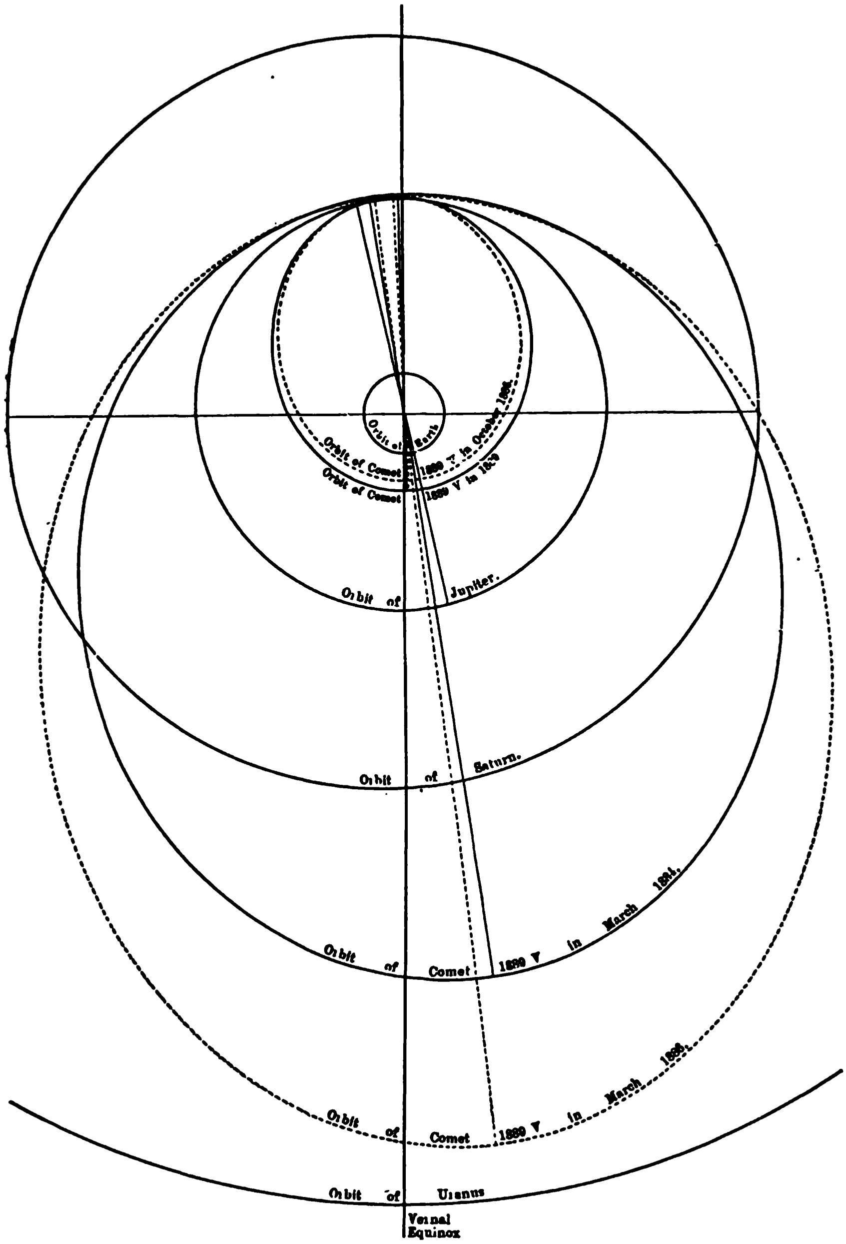


FIG. 1.—THE ORBITS OF COMET 1889 V BEFORE AND AFTER ITS APPROACH TO JUPITER IN 1886.

with only slight modifications by the planets. In 1921 another close approach to Jupiter will occur, which, though not so close as the one in 1886, will considerably change the orbit, probably making it larger and possibly removing the comet from the reach of our telescopes for a long period.

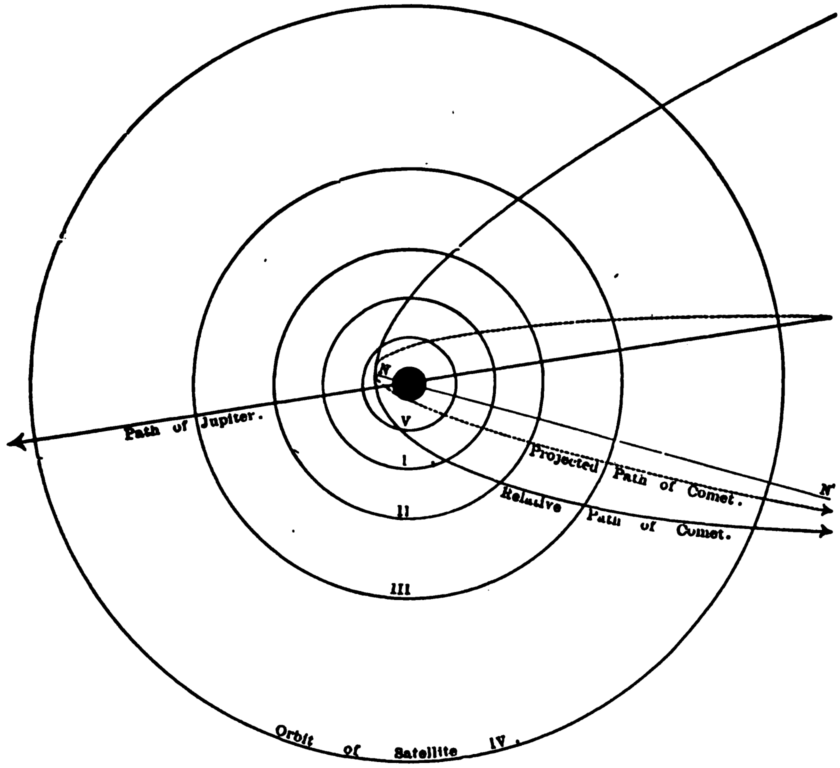


FIG. 2.—THE PATH OF COMET 1889 V THROUGH JUPITER'S SATELLITE SYSTEM JULY 18 TO 21, 1886.

Fig. 2 represents a portion of the hyperbolic orbit of the comet relative to Jupiter while it was passing through the system of the satellites, and is especially interesting in showing how very close the comet came to the planet and the satellites. The scale is nearly 4000 times that of Fig. 1. The time of nearest approach to Jupiter was found to be July 20, when the distance was only 2.31 radii of the planet, with the uncertainty expressed by ν in the formula

$$q = 2.31 + 0.033\nu$$

"That is, the comet not only passed through the system of Jupiter's satellites, but it actually passed within the orbit of the first satellite whose mean distance is 5.93 radii of the planet. Taking the extreme limits of ν we are safe in saying that the comet passed the center of Jupiter at a distance not greater than 3.63 and not less than 1.00 radii of the planet. In other words the center of the comet may have grazed the surface of Jupiter, and it certainly approached that surface to within a distance of 2.63 radii of the planet, or only 112,300 miles. Even this latter is a very small quantity.

"For the most probable hypothesis, that of $\nu = 0$, the comet was 2.65 days within the system of Jupiter's satellites, and during this time it made nearly a complete curcuit about the planet, passing over an arc of 313° of longitude. The comet entered the Jovian system in longitude 118° on July 18.77, passed the planet July 20.10, at a distance of only 2.28 radii, and July 21.43 left the system in longitude 71°. During this time it must have collided with one or more of the satellites."

The last two paragraphs are quoted from Mr. Poor's paper. In Fig. 2 the circles represent the orbits of Jupiter's satellites and the relative path of the comet is almost a hyperbola and was drawn from the mean of the parabolic elements given for Oct. 26.5 and March 24.5, 1886. It is necessary to understand that the path of the comet is a plane inclined at an angle of about 70° to the plane of the satellite orbits, so that the comet did not pass horozontally across them, but came up through from below. The line NN′ represents the line of the nodes or intersection of the planes of the comet's path and the ecliptic.

The reader must understand, too, that this is only the path relative to Jupiter and that the latter was at the same time moving rapidly along its orbit, so that while the comet, after July 20, was apparently moving backward with reference to Jupiter, with reference to the Sun it was moving forward and changing from the larger dotted orbit to the smaller one in Fig. 1.

It will be noticed that the path of the comet passes very close to that of the new satellite (V) of Jupiter and suggestions have already reached us from different sources, that possibly this comet had something to do with the origin of the new satellite, that in fact the satellite is a captured fragment of the comet. We cannot see how this could be, with the comet passing through the system just as it did, and supposing the capture to have occurred, cannot acconnt for its brilliancy, since the whole comet was invisible long before it reached the distance of Jupiter.

If the period of 31.38 years is correct this comet cannot be identical with Lexell's comet of 1770 unless marked perturbations occurred between 1886 and 1779 when the latter was in the vicinity of Jupiter and had its orbit greatly changed, for the interval of 107 years is not a multiple of 31.38 years or any number very near that. Mr. Poor finds that there was no very near approach of the comet to Saturn in that interval but that possibly a very close approach to Jupiter occurred in 1791. This, however, would be fatal to identity with Lexell's comet, for it would require the comet between 1779 and 1791 to have a period equal to that of Jupiter, that is an identical orbit.

SUGGESTIONS TO AMATEURS.

LEWIS SWIFT.

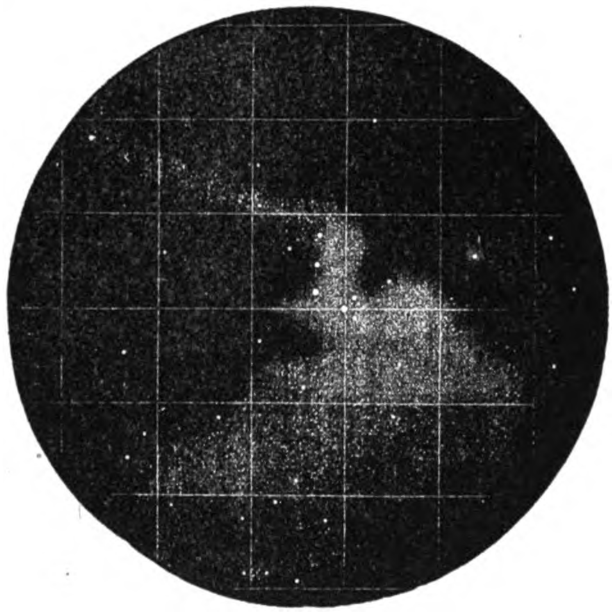
THE GREAT NEBULA IN ORION.

The largest and one of the brightest and, in many respects, the most remarkable nebula known is that found in the constellation of Orion, right ascension, about $5^h\ 30^m$; declination, south 5°. It is impossible to name its exact position, as is true of all the large, irregular nebulæ unless they possess a conspicuous central point for reference, which the Orion nebula has not. As examined with different telescopes under varied atmospheric conditions, its entire contour is changed with each, so that each individual observer, according to the size of the telescopes employed and the excellence of the seeing, locates the selected center. With my 16-inch glass, using a superior and large periscopic eyepiece giving a low power and a large field, I have several times traced the outlines of this nebula far beyond its generally assigned limits. Professor Wm. H. Pickering has given it an extension nearly equal to that of the constellation itself, and including several neighboring nebulæ heretofore supposed to have no connection with it.

When the constellation is veiwed with the naked eye, the first objects to attract attention are the three conspicuous stars of equal magnitude in a line about one and a half degrees apart called, variously, the three stars, the yard and ell, and the belt of Orion, but which Job designates as the Bands of Orion, "Canst thou bind the cluster of the Pleiades or loose the bands of Orion?" Job xxxviii: 31, Revised Ed.

Neither the date of discovery of this nebula nor the name of its discoverer is certainly known. It has been generally ascribed to

Huygens, in 1656, but eighteen years previous to its mention by Huygens, Cysat, of Lucerne, in describing the appearance of the head of the comet of 1618, compares it to the nebula in Orion. This allusion, while nullifying the claim of Huygens, does not, by any means, prove Cysat its discoverer, indeed it would rather argue its having been known previously, but Dr. Dreyer in his "New General Catalogue of Nebulæ" accords Cysat this honor.



NEBULA OF ORION (*Messier 1771*).

When viewed with small telescopes these hazy objects appeared only as small, whitish spots, but, looked at with larger glasses, some were resolved into stars, and so the inference was that all nebulæ were clusters and resolvable did we possess telescopes of adequate power. As a result of this erroneous theory, some astronomers, finding a star or two depicted on a nebula, have assumed and announced that the objects were no longer to be regarded as nebulæ but as clusters. Sir William Herschel claimed to have resolved into stars the great Whirlpool nebula in Canes and the great nebula in Andromeda, and others have asserted that the Orion nebula and the ring nebula in Lyra, also, had been found to be clusters of stars, while the truth is that the last two are pronounced gaseous by the spectroscope. It is only lately, with our mammoth telescopes, that a single star has been seen either on or within the ring of the last named.

The distance of the nebulæ from the earth has been a much discussed question, and it has been contended that they may not be so far off as the nearest stars, but as the distance of both is unknown, any assertion regarding this is futile. The Orion nebula has many stars, some bright, but mostly faint, scattered over its surface, but, judging from their telescopic apearance, they lie between us and the nebula.

Here we are confronted with some startling facts. All stars are suns, and all, even under the highest powers of the largest telescopes, appear as points of light. A point, having no extension, cannot, of course, be magnified. The nearest star to us, Alpha Centauri, is, presumably, as large as our Sun, and yet, so far away is it that though nearly a million and a half times the size of our Earth it is reduced to a mathematical point. Now, superimposed on the Orion nebula are stars as large as Alpha Centauri on which no telescope can raise a disc, while the nebula itself, probably somewhat spherical in form and probably as far distant as the stars, presents a disc covering at least one-hundred square degrees. What little things even the gigantic suns must be in comparison with this which is, however, only one of the eight thousand nebulæ which our telescopes reveal!

No lateral motion has ever been detected in any nebula. It is only because the stars are points that their proper motion, as it is termed, is measurable. The telescope only takes cognizance of this kind of motion, while the spectroscope is employed altogether for the detection of motion in the line of sight, either toward or from the observer. By the tele-spectroscope at the Lick Observatory Professor Keeler ascertained that the Orion nebula is moving from us or we from it at the rate of about ten miles per second. The probability is that this motion is nearly all, if not wholly due to that of the solar system toward the apex of the Sun's way, in the neighborhood of the constellation of Hercules.

Several nebulæ are scattered over the constellation of Orion which even in large telescopes, appear to be independent; but which with long photographic exposure (too long for the brighter portion of the great nebula) the negative shows to be connected with the principal nebula, whose proportions are thus expanded to an extent undreamed of a few years ago.

My library is largely packed for shipment and I cannot now recall wherein I recently read the statement that the nebulæ close to ζ Orionis, the lowest of the three stars of the Belt, were lately discovered by photography. Unless a new one is alluded to, which I doubt, this is all a mistake. Close to this star, so near, in fact, that to see them the star has to be placed out of the field of the telesocope, are four nebulæ with which I have been familar for more than thirty years. They or it, as he supposed, were discovered by Sir Wm. Herschel on New Year's Day, 1786, and registered as number 28 of his class V (large) and described as having "diffused nebulosity." Auwers' description says "divided in three or four large patches including a dark space. Cannot take up less than one half a degree, but I suppose it to be much more extensive." Dreyer, in New General Catalogue, where its number is 2024, after calling it a wonderful object says of it, "irregularly resolvable, very, very large black space inclosed." Of these descriptions Auwers' appears to me to be the only correct one. As to its resolvability I have very many doubts. Formerly, before the sky was illuminated by the electric lights, I saw them (for there are certainly four) as well with my 4½-inch as latterly with my 16-inch telescope. To see it well about one-fourth of the field should be hidden by a bit of smoked mica. This, if the eyepiece be properly rotated, will bring them into the center of the field with the star obscured.

My reasons for calling the attention of amateurs to this object are threefold:

1. To correct the statement that it was discovered by photography.

2. To suggest that it is visible in small telescopes by getting the star out of the field.

3. Because of the astonishing fact that, though 5° distant, it has been proved to be connected with the great nebula itself.

Sir William Herschel supposed he had discovered a very large, very faint nebula surrounding Epsilon Orionis (the Belt's middle star). For this I have sought many times with both telescopes, but always in vain, having never been able to detect anything more than the faint glow which surrounds every bright star. Auwers is inclined to believe in its existence, and Dr. Dreyer states that he has seen it at the Armagh Observatory as an exceedingly diffused nebula of the Merope type. This assertion that the star is eccentrically situated in the nebula, argues strongly against the glow hypothesis. There is a black opening or bay running into the nebula at the end of which small telescopes reveal four faint stars which, though on three sides close to the nebula appear to be not involved with it. The group is named the trapezium of Orion. Large telescopes show two of the stars to be double. Much speculation has been had as to the cause of the exceeding blackness of the opening. The same phenomenon may be observed in hundreds of places in the Milky Way, though most of these are small. A few, however, are large, one notably so, viz.: the coal-sack of Sagittarius which nearly fills the field of my 16-inch glass, and within which but three stars are found and one of those very difficult to perceive. Two opinions are advanced to account for the excessive blackness: Barnard, who has photographed it, revealing on the negative plate thousands of stars too faint to be detected by any telescope, thinks, as did Herschel, that it is simply an opening, while others ascribe it to a black nebula existing between us and it. Having given some attention to these "coal-sacks," especially to this one and the many scattered over the constellation of Cygnus, I have come to the conclusion that this darkness is not real, and that, in truth, they are no blacker than other portions of the sky, but that their apparent blackness is due wholly to the effect of contrast with the brightness of their surroundings. As to the final history of such a gigantic volume of self-luminous matter, the largest object on which the eye of man has ever rested, or the source of its self-luminosity it would be idle to speculate.

VARIABLE STARS. II.

J. A. PARKHURST.

In my first paper in the November POPULAR ASTRONOMY I gave the classification of variables with regard to their length of period. Before passing to the methods of observation the color of variables should be mentioned.

For some unknown reason the variables, if not white, are yellow, or orange, or red, and as a rule the longer the period, the more intense is the redness. Dr. Chandler has expressed the redness in a decimal scale in which 0 corresponds to white and 10 to the most intense red known in stars. Measured on this scale the stars with periods of from 150 to 500 days show a steady increase in redness. This will be seen from the following table in which the first column gives the limits of the periods, the second, the number of stars, and the third the average redness.

Period.	No.	Redness.
150 to 200	9	2.3
200 " 250	13	2.6
250 " 300	24	3.4
300 " 350	25	3.8
350 " 400	23	4.6
400 " 450	11	6.1
450 " 500	4	8.1

DESIGNATION OF VARIABLES.

The earliest mode of naming variables was by capital letters, beginning with R (suggesting the redness generally accompanying variability) prefixed to the name of the constellation. Thus R Cassiopeiæ stands for the first variable discovered in Cassiopeia. When the final letters of the alphabet are exhausted, they are doubled. Thus we have RR, RS, and RT Cygni, etc. But so much confusion has arisen from different letters being assigned to the same star by different authorities that Dr. Chandler has devised a more complete method by which that difficulty is avoided. The star's Right Ascension for the year 1900 is reduced to seconds of time and one tenth of the number is taken. For instance the Right Ascension of U Geminorum for 1900 is $7^h\ 49^m\ 10^s$, which equals $28{,}150^s$, so its number is 2815. When a star is suspected to be variable the number is placed in parenthesis; when the variability is proved the parenthesis is removed and the letter assigned. Thus (1805) Orionis is a star in Orion whose variability is suspected by Boss, and 2815 U Geminorum is the full designation of a star proved to be variable.

METHODS OF OBSERVATION.

The best method of observing a variable consists in comparing it with a star a little brighter and one a little fainter. In this way small changes of light can be readily detected, and with practice quite accurately estimated. Since only the relative light of two stars is concerned the accuracy of the observation will be but slightly affected by altitude, haze, moonlight or twilight, while the absolute brightness might be greatly changed by such varying conditions.

There are several ways of estimating the interval in brightness between the variable and the comparison star, but all things considered the method known as Argelander's seems the best. It is as follows: Select a star slightly brighter than the variable, calling it *a*, also one slightly fainter, call it *b*. If the variable seems equal to *a* the observation can be recorded *av* or *va*, (the variable being designated by *v*).

If *a* is a little brighter than the variable but to such a slight degree that you could not imagine a star between them in brightness and distinguishable from each, the observation is recorded *a* 1 *v*, the brighter star always written first. This interval is called a step or grade, and practically is the smallest interval in brightness which the observer can detect, If the interval is such that a star can be imagined between *a* and *v* differing a step from each, the record is *a* 2 *v*, if the interval is a little greater, it will be *a* 3 *v*. Intervals exceeding three or four steps are uncertain, so that comparison stars should be selected within a few steps of the brightness of the variable if possible.

In the same way compare the variable with a fainter star *b*, and make the record *v* 1 *b*, *v* 2 *b*, as the case may be, always writing the brighter star first. The value of a step will of course be different with different observers, but this is immaterial. With practice it will become quite a constant quantity with the same aperture and magnifying power but will decrease if an eye-piece of higher power is used. The value of a step with experienced observers is generally about one-tenth of a magnitude, for the beginner it is apt to be somewhat larger.

Pickering suggests another method of estimating the interval between the variable and the comparison stars. "Select two stars for comparison, one *a* slightly brighter than the star to be measured, the other *b*, slightly fainter. Estimate the brightness of *v* in tenths of the interval from *a* to *b*. Thus if *v* is midway between *a* and *b* the interval will be five-tenths, and we may write *a* 5 *b*. If *v* is nearly as bright as *a* we may have *a* 1 *b* or *a* 2 *b*. If *v* is not much brighter than *b* we may have *a* 8 *b* or *a* 9 *b*."

In comparing these two methods probably nine out of ten would at first prefer the latter, but after a little experience would find Argelander's better. The great superiority of the step method lies in the fact that the observations may be reduced and the star's light curve drawn, its maximum and minimum determined, without any previous knowledge of the magnitudes of the comparison stars. The observations themselves furnish a value for the brightness of the comparison stars by means of which a "light scale" can be formed and the variable's light curve drawn. If the observer already has well determined values of the magnitude of the comparison stars, this advantage would not count, but in general he will not have, so the method by which such values become unnecessary will be a great boon.

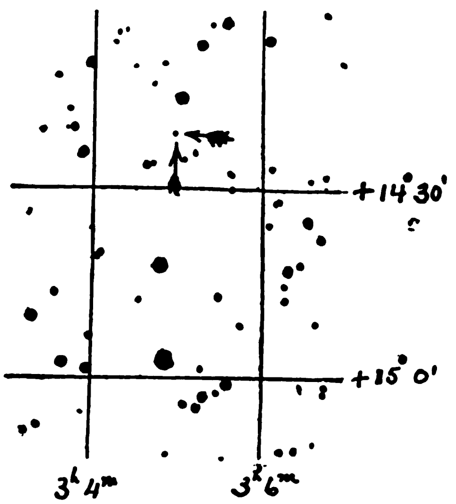
The method of reducing the observations, drawing the light curve and finding from it the maximum and minimum, will form the subject of the next paper. In the mean time some suggestions in regard to details of the observations will be in order.

The observer will need a list of comparison stars ranging in brightness from a little above the variable at its maximum to a little below it at its minimum. This list need not all be selected at once, indeed the exact brightness of the variable at maximum or minimum may not be known, but stars may be added to it from time to time as they are needed. The stars should be, if possible, not more than five or six steps, say half a magnitude, apart, and are most convenient if they are so placed that each can be seen in the same field with variable with the lowest power eyepiece. This ideal selection of comparison stars is not always possible, one is often compelled to choose between stars of convenient distance but large intervals in brightness, and good intervals but inconvenient distances. Avoid choosing a comparison star close to a brighter star as the estimate of the fainter star will thus become difficult and uncertain. Do not choose a double star if the components are visible with the power used. Make a sketch of the relative positions of the variable and the comparison stars chosen, as well as any other stars near. Letter the comparison stars with small letters, beginning with either the brightest or the faintest star used. In this way stars will always be designated in the record by letters and intervals by numbers, and thus confusion will be avoided. Low altitude, haze, twilight or moonlight injure the quality of the observations to some extent, since they affect white and red stars differently. Red stars gain in relative brightness when viewed under those conditions, and as a rule the variable is red and the comparison stars white. If observations are made at such times the record should show it, so that less weight may be given to the observation and any resulting anomalies accounted for. Note the time of the observation, if of an Algol star the hour and minute, if a long period variable the hour will suffice. It is best to bring the star observed to the center of the field, or if the two stars to be compared are not far apart, place them at equal distances from the center. A star looks brighter near the edge of the field than at the center. It is better to look carefully at each star separately, glancing back and forth several times, rather than to try to see two stars at once. The lowest power eyepiece is the most convenient to use, since it gives the widest field and the best choice of comparison stars. As far as possible use the same eyepiece for all the observations of a given star. Do not use too large an aperture with bright stars. When the variable is of the sixth to eight magnitude two inches aperture is better than three or four. The eye is not sensitive to small differences in bright stars.

The light used in consulting charts and making records should be no brighter than necessary. The eye should be screened at all times from its direct rays, and the comparisons themselves should be made in darkness. The ideal light is a one-half or one candle power incandescent lamp. This may be run by two chromic acid or storage cells, or by four Leclanché or dry cells. The writer uses a one-half candle power Edison lamp run by three storage cells, the latter charged by ten gravity cells. Three storage cells are used because the battery is in the cellar three hundred feet from the Observatory. The gravity cells are recharged only once in three weeks, so that the expense is small and the convenience great.

The accompanying table and charts will aid the amateur in identifying specimen variables.

		1900.0						Mag.		
No.	Star	Right Ascension			Declination		Redness	Max.	Min.	Period
		h	m	s	°	′				d
116	β Cassiopeiæ	0	19	15	+63	35.5		>1	?	
1113	U Arietis	3	5	30	+14	24		7.8	<11	330?
5955	R Draconis	16	32	23	+66	57.8	2.0	7.6	12.5	245.6
7609	T Cephei	21	8	13	+68	5.0	6.3	5.8	9.7	383.3



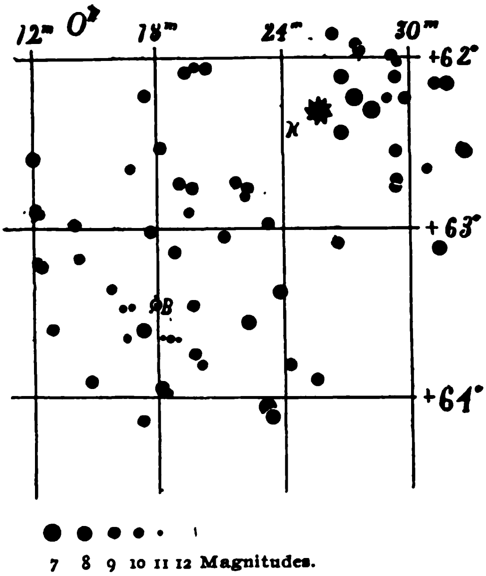
The chart for U Arietis is taken from *Astronomy and Astro-Physics* for October, 1892. The position of the variable is shown by the arrows. The stars shown are from the 8.7 to 11.5 magnitudes. Only one maximum of this star has been observed visually, 1893, Jan. 1. Its period is not definitely known, and observations are needed. The star is 5° south of the 4th magnitude star δ Arietis.

The other three charts are drawn from the *Astronomische Gesellschaft* Zone Catalogues. All the stars to about the 9th magnitude are shown besides some fainter stars near the variable, which is indicated by a dot in a circle, the conventional symbol for a variable. It will be noticed that the charts are drawn inverted, as the stars appear in an astronomical eyepiece, with north at the bottom, west to the left.

B Cassiopeiæ is Tycho Brahe's New Star of 1572. It can be readily located from the star marked κ (4.3 magnitude), the northernmost, and faintest, of the four stars forming the seat of the "chair." In answer to D. F.'s query in the October POPULAR

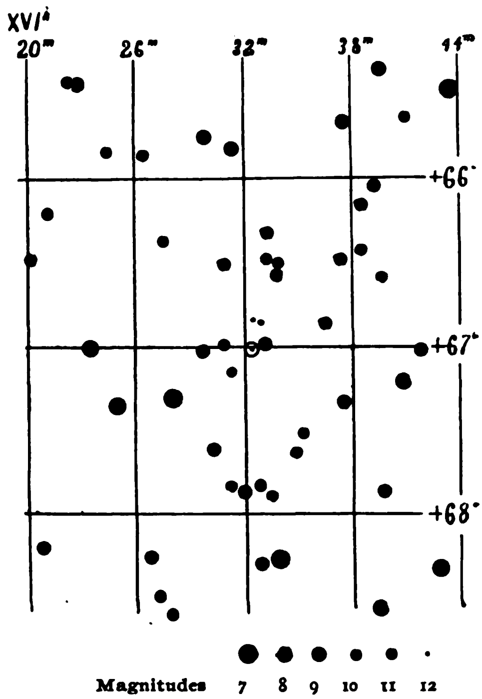
ASTRONOMY page 96, I, would say that if by 30′ Right Ascension he means 30^m, the star he observed was 12^m east of B, if he means 30′ his star was 16^m too far west. There is no star visible exactly in the position given by Tycho, but the two faint stars shown near it should be watched. They were of the 11th or 12th magnitude Nov. 13, 1893, and require a four-inch telescope to see them well. (See October number, p. 91.)

B CASSIOPEIÆ.



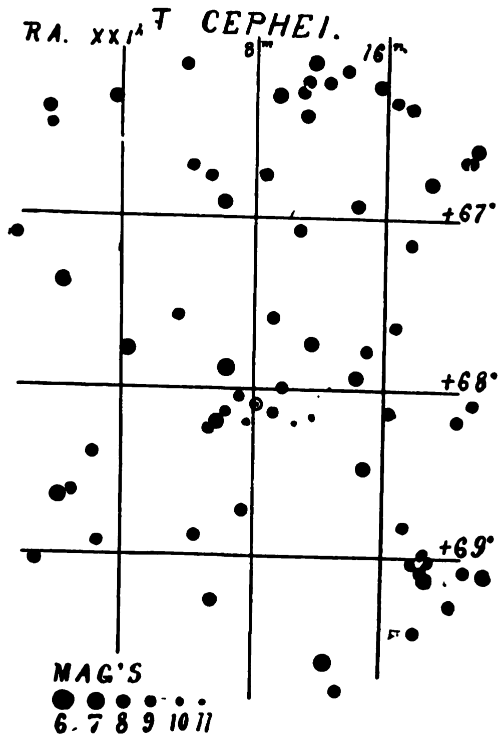
R Draconis is 5° north and ½° east of the third magnitude star η Draconis. T Cephei is 2° south and 1° west of β Cephei (3rd magnitude). All three stars, U Arietis, R Draconis and T Cephei will be near the 9th magnitude in December. Observation should be made and reported.

R DRACONIS.



If the observer has neither Heis', Proctor's nor Klein's atlas, Young's Uranography (Ginn & Co., 35 cents), will be found very convenient for locating variables.

Don't record your observations on slips of paper. Draw sketches and make records in a note book. Date the ob-



servations and record the quality of the seeing. Feel free to ask questions.

In the next paper the list of variables will be extended and methods of reduction given.

MARENGO OBSERVATORY,
1893, Nov. 1.

DANIEL KIRKWOOD.

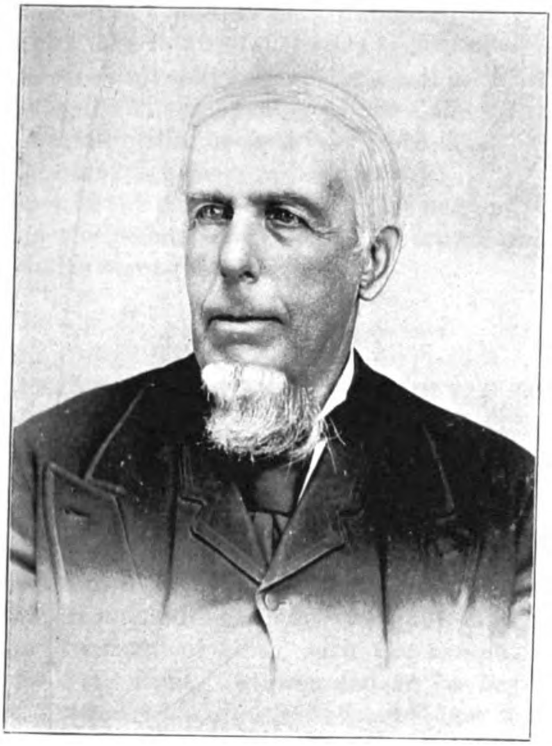
WM. W. PAYNE.

Daniel Kirkwood, the subject of this brief sketch, who resides at Riverside, California, and who is now in feeble health, was born in Harford County, Maryland, September 27, 1814. His parents, John and Agnes (Hope) Kirkwood, were both natives of Maryland, of Scotch-Irish descent, his ancestry having filled positions in the Presbyterian church for nearly two centuries. His father's farm was not very productive, and a residence on it afforded indifferent prospects for acquiring an education. His early efforts with that end in view are remembered as he informs us with mingled emotions of pain and pleasure. The boy in early life planned perhaps sometimes not wisely for the future.

The morning in May, 1822, is well remembered when his sister and himself, with their dinners safely wrapped in a small basket, started to a school kept by a Mr. Roderic Slayman, at Mount Horeb two miles east of his father's place. His mother's admonitions are not forgotten—her cautions in regard to his intimate associates, careful attention to Mr. Slayman's instructions, etc. His reading book (which has been lost for two-thirds of a century) was "*The Economy of Human Life.*" It seemed to have been based on Chinese maxims, the philosophy of Confucius, etc. The New Testament was taken later. Life was then new. Dreams of the future had not yet stirred the young blood. If distant glimpses of the years to come were sometimes caught they were temporary. Several years later the mysteries of numbers were encountered. New questions arose. At nineteen the thought of teaching occurred. A small country school in Hopewell, York County, Penn., was taken. Among his scholars a young man, who subsequently became a successful minister, presented himself. Mr. Kirkwood relates this incident in regard to this young man: "'Do you teach Algebra?" He asked me. I answered, 'No. I have heard it spoken of. The letters of the alphabet are used instead of figures, but I have not learned how to use them.' A neighbor of his had bought an old copy of Bonnycastle's Algebra at a book-auction, and disposed of it to the student. He brought the book with him, and together we solved its mysteries. The next spring, 1834, I found my way to the York County Academy, of which the Rev. Stephen Boyer, an alumnus of Jefferson College, was Principal. He at once assigned me to the Elements of Euclid, and started me on a course of mathematical study. My residence was with Professor Boyer till 1843, his faithfulness as a teacher and as a friend was long appreciated."

In speaking of early years Mr. Kirkwood says the instructors of his youth have been remembered with gratitude. Roderic Slayman, John Sharp, Henry Fulton, Dr. Joshua W. Bennett, John B. Henderson and Rev. Stephen Boyer, A. M., inspired his ambition. To the last named in particular, from early manhood, he felt under strong obligations. Entering his family about 1834, he continued a member till elected Principal of the

PLATE IX.



DANIEL KIRKWOOD.

Lancaster High School, in November, 1843. While in Lancaster, Mr. Kirkwood was united in marriage with Miss Sarah A. McNair. The ceremony was performed by Rev. Alfred Hamilton, Pastor of Fagg's Manor Presbyterian church, Chester County, Pennsylvania, December 25, 1845.

Mr. Kirkwood received the honorary degree of *Master of Arts* from *Washington College*, Pennsylvania, in 1848; and that of *Doctor of Laws* from the *University of Pennsylvania* in 1852. He is the well known author of *Meteoric Astronomy, Comets and Meteors* and *The Asteroids*, published by Lippincott & Co., Philadelphia, 1867—1888. He has been a professor in Delaware College, in the University of Indiana and in Washington and Jefferson College. At the opening of the Leland Stanford, Jr., University, in California, he was invited to accept the appointment of Non Resident Lecturer on Astronomy.

He is now in the eightieth year of his age and still has a lively interest in the recent advancement of science and writes for publication as his strength will allow.

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

JAMES E. KEELER.

III. *Practical Details Relating to the Adjustment and Use of the Instrument.*

A spectroscope like that described in my first article can be made without much difficulty by the amateur possessed of a fair amount of mechanical skill, with the exception of the prism, which may reasonably be assumed to be beyond his powers. Small spy-glasses with objectives from ¾-inch to 1-inch aperture can be bought for less than two dollars apiece, and their objectives are sometimes surprisingly good; at any rate they are good enough for the low power of seven or eight which is all that is required for the spectroscope. One of these spy-glasses will do for the observing telescope, although the terrestrial eyepiece could be advantageously replaced by an astronomical one of about an inch focus, and the other can be transformed into a collimator by removing the eyepiece and fitting a slit into its place. The telescope and prism should be mounted on a small wooden or metal table, in a manner which will readily occur to anyone with a mechanical turn of mind.

The slit requires some careful work, as any little irregularity in its jaws will show in the spectrum. The reason of this is evident; in observing the solar spectrum the slit is very narrow, say not more than a thousanth of an inch wide, and hence a variation of a fraction of this width will make a perceptible difference in the amount of light admitted. The jaws must be filed as straight as possible, and then ground together with fine emery until they fit exactly. In fine instruments the jaws are made of very hard steel or other hard substance to avoid danger of nicking. When they are mounted, one jaw may be held with a single screw so that it can readily be made parallel to the other, or movable one. If the slide of the latter is not carefully fitted, the slit will be liable to open faster at one end than at the other, a fault which is very annoying in observation.

I have referred to the prism as offering special difficulties of construction, and it may be worth while to consider what they are. We have seen that in order to give a distinct image of the slit, *i.e.* a sharp spectral line, the surfaces of the prism must be flat and the glass homogeneous, for otherwise the parallel rays which fall on the prism will not be parallel on leaving it. Now these conditions are not easily met, with the accuracy which is requisite. In ordinary language we speak of a table-top or a window-pane as being flat, but in optics we are held to a much stricter interpretation of "flatness." As all human workmanship is imperfect, it is a matter of great interest to determine *how nearly flat* the surface of a prism must be in order to give good definition, or more generally, how great a deviation is permissible in any optical surface from the true mathematical form which it should have. The answer to this important question is given by the wave-theory of light, and it has been shown that no considerable part of a wave-front of light should be more than a quarter of a wave-length from its proper place. A reflecting surface should therefore be true to within one-eighth of a wave-length, (the light has both to pass into and out of any depression), while a refracting surface of ordinary glass may be in error by half a wave-length without producing a greater error than a quarter wave-length in the refracted wave, the exact amount depending upon the refractive power of the glass. The small effect of oblique incidence of the light is not considered.

These results find immediate application in many practical problems. We may consider, for instance, (to make a slight digression), the highly interesting case of the silvered-glass reflector and inquire whether irregularities in the silver film can injuriously affect the image. Dr. Draper found that the silver film on his mirrors was $\frac{1}{200000}$ of an inch thick, which is about a quarter of a wave-length of light. As variations in the thickness could hardly be supposed to exceed half this amount, and are probably very much smaller, we conclude that the mirror is optically of exactly the same figure as if it were unsilvered.

Returning to the prism, we see that its surfaces should be true to within about half a wave-length, or $\frac{1}{100000}$ of an inch; as there are two surfaces which might possibly act together in producing errors, perhaps we should say to within half this amount.

Exacting as these requirements seem to be, they are easily met, and even greatly exceeded, by modern opticians. I have in my possession a small flat piece of glass by Mr. Brashear, the surface of which has no error exceeding one-twentieth of a wave-length, or about the millionth part of an inch.* Probably this degree of accuracy has never been surpassed. Holding the glass between the fingers instantly destroys the perfection of its figure.

It is possible for the errors in one surface of the prism to correct those in the other, although as the tendency in polishing is to make the surface convex, such a compensation is not likely to occur. Nearly all the older prisms I have examined have convex faces, and sometimes exhibit large and curious irregularities of figure. Such prisms may be serviceable, although they will not give the best results. The accuracy which I have described is equivalent to perfection, and something short of perfection can be tolerated.

If the glass is not homogeneous the parallelism of the rays will likewise be destroyed, and the Fraunhofer lines cannot be brought sharply into focus when the prism is used in the spectroscope. If the surfaces are found to be flat, a prolariscope will generally show strains in the glass, due to imperfect annealing. Only the best optical glass is suitable for fine prisms.

In adjusting the spectroscope, the refracting edge of the prism must be placed perpendicular to the plane containing the collimator and the telescope, *i.e*, vertical, if the prism table is horizontal. Sufficient accuracy can be insured by rotating the prism slightly about the position of minimum deviation, and observing whether the spectrum remains central in the field of the observing telescope as it travels to and fro. If it rises or falls, one of the prism angles requires elevation. A small obstacle

* Such minute errors as this cannot of course be directly measured, or even detected by the common method of testing the reflection from the surface with a telescope. Delicate interference methods must be used.

placed on the center of the slit will produce a strong "dust-line" in the spectrum, which may be of assistance in making this adjustment.

The slit must, as we have seen, be placed in the principal focus of the collimator lens, in order that the rays falling on the prism may be parallel. The usual method of effecting this adjustment is as follows: the telescope is removed from the spectroscope, and focused on a distant object, the eyepiece having first been focused on the cross-wires, if there are any. Then the telescope is placed so as to look directly into the collimator, and the slit is focused until it is distinctly seen; the slit is then (optically) at the same distance as the object on which the focus of the telescope was adjusted.

There is another method of making this adjustment which is more accurate than the preceding one, and which does not require the telescope to be removed from the apparatus. The prism must be movable. To adjust the collimator and telescope by this method the observer should proceed as follows: set the slit by guess, and focus the telescope on some particular line in the spectrum when the prism is in minimum deviation, first focusing the eyepiece on the cross-wires, if there are any, when the same line is in the center of the field. Now rotate the prism slightly, in such a direction that the light falls more obliquely on its first face, so as to displace the line perhaps half the breadth of the field, and move the telescope until the line is in the center of the field again. The line will generally appear much blurred. Focus the telescope until it is seen distinctly, without disturbing the collimator, and then rotate the prism back past the position of minimum deviation, and beyond it, until the same line is brought to the center of the field again, the rest of the apparatus remaining unchanged. The line will probably be blurred. Focus the collimator this time until the line is sharp, and repeat the operation, always focusing the telescope in the first position of the prism and the collimator in the second, until no further change is required. This method is so accurate that the difference of focus of the lenses for different parts of the spectrum can easily be measured.

Since in the first position of the prism the dispersion is less and in the second position greater than in the position of minimum deviation (see the experiment of our first article), we may lay down the following rule for this method of adjustment, in which it is not necessary to remember the angles of incidence on the prism faces; *focus the telescope when the dispersion is diminished,*

and the collimator when it is increased. As the spectrum is always under the eye of the observer, there is no danger of mistaking the position of the prism when this rule is used. If the prism is used in the wrong position every time, the telescopes will get farther and farther out of focus, instead of continually approximating toward it.

The *rationale* of the process is briefly outlined below. Parallel rays falling on a prism remain parallel after passing through it, in all positions of the prism, but rays that are inclined to each other will have their inclination changed, unless the prism is in the position of minimum deviation. Suppose that in setting the slit by guess, it is placed inside the principal focus; then the rays coming from the collimator will *diverge*, as if they came from an object (say) 25 feet away, and the telescope, when focused on the slit, or on the lines in the spectrum with the prism set to minimum deviation, will be adjusted for an object at this distance. When the prism is turned to position 1, the divergence of the rays passing through it is diminished, as if they came from an object (say) 100 feet distant, and if the telescope is now focused on the lines it will be set for an object at this distance, and will be more nearly right than it was before. On turning the prism to minimum deviation, and focusing the slit, the optical distance of the slit will be increased to 100 feet; or by focusing when the prism is in position 2, something still greater, so that by a series of approximations, the optical distance of the slit is made infinite, and the rays emerging from the collimator are parallel. The process described above in general terms is readily followed mathematically.

In observing the Fraunhofer lines it will be noticed that the focus of the telescope has to be changed considerably in passing from one end of the spectrum to the other, although the lenses of both telescope and collimator are nominally achromatic. This change is inconvenient and objectionable, particularly if distances between lines are to be measured, as any disturbance of the adjustments between the settings is liable to introduce errors; but it cannot be helped. With simple lenses, (which it has been suggested might be used in a spectroscope, since each line is formed of monochromatic rays), the difficulty would be very much increased, so that only a very small part of the spectrum could be seen distinctly at one time. For general purposes therefore the lenses should be achromatic, and in a fine instrument the eyepiece should be achromatic also. Even then, as the eye itself is not perfectly achromatic, the cross-wires cannot always be sharply seen without changing the adjustment of the eyepiece.

In the spectroscope which I have described, the Fraunhofer lines are not perfectly straight, but slightly curved, the convex side being turned toward the red end of the spectrum. Rays from the top of the slit are converged to form the lower end of its image and therefore pass obliquely through the prism. Only the rays which come from the centre of the slit and go to the center of the image pass through the prism in a horizontal direction, and as the angle between the sides of the prism is greater in an oblique than in a horizontal section, the oblique rays are slightly more deviated. Formulæ have been obtained for the curvature of the lines, but they are not of much practical use, and indeed very few cases arise in which the curvature has to be considered. In measuring the positions of lines the middle or least deviated points are bisected by the cross-wires.

The spectroscope assumes such a variety of forms that it is impossible in the space at our disposal to describe the different kinds in use. Only a few of them however are really effective, and we may consider the most important of these. In no form are the materials more advantageously applied than in the simple spectroscope which has already been described.

If another prism is added to this spectroscope the deviation and dispersion will be doubled, and the power may be still further increased by adding more prisms. Each prism must be in the position of minimum deviation, and the angle between the faces of adjacent prisms is the same throughout the whole train. As the dispersion is now so great that only a small part of the spectrum can be seen at once in the field of the telescope, the telescope must be moved to bring in any other part, and this involves the readjustment of all the prisms in the train—a very troublesome matter. To avoid the labor of adjustment the prisms are generally linked together in such a manner that each angle changes by the same amount. Assuming that the prisms are all alike, a little consideration will show that the following conditions must be fulfilled: The bases of all the prisms must be tangent to a circle, the diameter of which is variable, depending upon the part of the spectrum observed, and the center of the circle must travel on a line perpendicular to the collimator axis. One of the simplest ways of meeting these conditions is to connect the telescope and collimator by a broad metal spring, to which the bases of the prisms are fastened, and which by its elasticity keeps a circular form when bent, but there are other and probably better ways. Some old spectroscopes with prism trains are very defective in regard to these requirements. The prisms are adjustable in angle by linked tail-pieces, but not in distance from the center. At the ends of the spectrum most of the light is therefore lost. The prism train, ingeniously modified in many different ways, was formerly much used for solar observations where high dispersion is required, but it has now been almost superseded by the diffraction grating.

The compound prism now much used consists of a highly dispersive flint glass prism with large refracting angle (90° or more), enclosed between two thin crown glass prisms placed in reversed positions. The crown glass prisms partially counteract the effect of the dense one. They are cemented to the faces of the flint glass with Canada balsam, as otherwise the light would not emerge from the heavy prism, but would be totally reflected at its inner face.

The direct vision prism used in pocket spectroscopes may be regarded as an extreme case of the same construction, the crown glass wedges being enlarged until they equal the dense prism in refractive power for some middle part of the spectrum, while they do not entirely counteract its dispersion. Sometimes five prisms are put together in the same way, two of them being of flint and three of crown glass. This form of prism is not very efficient, as the same dispersion could be obtained with a much smaller single prism of the ordinary shape, but when the direct view is preferred they are convenient. The pocket spectroscope usually has no collimator,—only a single lens which is focused on the slit, and the rays are not parallel when they pass through the prism. It is a peculiarity of the direct-vision prism, resulting from the symmetry of its construction, that the divergence or convergence of a pencil of rays is not altered by it, and hence it will give distinct vision even when the rays passing through it are not parallel.* In this respect it resembles the single prism used in the position of minimum deviation.

(*To be Continued*).

To drop a pea at the end of every mile of a voyage on a limitless ocean to the nearest fixed star would require a fleet of ten thousand ships of 600 tons burthen, all starting with a full cargo of peas. SIR JOHN HERSCHEL.

---

* The pencil of rays remains *homocentric* after refraction; all the rays produced backward meet in a single point, and are therefore converged by the eye to a single point on the retina. A familiar instance of the confusion resulting from nonhomocentric rays is the difficulty of seeing objects in an aquarium, especially when they are viewed obliquely.

THE YERKES' TELESCOPE.

W. W. PAYNE.

We present elsewhere a fine picture of the Yerkes' telescope, prepared especially for this publication. In the October number of *Astronomy and Astro-Physics*, we gave a frontispiece plate of the same telescope, which is excellent in most particulars, but in some not quite satisfactory. The plate herewith given shows the details of the mounting at the top of the pier more favorable and about as faithfully as can be done by an engraving of the kind. The background, however, does not show in as lively contrast, nor is it as definite in detail as the other picture evidently because most of the objects composing it are farther removed from the telescope. In this picture the telescope is the prominent object as it manifestly ought to be.

Some idea of the size and weight of the different parts of this great telescope may be gained from a statement of the leading facts pertaining to them, as given by Mr. W. R. Warner, of Messrs. Warner & Swasey, of Cleveland, Ohio, in a paper read before the Congress of Astronomy and Astro-Physics at Chicago. The three great telescopes of this country are, the new 26-inch equatorial of the Naval Observatory at Washington, the 36-inch Lick telescope at Mt. Hamilton and the 40-inch Yerkes instrument of Chicago University. In these great telescopes special attention must be given to the manner in which the tubes are made which carry the lenses. The two essential points are, lightness and ridigity, the former for ease of motion, the latter to make the flecture of the tubes as small as possible. The material best calculated to give these two qualities is sheet steel. The form of the tube has much to do with its ridigity, a slight increase in diameter at the center serving to stiffen it, and, on this account thinner material can be used. The following is Mr. Warner's description of the principal features of the mounting:

"The tube for the 40-inch Yerkes telescope is 42 inches in diameter at the objective end, 52 inches at the center, and 38 inches at the eye-end. The sheet steel forming the tube varies from 7.32 inches in thickness at the center to 1.8 inches at the ends. The total weight of the tube is six tons.

The declination axis carrying the tube is of forged steel, 12 inches in diameter and 12 feet long, its weight being 1½ tons. This runs in segmental babbitt bearings in the declination sleeve, which weighs 4 tons. The polar axis carrying the whole system is of hard forged steel, 15 inches in diameter at the upper bearing and 12 inches at the lower bearing, and weighs 3½ tons.

Just above its upper bearing it carries the main driving gear, weighing 1 ton and having 330 teeth, by which the movement of the driving clock is communicated to the polar axis.

The great weight of the bearings of these axes is almost wholly relieved, and the resistance changed from slidng to rolling friction by means of three bracelets or live rings of steel rolls. One of these encircles the declination axis near the tube, and one is placed above each bearing on the polar axis These anti-friction live rings run in steel yokes, and are pressed against the axes by means of adjustable spring levers.

The live ring of rolls which is on the declination axis near the tube is the centre of gravity of the system comprising the tube and the declination axis with their attachments, this one series of rolls serving to take the weight off both bearings of the declination axis, and so nearly eliminating friction that less than one pound of direct pressure on the tube is required for each ton of weight moved. This live ring is composed of 16 inch rolls, 5 inches long, and 3 inches in diameter, and carries a total weight of 8 tons.

The live ring at the upper end of the polar axis is composed of 16 rolls, 6 inches long, and 4 inches in diameter. This sustains a weight of nearly 20 tons. The end-thrust of all this great weight, due to the angle at whieh the axis is placed, is taken on a double series of 40 one-inch hardened steel balls.

The methods of balancing the movable parts of the Yerkes telescope have been a special study, with results which seem all that can be desired.

The heaviest accessory to be used with the telescope is the solar spectroscope. With this in position, the tube is accurately balanced. Weights are then placed on the extension of the declination sleeve until the whole system is in balance. When the solar spectroscope is to be removed sufficient supplementary weights are placed at the side of the eye-end of the tube, so the balance is not disturbed.

The equatorial head and its bearings supporting the polar axis and the entire movable part of the telescope, are cast in one piece, its base conforming to the rectangular shape of the column.

The column is 11 ft. × 5 ft. at the base, tapering to 10 ft. × 5 ft. at the head. It is cast in five sections, having internal flanges for securely bolting it together. In the upper section is placed the driving clock. A spiral staircase at the south side of the column gives easy access to the driving clock, and also to the balcony surrounding the head.

The Driving Clock is governed by a double conical pendulum, mounted isochronously, and making sixty revolutions per minute. A driving weight, considerably in excess of the amount required to drive the telescope, is used with this clock, the surplus of power being taken by a friction ring placed just above the pendulum. The arms of the pendulum are so arranged that in operation they always take their natural and theoretical positions, not being swerved therefrom by the action of the power on the friction ring above mentioned. When the clock is unclamped from the polar axis, all the power required to move the telescope is instantly transferred to the friction ring, and the pendulum maintains its theoretical position and normal rate. An electric motor is provided for automatically winding the clock.

When the 40-inch objective is completed a detailed statement about it of interest to the general reader will be given. The lenses are now in the hands of Mr. Alvan G. Clark, of Cambridgeport, Mass., who is working on the local corrections necessary to the high excellence which is always found in the Clark lenses.

VISUALIZING THE EARTH'S ANNUAL MOTION.

ELIZA A. BOWEN.

My design in writing this article is to show how the Earth's annual motion can be visualized.

We can fix with exactness the position which the Earth has at any time relative to the Sun, by supposing a straight line passing through the centers of the two bodies, and then finding the two points through which it would extend among the stars on the celestial sphere. Such a line, passing through the Sun, the center of that sphere, would be a diameter of it, and the two points must be 180° apart. The method of finding such points with instruments is easy to understand, but it is in books, and to explain it here would make this article too long. Those who have made the measurements tell us that during the latter part of December, such a line through the centers of the Earth and Sun, would reach a point in the constellation Sagittarius on the side of the Sun; and on the side of the Earth, a point in Gemini.

The observer should first go out at sunset. He can imagine the line spoken of as touching the celestial horizon behind the center of the Sun, then passing through the Sun and Earth, and touching the celestial horizon in the East. Sagittarius, of course, is obscured by the Sun, which appears to be on the celestial sphere. This appearance, however, is due to perspective. We know, because the Earth has been between Saggittarius and the Sun, that the constellation is at a very great distance from the Sun, and the observer must get this fact firmly fixed in his mind.

The observer sees that the constellations of the zodiac form a ring round the heavens, and that the Earth's path, or orbit, lies within this ring. But those persons who have discovered all the points on the sphere which, during a year, would be successively reached by the lines through the centres of Earth and Sun, tell us that they lie on the circumference of a great circle extending along the middle of the zodiac. The area within the circumference of a circle is a plane, therefore the Earth's center moves round the Sun in one plane. This plane is called the ecliptic, and the circle is called the circle of the ecliptic.

At any sunset, the Earth's path for the previous six months always lies in the space above us, a great semi-circle (nearly) with one end beyond the opposite side of the Sun, and the other coming down to the centre of the Earth. The band, or ring, of zodiacal constellations shows the direction of this path.

The part of the plane of the ecliptic which appears to lie within the celestial sphere is surrounded by the circle of the ecliptic. The line of this circle extends along the middle of the band or ring of the zodiacal constellations. The axis of the celestial sphere is a line passing through the poles of the heavens and through the centre of the plane of the ecliptic. You cannot see the axis, but you can identify its northern extremity by the pole star.

Numeration of the Asteroids discovered in 1893.—Numbers have recently been assigned to twenty-one of the asteroids discovered by photography this year. Seven others designated 1893 C, D, M, O, U, X, and Y, were not sufficiently observed to permit of determining their elliptic orbits. They therefore receive no numbers. The asteroid 1893 Q has been found to be identical with (104) Klymene, Z with (175) Andromache, AF with (158) Koronis, and AG with (107) Camilla.

The numbers assigned are as follows:

1893 A	Jan. 17	Charlois	354	1893 S	Mar. 17	Charlois	363
B	12	Wolf	352	T	19	"	364
E	20	Charlois	356	V	21	"	365
F	16	Wolf	353	W	21	"	366
G	21	Charlois	355	AA	May 20	"	367
J	Feb. 11	"	357	AB	20	"	368
K	Mar. 8	"	358	AC	July 14	"	370
L	9	"	359	AD	16	"	371
N	11	"	360	AE	5	Borrelly	369
P	11	"	361	AH	Aug. 19	Charlois	372
R	17	"	362				

THE FACE OF THE SKY.

CHARLOTTE R. WILLARD.

Six o'clock December twentieth will afford a convenient opportunity for making thought definite in regard to sidereal time. We say it is noon when the sun is on our meridian, just so it is sidereal noon when the "First of Aries" is on the meridian; this will occur at six o'clock on the day named. Noticing carefully what stars are crossing the meridian at this time the brighter ones are, one in the base of the Great Dipper (γ Ursæ Majoris), the most western star in Cassiopeia (β) and one of the western stars in the Square of Pegasus (α Andromedæ). It will be noticed that the line of these stars passes through the pole star, and is perpendicular to the horizon; it will be of interest to observe these one, two and three hours later noticing the angle which their line then makes with the perpendicular drawn through the pole to the horizon; practice will enable one to estimate this angle with a fair degree of accuracy and so to determine approximate sidereal time. Sidereal noon comes nearly four minutes earlier on each succeeding night. The distance from β Cassiopeiæ to α Andromedæ is 30°, following their line for nearly 30° farther south, we locate the intersection of the celestial equator and the ecliptic (*i. e.* The First of Aries). The equator may be traced from this point to the east passing close to the star δ Orionis and to the west passing 9° below Altair (α Aquilæ). The ecliptic passes eastward between the Hyades and Pleiades, and to the west a few degrees above the second magnitude star δ Capricorni.

The most beautiful of all constellations and the most brilliant of fixed stars will be noticeable objects in the western sky during the coming month. The star Sirius will rise at about seven o'clock on the first of January, preceding it by two hours is the very striking constellation Orion, sometimes described as a kite. The central part of this constellation is marked by the belt of Orion, a line of three second magnitude stars (δ, ε and ζ). Two first magnitude stars are located symmetrically north and south of this line—the northern Betelgeuse (α Orionis) and the southern one Rigel (β Orionis). It is interesting to notice that β is now brighter than α. About 8° preceding α is γ, a second magnitude star, these two mark the shoulders of Orion, and between them is a group of three fainter stars forming the head. From the belt depend three stars known as the sword. Rigel is one of the many double stars of this constellation; its components are of first and ninth magnitude, they have been distinctly seen with a 4½-inch telescope and just detected with a 1½-inch. δ is a double with magnitudes 2 and 7. σ, a faint star below ζ, is triple, the magnitudes being 4, 8 and 7; it has been seen as triple with a 4⅞-inch glass. Rigel and ε are said to be moving directly away from us at rates respectively of 39 and 35 English miles a second, and yet so immense is their distance that they seem to shine with undiminished light from night to night. θ, the middle star of the sword, is really two stars θ and θ'; θ' is of peculiar interest. "On very slight telescopic persuasion it allows itself to be seen as quadruple;" these four stars respectively 5, 6, 7 and 8 in magnitude form the well known trapezium of the great nebula of Orion. Two and a half centuries of observations cannot detect the slightest shifting of their positions, and seem to declare their distances enormous even on the scale of stellar distances. Two other much fainter stars have been seen in the group by aid of glasses of 3 and 4 inch aperture. "The whole frame work of the great nebulous structure in the Sword of Orion seems to rest upon this stellar group." This is one of the many cases where multiple stars seem to bear close relation to nebulæ; such cases suggest the question as to whether the formation of a double in the nebulous field may not be the first step toward the formation of crowded clusters like the Pleiades. Space will not admit of a description of the Great Nebula—it is appearing greater and greater as improved instruments push its boundaries farther from the centre.

Sirius is by far the brightest of all fixed stars, for this reason astronomers have from earliest time paid much attention to problems concerning it. The story of their slow yet marvelous progress in its study is most fascinating. It was found to have a measurable parallax, its distance was calculated, its motion, though apparently slight, was found to be disturbed, and astronomers said "Sirius has a companion which no man has seen." This companion was studied and its motions confidently described for twenty years before any man succeeded in seeing it. Faith was the evidence of things not seen. It was first seen in 1862 by an 18-inch glass. Sirius is believed to emit forty times as much light as our Sun. The companion is strangely lacking in brilliancy.

PLANET NOTES FOR JANUARY.

H. C. WILSON.

Mercury having been at greatest western elongation Dec. 14 will in January be too close to the Sun for observation. He will be at superior conjunction Jan. 29 at 6^h 36^m A. M.

Venus which has been such a brilliant object in the early evening sky during the past month will be still more brilliant during the first part of January. This planet will attain its maximum brilliancy on Jan. 10 when the light will be 218 as compared with 145 on December 1. The position of Venus is becoming a little more favorable for observation in northern latitudes, as the planet moves northward in declination. Venus and the crescent Moon will be in conjunction on the morning of Jan. 10 and the two will form a pretty pair on that evening and the preceding.

Mars will be morning planet during January, visible in the southeast after five o'clock. The low altitude will prevent good observations in our latitude, but south of the equator something may be done in the study of the surface markings of the planet. Mars and the waning Moon will be in conjunction on the morning of Jan. 3, the latter passing 4° south of the former.

Jupiter will be in excellent position for observation during the first half of the night in January. The planet will be stationary among the stars of Taurus on Jan. 15, after which it will move slowly eastward.

Saturn is getting into better position for observation in the morning but the majority of observers will prefer to wait two or three months until the planet is visible in the evening. Saturn will be at quadrature, 90° west from the Sun, Jan. 14. Saturn is in the constellation Virgo a little northeast of Spica and is moving very slowly eastward. The Moon will be 4° south of Saturn at noon Jan. 27.

Uranus is in the constellation Libra a little way east of the star α. It is not yet in very good condition for observation in our latitude.

Neptune having passed opposition in December will be in excellent position for observation in January. It will move very slowly westward during the month, the position January 1 being a little more than ⅛ of the distance on a straight line from ι to ε Tauri. There is no star of equal brightness within a radius of 1°.

Planet Tables for January.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Jan. 5	18 06.0	− 24 00	6 44 A. M.	11 04.9 A. M.	3 25 P. M.
15	19 14.0	− 23 53	7 12 "	11 33.3 "	3 54 "
25	20 24.1	− 21 26	7 31 "	12 04.0 P. M.	4 37 "
			VENUS.		
Jan. 5	22 01.3	− 11 39	9 43 A. M.	2 59.5 P. M.	8 16 P. M.
15	22 18.6	− 8 06	9 06 "	2 37.6 "	8 09 "
25	22 23.6	− 5 16	8 21 "	2 03.2 "	7 46 "
			MARS.		
Jan. 5	16 04.4	− 20 33	4 26 A. M.	9 03.6 A. M.	1 41 P. M.
15	16 33.2	− 21 49	4 22 "	8 53.0 "	1 24 "
25	17 02.6	− 22 47	4 16 "	8 43.0 "	1 10 "
			JUPITER.		
Jan. 5	3 17.6	+ 17 16	1 00 P. M.	8 15.0 P. M.	3 30 A. M.
15	3 17.0	+ 17 16	12 20 "	7 35.0 "	2 50 "
25	3 17.7	+ 17 22	11 41 A. M.	6 56.3 "	2 12 "
			SATURN.		
Jan. 5	13 34.8	− 7 12	12 59 A. M.	6 33.8 A. M.	12 09 P. M.
15	13 35.8	− 7 19	12 22 "	5 56.1 "	11 30 A. M.
25	13 36.8	− 7 21	11 43 P. M.	5 17.7 "	10 52 "
			URANUS.		
Jan. 5	14 48.6	− 15 49	2 49 A. M.	7 48.1 A. M.	12 47 P. M.
15	14 49.9	− 15 55	2 12 "	7 10.1 "	12 09 "
25	14 51.0	− 15 59	1 33 "	6 31.8 "	11 30 A. M.
			NEPTUNE.		
Jan. 5	4 39.8	+ 20 36	2 04 P. M.	9 36.9 P. M.	5 09 A. M.
15	4 39.0	+ 20 35	1 24 "	8 56.8 "	4 29 "
25	4 38.3	+ 20 34	12 44 "	8 16.8 "	3 59 "
			THE SUN.		
Jan. 5	19 07.1	− 22 34	7 38 A. M.	12 05.8 P. M.	4 34 P. M.
15	19 50.5	− 21 02	7 35 "	12 09.8 "	4 45 "
25	20 32.8	− 18 50	7 27 "	12 12.6 "	4 58 "

Phases and Aspects of the Moon.

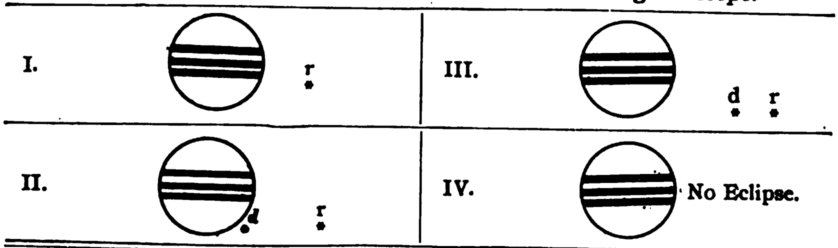
		d	*Central Time.* h m
Apogee	Jan.	5	6 00 A. M.
New Moon	"	6	9 07 P. M.
First Quarter	"	14	6 09 P. M.
Perigee	"	20	9 12 A. M.
Full Moon	"	21	9 12 A. M.
Last Quarter	"	28	10 51 A. M.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

Jan.	h m		h m		h m
2	12 40 A. M.	12	6 48 P. M.	22	5 06 P. M.
2	8 31 P. M.	14	12 36 A. M.	23	10 53 "
3	4 23 "	14	8 27 P. M.	24	6 45 "
4	10 10 "	15	5 18 "	26	12 31 A. M.
5	6 01 "	16	10 06 "	26	8 24 P. M.
6	11 48 "	17	5 57 "	27	4 15 "
7	7 40 "	18	11 44 "	28	10 02 "
9	1 27 A. M.	19	7 36 "	29	5 54 "
9	9 18 P. M.	21	1 22 A. M.	30	11 41 "
10	5 10 "	21	9 14 P. M.	31	7 33 "
11	10 57 "				

Jupiter's Satellites for January.

Phases of the Eclipses of the Satellites for an Inverting Telescope.



Configuration at 9h for an Inverting Telescope.

Day.	West		East.
1	2· 1·	O	3· 4·
2	·2	O	3·1· 4·
3	3· ·1	O	4· ·2
4	3·	4· O	2· 1·
5	2· 4· ·3 ·1	O	
6	4· 1·	O	·3 ·2●
7	4·	O	·1 2· ·3
8	4· 2· 1·	O	3·
9	·4 ·2	O	3· ·1
10	·4 3· ·1	O	·2
11	3· ·4	O	2· 1·
12	·3 2· ·1 ·4	O	
13	O1· ·3	O	·4 ·2●
14		O	2· ·3 ·4 ·1●
15	2· 1·	O	3· ·4
16	·2	O	·1 3· ·4
17	1· 3·	O	·2 4·
18	3·	O	2· 1· 4·
19	·3 2· ·1	O	4·
20	·2 ·3	O	1· 4·
21	4·	O	·2 3· ·1●
22	4· 1·2·	O	·3
23	4· ·2	O	·1 3·
24	4· 1· 3·	O	·2
25	·4 3·	O	1·2·
26	·4 ·3 2· ·1	O	
27	·4 ·3·2	O	1·
28	·4 ·1	O	·3 ·2
29	O2· 1·	O 4	·3
30	·2	O	·1 ·43·
31	O3· 1·	O	·2 ·4

In the preceding diagram the light discs in the middle vertical row represent the planet Jupiter. The numbers give the relative positions of the satellites respectively and the periods near them their direction of motion. The black discs on the right with the numbers show which satellites are occulted or eclipsed; the light discs on the left, which are in transit on the face of Jupiter. The letters *r* and *d* at the top of the page mean reappearance and disappearance respectively.

Phenomena of Jupiter's Satellites.

Central Time.

		h m			
Jan.	5	12 07	A. M.	II	Tr. In.
		12 18	"	I	Tr. In.
		1 22	"	I	Sh. In.
		2 13	"	II	Sh. In.
		2 28	"	II	Tr. Eg.
		2 30	"	I	Tr. Eg.
		3 34	"	I	Sh. Eg.
		9 32	P. M.	I	Oc. Dis.
	6	12 47	A. M.	I	Ec. Re.
		6 38	P. M.	II	Oc. Dis.
		6 46	"	I	Tr. In.
		6 48	"	III	Oc. Dis.
		7 51	"	I	Sh. In.
		8 37	"	III	Oc. Re.
		9 58	"	I	Tr. Eg.
		10 03	"	I	Sh. Eg.
		11 05	"	II	Ec. Re
		11 18	"	III	Ec. Dis.
	7	12 57	A. M.	III	Ec. Re.
		4 00	P. M.	I	Oc. Dis.
		7 16	"	I	Ec. Re.
	8	4 32	"	I	Sh. Eg.
		5 54	"	II	Sh. Eg.
	12	11 23	"	I	Oc. Dis.
	13	2 43	A. M.	I	Ec. Re.
		8 35	P. M.	I	Tr. In.
		9 03	"	II	Oc. Dis.
		9 46	"	I	Sh. In.
		10 27	"	III	Oc. Dis.
		10 48	"	I	Tr. Eg.
		11 25	"	II	Oc. Re.
		11 26	"	II	Ec. Dis.
		11 58	"	I	Sh. Eg.
	14	12 19	A. M.	III	Oc. Re.
		1 41	"	II	Ec. Re.
		5 50	P. M.	I	Oc. Dis.
		9 12	"	I	Ec. Re.
	15	3 03	"	I	Tr. In.
		3 49	"	II	Tr. In.
		4 14	"	I	Sh. In.
		5 15	"	I	Tr. Eg.
		6 11	"	II	Tr. Eg.
		6 11	"	II	Sh. In.
Jan.	15	6 27	P. M.	I	Sh. Eg.
		8 33	"	II	Sh. Eg.
	17	5 22	P. M.	III	Sh. In.
		7 15	"	III	Sh. Eg.
	20	10 26	"	I	Tr. In.
		11 30	"	II	Oc. Dis.
		11 41	"	I	Sh. In.
	21	12 39	A. M.	I	Tr. Eg.
		7 42	P. M.	I	Oc. Dis.
		11 08	"	I	Ec. Re.
	22	4 54	"	I	Tr. In.
		6 10	"	I	Sh. In.
		6 21	"	II	Tr. In.
		7 07	"	I	Tr. Eg.
		8 22	"	I	Sh. Eg.
		8 43	"	II	Tr. Eg.
		8 50	"	II	Sh. In.
		11 12	"	II	Sh. Eg.
	23	5 37	"	I	Ec. Re.
	24	5 35	"	II	Ec. Re.
		6 09	"	III	Tr. Eg.
		9 24	"	III	Sh In.
		11 18	"	III	Sh. Eg.
	28	12 19	A. M.	I	Tr. In..
		1 36	"	I	Sh. In.
		2 00	"	II	Oc. Dis.
		9 35	P. M.	I	Oc. Dis.
	29	1 04	A. M.	I	Ec. Re.
		6 47	P. M.	I	Tr. In.
		8 05	"	I	Sh. In.
		8 54	"	II	Tr. In.
		8 59	"	I	Tr. Eg.
		10 18	"	I	Sh. Eg.
		11 17	"	II	Tr. Eg.
		11 29	"	II	Sh. In.
	30	1 50	A. M.	II	Sh. Eg.
		4 04	P. M.	I	Oc. Dis.
		7 33	"	I	Ec. Re.
	31	5 39	"	II	Oc. Re.
		5 55	"	II	Ec. Dis.
		8 03	"	III	Tr. In.
		9 11	"	II	Ec. Re.
		10 03	"	III	Tr. Eg.

Occultations Visible at Washington.

Date 1894.		Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration. h m
Jan.	11	χ Aquarii	5½	6 52	89	7 48	198	0 56
	18	136 Tauri	5	16 16	105	17 05	266	0 49
	19	W. VI, 1656	8	17 08	140	17 48	247	0 40
	20	e Geminorum	6	4 49	110	5 38	254	0 49
	20	ω^1 Cancri	6	12 19	83	13 25	319	1 06
	20	ω^2 Cancri	6	12 54	129	14 04	273	1 10

Elongations of the Satellites of Saturn.

(The western elongations will be found approximately half way between the eastern and other positions may be easily interpolated.)

MIMAS.

		h		
Jan.	2	5.7	A. M.	W
	3	4.3	"	W
	4	2.9	"	W
	9	7.3	"	E
	10	6.0	"	E
	11	4.6	"	E
	12	3.2	"	E
	13	1.8	"	E
	17	7.6	"	W
	18	6.2	"	W
	19	4.9	"	W
	20	3.5	"	W
	21	2.1	"	W
	25	7.9	"	E
	26	6.5	"	E
	27	5.1	"	E
	28	3.7	"	E
	29	2.3	"	E

ENCELADUS.

Jan.	2	2.2	A. M.	E
	3	11.9	"	E
	4	7.9	P. M.	E
	6	4.8	A. M.	E
	7	1.7	P. M.	E
	8	10.6	"	E
	10	7.5	A. M.	E
	11	4.3	P. M.	E
	13	1.2	A. M.	E
	14	10.1	"	E
	15	7.0	P. M.	E
	17	3.9	A. M.	E
	18	12.7	P. M.	E
	19	9.6	P. M.	E

ENCELADUS Cont.

		h		
Jan.	21	6.5	A. M.	E
	22	3.4	P. M.	E
	24	12.3	A. M.	E
	25	9.1	"	E
	26	6.0	P. M.	E
	28	2.9	A. M.	E
	29	11.8	"	E
	30	8.7	P. M.	E
Feb.	1	5.5	A. M.	E

TETHYS.

Jan.	2	11.7	P. M.	E
	4	9.0	"	E
	6	6.3	"	E
	8	3.6	"	E
	10	12.9	"	E
	12	10.2	A. M.	E
	14	7.5	"	E
	16	4.8	"	E
	18	2.1	"	E
	19	11.4	P. M.	E
	21	8.7	"	E
	23	6.0	"	E
	25	3.3	"	E
	27	12.6	"	E
	29	9.9	A. M.	E
	31	7.2	"	E

DIONE.

Jan.	2	12.7	P. M.	E
	5	6.3	A. M.	E
	7	midn.		E
	10	5.7	A. M.	E
	13	11.4	A. M.	E

DIONE Cont.

		h		
Jan.	16	5.0	"	E
	18	10.7	P. M.	E
	21	4.4	"	E
	24	10.1	A. M.	E
	27	3.7	"	E
	29	9.4	P. M.	E

RHEA.

Jan.	2	5.0	P. M.	E
	7	5.4	A. M.	E
	11	5.9	P. M.	E
	16	6.1	A. M.	E
	20	6.5	P. M.	E
	25	6.9	A. M.	E
	29	7.3	P. M.	E

TITAN

Jan.	3	8.2	P. M.	S
	7	3.5	"	E
	11	1.2	"	S
	15	5.0	"	W
	19	7.1	"	S
	23	2.3	"	E
	27	noon		I
	31	3.6	"	W

HYPERION.

Jan.	6	3.9	A. M.	E
	12	12.1	P. M.	I
	17	8.5	"	W
	22	6.3	A. M.	S
	27	10.1	"	E

IAPETUS.

Jan.	20	4.3	P. M.	E
Feb.	7	10.5	"	I

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

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

Jan.	5	1 A. M.
	9	midn.
	14	"
	19	"
	24	11 P. M.
	29	11 "

ALGOL.

R. A. .... $3^{h}\ 1^{m}\ 1^{s}$
Decl. .... $+42°\ 32'$
Period .... $2d\ 20^{h} 49^{m}$

Jan.	2	2 A. M.
	4	11 P. M.
	7	8 "
	10	5 "
	22	4 A. M.
	25	1 "
	27	10 P. M.
	30	7 "

R. CANIS MAJORIS.

R. A. .... $7^{h}\ 14^{m}\ 30^{s}$
Decl. .... $-16°\ 11'$
Period .... $1d\ 3^{h}\ 16^{m}$

Jan.	1	9 P. M.
	2	midn.
	4	3 A. M.
	9	7 P. M.
	10	11 "
	12	2 A. M.
	13	5 "
	17	6 P. M.
	18	10 "
	20	1 A. M.
	21	4 "
	26	8 P. M.
Jan.	27	midn.
	29	3 A. M.
	30	6 "

S CANCRI.

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

Jan.	7	4 P. M.
	17	3 A. M.
	26	3 P. M.

S ANTLIÆ.

R. A. .... $9^{h}\ 27^{m}\ 30^{s}$
Decl. .... $-28°\ 09'$
Period .... $0d\ 7^{h}\ 27^{m}$

Jan.	1	2 A. M.
	2	1 "
	2	midn.
	3	"
	4	11 P. M.
	5	10 "
	6	10 "
	7	9 "
	8	5 A. M.
		8 P. M.

S. ANTLIÆ CONT.

Jan. 9	4 A. M.	
	8 P. M.	
10	4 A. M.	
	7 P. M.	
11	3 A. M.	
12	2 "	
13	2 "	
14	1 "	
14	midn.	
15	"	
16	11 P. M.	
17	10 "	
18	10 P. M.	
19	5 A. M.	
	9 P. M.	
20	5 A. M.	
	8 P. M.	

S. ANTILÆ CONT.

Jan. 21	4 A. M.
	8 P. M.
22	3 A. M.
23	3 "
24	2 "
25	1 "
26	1 "
26	midn.
27	11 P. M.
28	11 "
29	10 "
30	9 "
31	9 "

δ LIBRÆ.

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

Jan. 2	1 A. M.
9	1 "
15	midn.
22	"
29	11 P. M.

U. CORONÆ.

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

Jan. 11	7 A. M.
18	4 "
24	2 "
31	midn.

COMET NOTES.

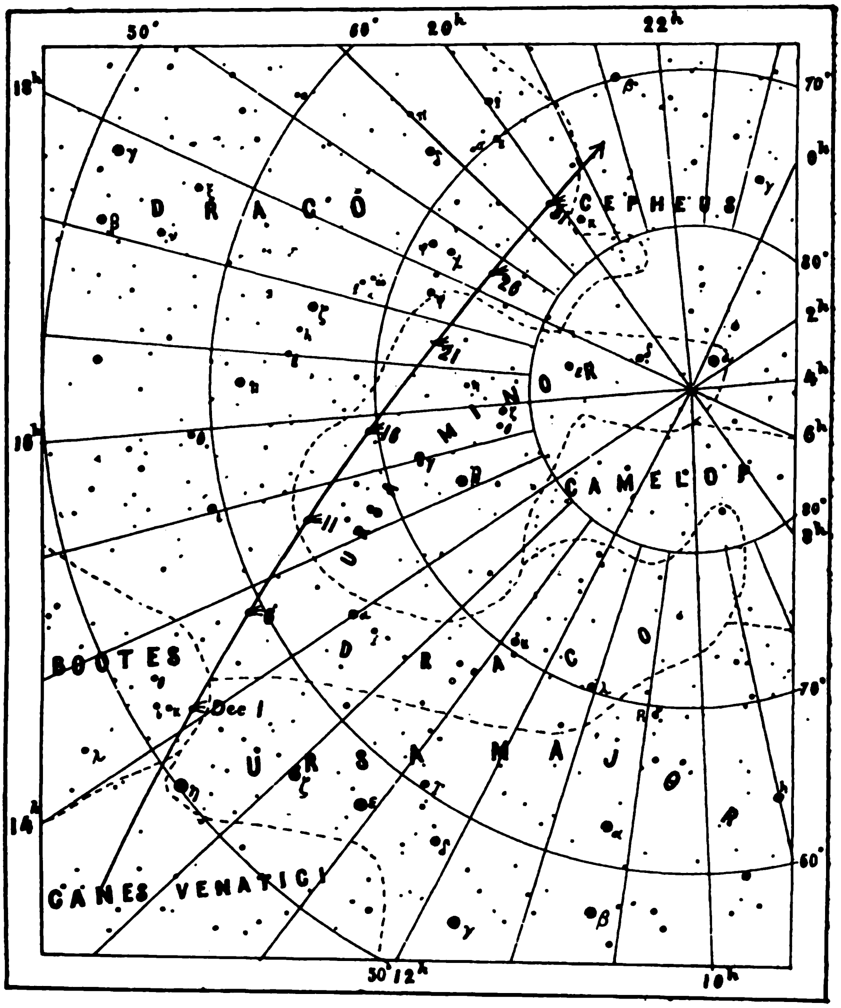
Elements and Ephemeris of Comet *c* 1893.—I send you herewith elements and ephemeris of Comet *c* by Mr. Phillips Isham and myself.

$$\left.\begin{aligned} T &= \text{Sept. } 19.3055 \text{ Berlin M. T.} \\ \Omega &= 174^\circ\ 54'\ 21'' \\ i &= 129\ \ 47\ \ 44 \\ \omega &= 347\ \ 33\ \ 10 \\ \log q &= 9.91033 \end{aligned}\right\} 1893.0$$

Berlin midn.		α app. h	m	s	δ app. °	′	log Δ
Dec.	1.5	14	03	53	+ 53	15.1	0.119
	2.5		08	27	54	23.9	
	3.5		13	15	55	32.7	0.118
	4.5		18	21	56	41.4	
	5.5		23	44	57	50.0	0.117
	6.5		29	25	58	58.4	
	7.5		35	25	60	06.2	0.118
	8.5		41	48	61	13.2	
	9.5		48	35	62	19.4	0.119
	10.5		55	50	63	24.8	
	11.5	15	03	33	64	28.8	0.120
	12.5		11	48	05	31.0	
	13.5		20	36	66	31.9	0.122
	14.5		29	59	67	31.7	
	15.5		40	03	68	29.0	0.125
	16.5		50	52	69	23.4	
	17.5	16	02	26	70	15.3	0.130
	18.5		14	47	71	04.4	
	19.5		27	57	71	50.2	0.136
	20.5		41	59	72	32.4	
	21.5		56	50	73	10.7	0.143
	22.5	17	12	30	73	45.0	
	23.5		28	57	74	14.9	0.149
	24.5		46	06	74	40.2	
	25.5	18	03	43	75	00.5	0.156
	26.5		21	34	75	16.1	
	27.5		39	38	75	26.5	0.164
	28.5		57	53	75	32.5	
	29.5	19	15	53	75	33.8	0.172
	30.5		33	28	75	30.7	
	31.5		50	33	+ 75	23.3	0.181

J. G. PORTER.

Comet Brooks (*c* 1893).—This comet, discovered by the writer on Oct. 16, has been observed on every possible occasion, and we have been favored with an unusually fine autumn in this locality—unusual in the great number of clear days and nights. Although the comet had passed perihelion at the time of discovery, it has held its light well, and has been a conspicuous telescopic comet. On the morning of Oct. 21, 17^h, the comet appeared brighter than at any previous observation. The tail could be easily traced to a distance of 3½°.



PATH OF COMET *c* 1893 (BROOKS) THROUGH THE CONSTELLATIONS FOR DECEMBER.

Some interesting changes have been noticed in the shape and structure of the tail. Its normal appearance might have been called straight, but on the morning of Oct. 21, 17^h (when the comet appeared at its brightest here), there was a sharp curve in the tail close to the head towards the south, and a faint secondary tail was seen issuing from the head at an angle of 30° to the main tail towards the north.

Bright moonlight then interfered for several days, but when the comet was seen again, on Nov. 4, its tail had assumed its usual straight form with only slight curvature towards the extreme end. On Nov. 9, 17^h, however, another decided and interesting change was detected in the formation of the tail. It was straight for a length of half a degree from the head, where it became forked, the larger portion curving gracefully to the south, the fainter part straight or nearly so, branching to the north, the two branches making an angle with each other of about 25°. The comet on this occasion was bespangled with numerous small stars, forming altogether a most charming telescopic picture.

WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y., Nov. 14, 1893.

PRACTICAL SUGGESTIONS.

It is thought best to give some space each month to queries and answers pertaining to astronomical themes. Contributors are requested to remember this corner and to write briefly and frequently for it.

2. Are the rising and the setting of the heavenly bodies the same in Eastern time as in Central? M. B. T. H.

Answer: The times of rising and setting of planets at any given place would be one hour later by Eastern than by Central time. The times given in our tables for these phenomena are local times for places in latitude 44° 28′, and are practically the same for the whole of the United States.

3. In the case of phenomena that do not depend on the rotation of the Earth, as the minima of Algol, is the longitude of the place necessarily considered? M. B. T. H.

Answer: No.

4. Given a 4-inch telescope, so good that it will easily resolve α Scorpii, or α Lyræ with a power of 95, and will separate π Arquilæ (1″.7), or ε Arietis (1″.3) with a power of 180 on any good night. If the above aperture be cut down to 2 inches by an annular diaphragm, it will resolve Rigel with a power of 95, If a stop be applied cutting out the central 2 inches, the glass will resolve Rigel with difficulty. A central stop cutting out 2¾ inches, but exposing a margin of more than twice the area of the first central two inches will fail to resolve Rigel. Do all good objectives suffer in like degree from uncorrected spherical aberration? The above seems to indicate that the central 2 inches of a 4-inch glass will resolve more than a whole 3-inch objective, especially on a bright object. S. G. S.

Answer:—In answering this question, I would say that there is some ambiguity about the question itself. That a central 2″ area of a high class objective should do better work than the whole of a 3″ high class objective is utterly impossible. The only thing that it would indicate is that there is something wrong with the 3″ objective. Diaphragms will not improve a first class objective, the fact of the matter is that the old fashioned way of testing the goodness of an objective is possibly good enough for one that has spherical aberration, but I have all along insisted that it is not the way to test a first class objective.

It is true that to explain the reason why to an amateur, is rather a dfficult matter as it involves the phenomena of interference which in a telescope is a function of the limiting aperture.

If the objective of S. G. S. is a first class objective the reason that it will not show companions to stars with an annular ring of the objective exposed, is that the limiting aperture gives extra thickness to the diffraction rings and robs the star discs of the light that would otherwise go into them.

I have always insisted, and in this I believe I have the best observers on my side, that a thoroughly corrected objective will always show more with its full aperture than when diaphramed down. J. A. B.

5. What are the practical difficulties in the way of better eyepieces? Do not expert opticians prefer to temper the objective to the eyepiece rather than to attack the latter and attempt to improve it? The negative eyepiece is fair, but is it not much behind objectives in perfection? S. G. S.

Answer: In answer to this question I might say that there is no difficulty in the way of making good eyepieces for telescopes, although I find that the best observers prefer to use the good old fashioned Ramsden positive and Huygenian negative eyepiece. For high powers, indeed for all negative eyepieces above ¾ inch equivalent focus. the writer prefers the solid eyepiece. They give nearly one-third more light, have but two surfaces to reflect the light back again, and the definition in the center of the field with a good objective is of the highest class.

He would be a sorry optician who would "temper the objective to suit the eyepiece." I know such a method has been advocated, but what if you temper an objective to suit the various kinds of eyepieces used? The optician would have a more difficult contract to fulfil than he now has, and as it is the conditions are difficult enough. J. A. B.

6. There is a faint star in Cassiopeia not far from $\varkappa$, the location of Tycho's Nova, as given by Dr. Klein which I have been watching for a week, and can find nothing to correspond with it in Klein's map and D'Arrest's chart. Is it not worth the while of observers to examine it? Its position roughly is 30′ right ascension and 63° 20′ declination. B. F.

Answer: A photograph of the constellation Cassiopeia taken at Northfield, Sept. 21, with the 2½-inch camera shows no star brighter than 8 or 9 magnitude near the places of Tycho's Nova. See also page 166.

7. What is the latitude and the longitude of Goodsell Observatory, Carleton College?

Answer: Latitude $= + 44° 27' 41''.6$; longitude $= 6^h 12^m 35^s.86$ west from Greenwich.

8. Would it not make your predictions of current celestial phenomena more valuable to the average person if reduced to Central Standard time?

Answer: The times of all the phenomena are reduced to central time except the times of rising and setting of the planets and those of occultations The times of rising and setting depend upon the location of the observer and the central times of these are different for every different longitude, while the local times are practically the same for all places in nearly the same latitude. To obtain the standard times the observer has only to apply the reduction from local to standard time for his own place.

The times of occultations vary so much, because of parallax, as seen from different places, that we have not thought it worth the while to reduce them to standard time, which would be correct only for Washington.

9. Will you kindly inform me through your question and answer column, what is the exact course of the light rays through a photographic portrait lens? No books to which I have access give a satisfactory diagram. I am using a Darlot lens of this description for stellar photography, and it is of course important to take advantage of the full aperture. The question has arisen, whether there is a loss of light from the fixed diaphragm between the lenses. I suppose that there is no doubt that the definition of an ordinary commercial lens is improved by it, but is there not a certain loss of light, even if its aperture is as great as a section of the cone of rays from the front lens. My "Shoptician," as Leckey calls a mere dealer in optical wares, insists that the rays cross between the lenses and that therefore quite a small stop may be used at the point of intersection. This seems to me to be nonsense, as the focus of the front lens is more than ten times as long as the distance between it and the diaphragm referred to, and yet I confess that I do not see why the back lens should have an aperture nearly as great as that of the front, unless its large aperture is intended to subserve some useful purpose.

I am also doing some photographic work with an enlarging lens, attached to my telescope and should be grateful for a formula to obtain the magnification of a given projection, *e. g.*, if I use an enlarging lens of 2-in. *e. f.* with an objeet glass of 70 inches focus, at what distance should the screen be placed to obtain a magnification of ten diameters? Is the practice of measuring the image of the Sun, on a photographic plate taken at the principal focus, and comparing this diameter with that of the enlarged projection a correct one? P.

(1) Regarding "the exact course of the light rays through a photographic portrait lens," there are two ways in which the subject may be approached.

All that happens to a ray of light, on passing through a portrait lens, is simply a series of successive refractions at successive spherical surfaces. The law of refraction at a single spherical surface is given in all the elementary books. As a first method, then, the inquirer may trace the ray through the crown, into the flint, then into the space between the front and back lenses and again through the flint and crown into the air. To do this accurately one must know the radii of curvature and the refractive indices of the lenses. He must also know the relative position of the separate lenses as well as the direction and point of incidence of the incident ray. But, if the focal lengths of the front and back lenses are each known, there is no difficulty in tracing the ray in a sort of general way without any more exact information, remembering simply that the back lens receives a cone of rays which have had new directions impressed upon them by the front lens.

The back lens, in turn, makes this cone still more convergent, so that the apex of the cone falls on the ground glass, when the instrument is properly focused.

A second, and vastly more elegant, method of treating such a lens is that introduced by Gauss. The beauty of his treatment is that it disregards at once and entirely the actual path of the ray in the glass. He determines four points on the optical axis of the lens—the so-called cardinal points. These being once determined, the path of any emergent ray is determined immediately and simply from the path of the incident ray. Space does not permit us to go into further detail than to say that two of these cardinal points are the two principal foci of the lens and that the other two are known as the "principal points" of the lens. These latter are defined by this remarkable property, *viz.*, that an object placed at one of the principal points will give an *erect* image of the *same size* at the other principal point.

Any one who cares to look into this matter further will find the matter discussed in an elementary way in Pendlebury's "*Lenses and Systems of Lenses:*" also in Heath's *Geometrical Optics.*

(2) In answer to the second inquiry, it is to be noted that in general the use of a diaphragm occasions a loss of light. But, in the particular case mentioned, where the aperture of the stop is as great as the section of the cone of rays at that point, of course there can be no loss of light.

It must not be forgotten, however, in this connection, that the diameter of the stop is not the same as the effective aperture of the lens when used with this stop.

Not only does a stop in general produce a loss of light, but it also changes the distribution of light on the ground glass, diminishing the intensity near the edge of the plate.

(3) As to the necessity for a large aperture in the rear lens, this is not avoided by the use of a small stop. For, consider a bundle of rays coming from any point on the extreme right of the field. This bundle will pass through the right hand edge of the front lens, then through the small stop, and lastly through the left hand edge of the rear lens.

No two rays from any real point will intersect between the front and back of a portrait lens. Such an intersection occurs only at some focus. But, certainly, rays from different points of the field will cross each other in the plane of the diaphragm.

(4) As to the magnifying power of an enlarging lens, this is given immediately by the ratio of the focal length of the combination to the focal length of the objective.

By "focal length" is here meant the true focal length and not the so-called "back focus."

The only question involved is, then, the determination of the focal length of the combination. Let us call this quantity F. Then

$$F = -\frac{F_1 F_2}{D}$$

where $\begin{cases} F_1 = \text{true focal length of objective.} \\ F_2 = \text{true focal length of enlarging lens.} \\ D = \text{distance between second principal focus of objective and first principal focus of enlarging lens.} \end{cases}$

D is positive when the two lenses are separated by a greater, and negative when they are separated by a less, distance than the sum of their focal lengths. In the case of the ordinary astronomical telescope, when adjusted for eye observations, $D = 0$.

Knowing F, we now know the magnifying power of the combination. It remains to find the position at which the screen or ground-glass must be placed: in other words, we must find the "back focus" of the combination.

But this is easily done, for we have only to add to the true focal length the quantity C, in order to obtain the "back focus," where very approximately

$$C = \frac{F_2 (D + F_1 + F_2)}{D}$$

In the particular lens cited in the inquiry, the writer does not state whether the enlarging lens is negative or positive. In order to show the application of the above formulæ to his case we shall assume that he is using a double concave, as in the ordinary telephotographic combination.

Then we have given

$$F_1 = + 70 \text{ inches}$$
$$F_2 = - \ 2 \text{ ''}$$
$$\text{Magnifying power} = 10$$

Hence

$$F = F_1 \times \text{magnifying power} = 70 \times 10 = 700 \text{ inches}$$

$$D = + \frac{70 \times 2}{700} = + 0.2 \text{ inches}$$

and

$$C = - \frac{2\,(0.2 + 70 - 2)}{0.2} = - 682 \text{ inches.}$$

Adding this correction, C, to the true focal length of the combination, 700 inches, we have 18 inches as the "back focus" of the system. In other words, the system will magnify ten times when the ground-glass is 18 inches behind the rear lens and the rear lens is $(2 - 0.2) = 1.8$ inches in front of the principal focus of the first lens. This result agrees, as will be seen, with the general rule that the magnifying power of any lens is the ratio of the distances of the image and object from the center of the lens. H. C.

GENERAL NOTES.

Patrons will please notice the first page of the advertisements which gives some idea of the circulation of this new periodical.

The wide area that our circulation covers is largely due to the favorable and generous notice that the press has given of POPULAR ASTRONOMY very generally at home and abroad.

Goodsell Observatory has just received a new photographic camera; lenses 6-inches clear aperture and focal-length 30-inches, giving a field of view in the sky of 16½° in diameter. The curves of the lenses were computed by Professor C. S. Hastings, of Yale University, the grinding and polishing was done by J. A. Brashear of Allegheny, Pa., and the mounting was made by Warner & Swasey, Cleveland, Ohio.

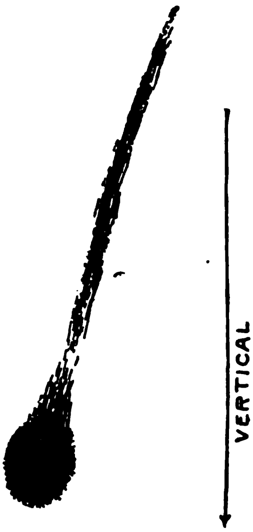
POPULAR ASTRONOMY will soon give some fine pictures of celestial objects from photographs made by this new camera.

Peculiar Phenomena.—About 10 o'clock P. M., central standard time, Nov. 18, there appeared in the north a *fire-red streak* of marked brilliancy. It began about 10° above horizon and extended about 15° or 20° exactly in the meridian so far as could be judged by observation.

It was not over a degree or so wide, with its edges sharply marked. There was only one streak and it maintained its position in the sky and its length and breadth for the 15 minutes that it was observed. Its brilliancy remained a constant to the end except that a *very slight* reddish haze seemed to form about the lower end of the streak. Its sharpness of outline was perhaps magnified by the background of floating dark clouds. No one to my knowledge saw it form; it melted away very suddenly. To my mind it seemed like a most intense electrical discharge, like a gigantic Geissler tube. There was no flickering, no wavering, but it was constantly steady.

R. L. SACKETT.

Meteor in Daytime.—Miss E. M. Bardwell, South Hadley, Mass., has given us an account of a meteor seen at the above named place at 10 o'clock A. M., Standard Eastern Time, in the N. N. W., about 25° above the horizon, moving nearly vertically downward, in a path slightly curved and about five degrees long. The meteor was of a beautiful green color, somewhat elongated and sharply defined, the shortest diameter about one third that of the moon; motion slow. There was considerable haze in the atmosphere with some white floating clouds at the time, yet the meteor was seen by several students on the way to recitation while they were going N. N. E. It is remarkable that the meteor should have been seen under such circumstances and especially that the break in the train should have been noticed as shown in the accompanying cut.



Brilliant Meteor.—At 7.12 (E. time) this evening, a brilliant meteor was observed just east of the moon, moving in a south westerly direction. It passed near β. Capricorni and disappeared, below Altair, 30° from horizon, covering, I should judge, about 70° of the sky, and occupying 3 seconds of time. The moon 12 days old, was clear and bright rendering it difficult to locate the exact path or point of disappearing. The meteor was of a deep *bluish hue*, slightly pear-shaped, with no trail and apparently larger and brighter than Jupiter, then above E. horizon. Just before disappearing a fragment separated from its northern side, (no report heard), moving in same direction but gradually dropping behind, this was of a decided *orange* tint, and vanished from view a trifle earlier than the larger one.

J. C. SANFORD.

Marblehead, Mass., Oct. 21st, 1893.

The November Meteors.—The Leonid meteor radiant was photographed on the mornings of Nov. 14 and 16, with the 2½-inch Darlot lenses of Goodsell Observatory. Two exposures were made on the morning of the 14th, the one from 3^h 50^m to 5^h, the other from 5^h to 6^h. The field covered by the plates is 24° in diameter, ζ Leonis being placed in the center. The first plate on the 14th shows one meteor trail near the star $\varkappa$ Leonis. It is about 1° long and points exactly toward the Leonid radiant. It is near the edge of the plate where the definition is poor, so that it is not well shown. The other plates show no trails at all. I saw but few meteors while the exposures were being made, and no very bright ones. The few Leonids I did see moved so swiftly that it is doubtful whether their trails would have been impressed upon the plate had they been within the range of the camera.

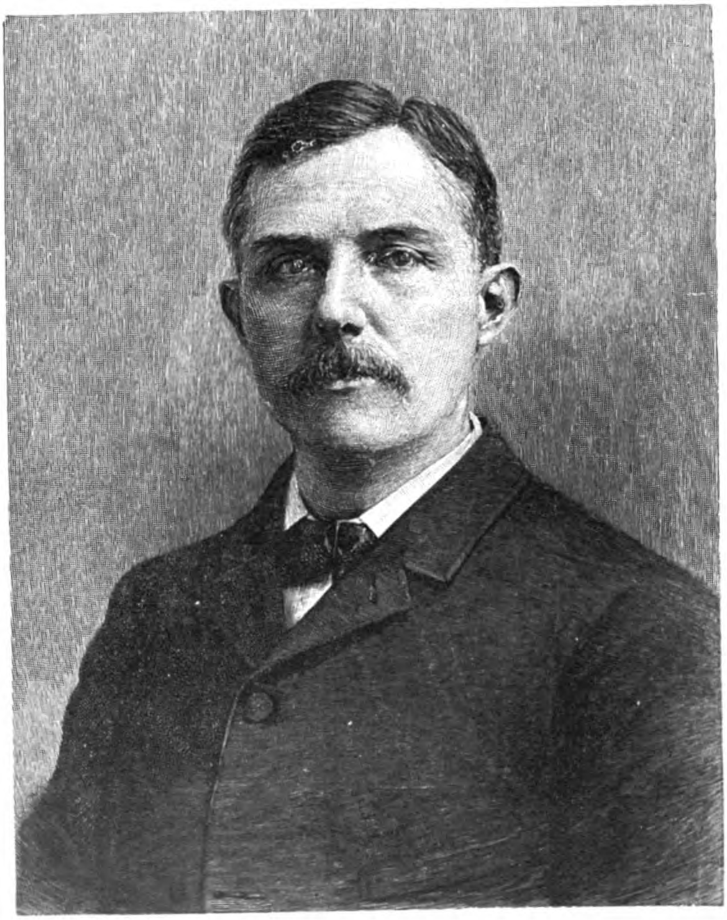
H. C. W.

November Meteors.—The November meteors were far more abundant this year than I have ever seen them before. Especially were they plentiful on the mornings of November 13, 14, and 15. Many very brilliant ones were seen. One on the morning of the 14th burst just below Coma Berenices. It was nearly as large as the full Moon. On November 15th at 14^h 50^m a splendid meteor from Leo shot across the sky and burst between Zeta and Eta Ursæ Majoris. This left a persistent train about 10° long which remained bright and straight for about five minutes—like a slender comet—it then collected into a cloudy mass at the point of explosion. This elongated mass of luminosity remained distinctly visible for half an hour, drifting due east in the meantime about 7°. As I was photographing the comet at this time I could not turn my telescope to it to see how long it remained visible after it had ceased to be seen with the naked eye.

Mt. Hamilton, Nov. 19, 1893.

E. E. BARNARD.

PLATE X.



EDWARD EMERSON BARNARD.

POPULAR ASTRONOMY No. 5.

By permission from HARPER'S MAGAZINE.

Popular Astronomy.

Vol. I. JANUARY, 1894. No. 5

EARLY LIFE OF E. E. BARNARD.*

S. W. BURNHAM.

Edward Emerson Barnard was born in Nashville, Tennessee, December 16, 1857. His early education was limited to two months' attendance at a common school, and such instruction as his excellent mother could give him at home; and all of his acquirements in literature, the sciences and languages in late years are the results of his own earnest efforts. Fatherless and destitute at the close of the war, he began at the age of eight or nine to work in a large photographic studio in Nashville, and continued to follow the occupation of photographer until 1883. During this time he had mastered every department of the photographic art, and had become invaluable to his employers as a faithful and accomplished assistant. His has been a struggle single-handed for existence. Handicapped by sorest distress and poverty from the first, he has fought the battle of life alone and is in the supremest sense of the word a self-made man, as can be well attested by the people of his native city.

From an early age he had been interested in optical matters, and this interest was increased by the use of the various lenses employed in the gallery. He was always interested in watching the heavens at night, the change of the face of the sky from month to month, the movements of the planets, the phenomena of eclipses, and other striking astronomical events. This interest received an impulse in a curious way. In 1876 a friend happened to leave in the young photographer's possession for a few days an old book which he was delighted to find was a copy of Dr. Thomas Dick's Practical Astronomer. This book was studied with great avidity, and it awakened a thirst for astronomical knowledge which has never since ceased to be controlling. This work, long since left behind in the great advance of the science was like a revelation. It told the stories of the stars and the planets, and the wonders revealed by the telescope. Now, for the first time, he had some idea of the uses of astronomical instru-

* This is the first of a series of articles portions of which have already appeared in *Harper's Magazine*, August, 1893.

ments. He had never seen either a telescope or an Observatory. All he knew of the literature of the subject was found in this old book. In its day it was one of the most valuable general works on the subject, and it is still a delightful book to read; but modern observers, aided by improvements in methods and instrumental appliances, have made many discoveries since that time, and a treatise on the new astronomy of the nineteenth century must bear a recent date. From the maps of the constellations and other engravings, he speedily learned to identify the objects in the sky about which he had been reading; and the descriptions of celestial wonders had now a new interest. Then came the desire to possess some kind of telescope, and finally he obtained the object lens of a common spy-glass, and mounted it in a paper tube made by himself. This lens was about one inch in diameter and, of course, was never intended for looking at celestial objects. Still it revealed the heavens as they can never be seen by the unaided eye, and showed the beautiful crescent form of Venus and the discs of Jupiter and other planets. It is certain that the intense excitement caused by the views obtained by this crude instrument was never equalled in after years when he was occupied in making a series of brilliant discoveries with the largest and most powerful telescope in the world. Such excitement comes but once in a lifetime, although the enthusiasm and interest in the subject may never be abated.

About this time a traveling showman with a small glass for street exhibition appeared in Nashville, and young Barnard was a steady patror whenever nickels were sufficiently plenty to warrant such a dissipation. This was not much of a telescope, but it was superior to the home-made affair he had constructed for himself. He resolved to have a better instrument of his own, and after practicing the most rigid economy, he was enabled in 1877 to purchase a telescope of five inches aperture with a proper mounting, and a suitable equipment of eye-pieces and other accessories. In August of that year he met in Nashville Professor Simon Newcomb, the distinguished Washington astronomer and received from him advice and kindly suggestion in regard to the future; and this encouragement was of much value in his efforts to accomplish something with the new instrument. In these days of expensive equatorials mounted in revolving domes with every mechanical and optical appliance of the most perfect description, a portable instrument to be used on the house top, in the back yard, or wherever it was most convenient, would hardly be thought worthy of mention, but still it was an instrument with which the young astronomer, with a zeal and enthusiasm superior to all outside discouragements, could do valuable astronomical work and this may be said to be the beginning of an unbroken series of brilliant discóveries and observations of permanent value in a wide range of practical astronomical subjects.

His first systematic work of any importance with this telescope was a careful study of the planet Jupiter, and the popular scientific periodicals of the time contain many of his contributions on this subject. This planet, the largest of the solar system, seems to have had a special charm for the young astronomer at the very beginning of his use of the telescope; and, to use his own modest statement at the time, he "began regular observations of Jupiter and contributed his mite in drawings and observations of that changing old planet." In late years this work was continued with instruments of much greater power, and finally culminated, as will be referred to hereafter, in the grand discovery of a new member of the magnificent Jovian system. It may be worth mentioning in this connection that when he first went to work in the photographic gallery he was placed on a large platform in charge of the printing with an immense solar camera on the roof of the gallery. This was the largest camera of the kind in existence in this country or elsewhere, and was designed to print directly life-sized figures on silvered paper. It was his duty to keep the camera accurately directed to the Sun, the sunlight being passed through the mammoth condensers and the negative thus projecting the image on the sensitized paper. This colossal instrument bore its name significant now, in large letters, painted on its side, "*Jupiter.*"

THE FIXED STARS.

W. H. S. MONCK, DUBLIN, IRELAND.

I.

Probably the greatest advance that astronomy has made within the present century has been in Stellar Astronomy—the department of the fixed stars and the nebulæ that belong to the same remote region. And it is in this department also that astronomy is at present advancing with the most rapid strides—so much so that any treatise on Stellar Astronomy, unless frequently rewritten would soon be out of date. A periodical like POPULAR

ASTRONOMY has the advantage of being able, not only to give a sketch of the state of the science at the existing juncture, but to note its advances from time to time.

The history of Stellar Astronomy is interesting, but until recently it did not form a science. Star catalogues may form the basis of a science, but they are not scientific in themselves. The discovery implied in the very title of Fixed Stars is no doubt of early date; but it was reserved for the moderns to ascertain that they are not fixed and to determine within certain limits the velocity and direction of their motions. But before the great discovery which is associated with the name of Copernicus the fixity of these stars was calculated rather to mislead astronomers than to direct them to the truth. How could a number of stars, situated at various distances, but measured in all cases by thousands of millions of miles, perform a revolution round the Earth in every twenty-four hours? The velocity supposed by such a theory was inconceivable, and the natural supposition was that they were situated pretty nearly at the same distance from us and that not a very great one. And without forming some tolerable notion of their distances it was impossible to arrive at any trustworthy conclusion with respect to their nature. If comparatively near us their light must fall greatly short of that of the Sun, and if sun-like bodies they must be either much smaller or much fainter than the luminary of our system. The Copernican theory had to win its laurels before any real progress could be made. When that theory was once established, it was natural to suppose that the apparent motionlessness of the fixed stars arose from their distances being vastly greater than those of the Sun or planets. That bodies situated at such vast distances should shine as brightly as they do by reflected sunlight seemed improbable. They gave light of their own. They were suns; though whether they were not much smaller suns than ours remained still undecided. The Copernican theory too was speedily followed by the discovery that the Sun was more remote than had hitherto been supposed, and of course the distances of the fixed stars were proportionally augmented.

It was soon found that the only way of endeavoring to ascertain the distance of a fixed star was by means of its annual parallax or the angle which the radius of the Earth's orbit subtended at the star. Hooke appears to have been the first to make this attempt. He obtained for the star γ Draconis an annual parallax of nearly half a minute. This was of course altogether wide of the mark, but still it made the star about

7,000 times as distant as the Sun, at which distance the Sun's light would be reduced in the proportion of 50,000,000 to 1. The sun-like character of the star was thus confirmed. But even if astronomical instruments had then been much more perfect than they were at this period, no satisfactory result could have been attained. It was not until after Bradley's discovery of the aberration of light that the problem of ascertaining the distance of a fixed star could be taken up with any real prospect of success. The result of repeated trials was that the parallax rarely exceeded the limits of error, and that even where it did so the limits of error usually bore a considerable proportion to the result. It may, I think, be laid down that no star hitherto examined (and most of those likely to have sensible parallaxes have been examined) has a parallax of as much as one second or is situated nearer to us than 200,000 times the distance of the Sun. The Sun's light would be reduced in the proportion of 40,000,000,000 to 1 if it were removed to this distance; and though it is no easy task to compare the light of the Sun with that of a star, I think most readers will be prepared to admit that 40,000,000,000 stars as bright as Sirius would give more light than the Sun.

The telescope had not been long in use before some double stars were discovered and the hypothesis that one of these stars revolved round the other as the planets revolve round the Sun was not an unnatural one to form. It was reserved for Sir William Herschel however to discover that such was the fact, and the discovery I believe belongs to the present century. Besides the difficulty of measuring distances and angles with the requisite accuracy, however, another difficulty presented itself in our efforts to extend the law of gravitation to the fixed stars. The smaller star ought under the influence of that law to describe an ellipse having the larger star in the focus But if an ellipse is presented sideways to the eye—as the orbit of a double star usually will be—it will indeed still appear to be an ellipse but the focus will generally be displaced. The usual result therefore is that one star will revolve round the other in an ellipse, but the larger star will not appear to be in the focus. We can find, however, at what angle the plane of the orbit should be inclined to the line of sight so as to make the larger star the focus of the real ellipse; and in this way the orbits of about seventy double stars have been already computed. But that these stars are moving under the influence of gravitation is assumed, not proved. To prove it we should be able to show that the orbit is really inclined to the line of sight at the supposed angle. The spectroscope may clear up this doubt hereafter by ascertaining the velocity of the smaller star in the line of sight at different points of its orbit. But that instrument has to a large extent removed the doubt already. It has proved that the atmospheres of the stars contain elements such as hydrogen and iron which are known to gravitate. If these elements gravitate when within the limits of the solar system few persons will suppose that they lose their attraction when they pass beyond those limits—that, for instance ,the carbon in a comet which moves in a parabolic or hyperbolic orbit loses its attractive force when it gets to a sufficient distance from the Sun, or else that it continues to attract and to be attracted by the Sun, though it is uninfluenced by the carbon of the other stars which it approaches in its grand sweep though the sky.

That the fixed stars are gravitating bodies shining by their own inherent light and comparable with the Sun both as regards mass and brilliancy seems thus to be established. Yet probably an astronomer who made this assertion in the last year of the eighteenth century would have gone somewhat beyond the evidence then available. And as there are very few stars whose parallaxes can as yet be regarded as reliable there are also very few binary stars whose orbits can be regarded as certain. But these uncertainties do not affect our general results. In the first place we know that the error cannot exceed limits which in some cases are rather moderate. In the second place when we are dealing not with individual stars but with classes of stars the averages are much more reliable than any single result. And the average parallaxes or distances of the stars are confirmed in other ways. As soon as it was conjectured that the stars were subject to the law of gravitation it was inferred that they were not motionless. Comparison of different catalogues compiled at different times have established the fact that many of them move, and have enabled us to determine the amount of the motion measured on the celestial sphere. Since the introduction of the spectroscope we have obtained another measure of velocity —velocity in the line of sight. The former velocity, however, is measured in arcs on the celestial sphere—the latter in miles per second. As the stars are too distant to be much influenced by the motions of the solar system we may fairly assume that, on a general average, the motion in any given direction will be about equal to that in another direction at right angles to it; and in this way we can estimate what motion in miles per second is equivalent to a given motion in seconds or fractions of a second on the celestial arc. The result is to confirm the great distances of the fixed stars. The average motion of about fifty stars in the line of sight, according to Vogel's observations, is a little over 10 miles per second. Stars of this brightness have a motion (on the average) on the celestial vault of less than half a second annually; and this embraces the motions in two out of three directions mutually at right angles where the motion in the line of sight gives the third. Very small parallaxes or very great distances are thus indicated. But my present object is rather to point out that all the stars are in motion as they would be if under the influence of gravitation. Indeed in some cases the motion seems to be too great to be accounted for by gravitation alone; but Newton had to combine an original projectile force with gravitation in order to explain the motions of the planets; and the attempt to get over this difficulty by means of the nebular hypothesis has not proved as successful in the case of the comets as of the planets. Now there is every reason to believe that an original projectile force combined with gravitation will explain all the motions of the fixed stars and that the law of gravitation thus extends to the utmost limits of the universe.

The principles that the fixed stars are similar to the Sun not to the planets in their self luminosity, in the intensity of their light, and in their masses, and that they are gravitating bodies moving through space with great velocity, may be said to form the foundation of stellar astronomy. These stars are connected with us in two ways which our descendants may yet resolve into one —by the universal gravitation, and by the ether whose undulations convey their light to us, and which must therefore occupy the whole of the intervening space. This ether apparently does not gravitate, but it may notwithstanding be the medium by which the influence of gravitation, as well as of heat, light and electricity, is propagated.

One fact which deterred the earlier astronomers from accepting the enormous distances of the fixed stars to which modern research leads us was the discs which these stars present in the telescope. But these discs are no doubt spurious, arising from the defects of our telescopes as optical instruments. When we use higher magnifying powers they do not increase proportionally as those of the planets do; and when the dark edge of the Moon passes over a fixed star it is usually occulted instantaneously instead of being gradually extinguished as would be the case if it represented a really sensible disc. The few exceptions to this rule probably arise either from the existence of a faint lunar atmosphere, or from the star being a close double star. Stars which must present towards us surfaces of vast extent—in many cases probably larger than that of the Sun—are so distant that any measure of their real discs is unattainable. Probably in no case does the true diameter of a fixed star as seen from the Earth amount to the thousandth part of a second! Yet everyone knows how brilliant some of them look in our midnight sky. We need not be surprised to learn that in point of brilliancy many of them rank higher than the Sun himself. But our reasons for arriving at this latter conclusion must be deferred for another article.

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

JAMES E. KEELER.

III. *Practical Details Relating to the Adjustment and Use of the Instrument.*

We now turn to a consideration of the conditions on which the efficiency of the spectroscope depends. It is desirable that the spectrum shall be bright, for we are seldom troubled with too much light, and that the lines shall be fine and sharp, or in other words that the spectrum shall be pure. These are directly conflicting requirements, for the brightness of the spectrum is increased by widening the slit (unless it consists of isolated bright lines), and the purity is increased by narrowing it. Hence in practice a compromise is adopted, determined in each case by direct experiment. By using a higher magnifying power on the telescope we can increase the apparent size of the spectrum, but as the lines are magnified, at the same time the purity is not changed and the spectrum is dimmed. In fact the laws which apply to the telescope when used to examine the spectrum are the same as when it is used for any other purpose.

When the dimensions of other parts of the instrument are altered the effect is not quite so simple. It should be observed that the different parts should be adapted to one another in a well constructed instrument, so that no light may be wasted, and at the same time no unnecessary material may be employed. Thus, the prism should evidently be large enough to transmit the full cylindrical beam of light from the collimator, and it would be a waste of material to make it larger. For the same reason the telescope objective should be of the same size as the collimator lens. Assuming that these principles of construction are observed, we may call the diameter of the collimator lens the *aperture* of the spectroscope.

It is an important proposition that the brightness of the spectrum is proportional to the square of the aperture of the spectroscope. Without attempting to demonstrate the proposition I will give some examples to illustrate its truth. Suppose that the collimator has a focal length of twelve inches, and an aperture of one inch, and that the observer has adjusted the width of the slit until the brightness and purity of the spectrum are satisfactory. Now let the slit with its width unchanged be placed in a collimator of six inches focal length, and half an inch aperture, and the new collimator be screwed into the place of the old one. It might seem at first sight as if the brightness would be the same, for the new lens catches all the light that fell upon the old one; but with the new collimator each monochromatic image of the slit is twice as long and twice as wide as before, while the length of the spectrum is unchanged; hence the purity of the spectrum has suffered, and if the slit is narrowed until the original purity is restored, the brightness will be reduced to one-fourth of its original value.

The same thing may perhaps be seen more clearly by imagining the collimator lens to be increased in size, the focal length remaining the same. Starting with the original conditions, if the aperture of the collimator is made two inches, the prism and telescope objective being increased in proportion, the purity will not be changed, for the slit-width remains the same, and the focal length of the collimator remains the same, but the new lens receives four times as much light as the old one, and the spectrum will be four times brighter.

Hence in estimating the efficiency of a spectroscope with regard to brightness of the spectrum, the aperture is to be considered as the essential feature. The focal lengths of the telescopes have no bearing on the subject, and may be anything that is convenient.

The *resolving power* of a spectroscope expresses its power of dividing close double lines in the spectrum. With the same aperture it may be increased by increasing the dispersion, either by adding more prisms or by using more highly dispersive material, for the lines in the spectrum are thereby more widely separated without being widened themselves; or the dispersion remaining constant, it may be increased by using a larger aperture, which gives finer and sharper images for the lines, just as increasing the aperture of a telescope diminishes the size of star-discs and allows closer double stars to be separated. It has been shown that with simple prisms of the same material, the resolving power is directly proportional to the difference between the longest and shortest paths of the light in traversing the prisms; that is, if the prisms are properly proportioned, to the sum of their bases. Hence one large prism may be equal in resolving power to several small ones.

If we take as unity that resolving power which allows the separation of two lines differing by the thousandth part of their own wave-length* (which is very nearly the resolving power required to separate the D lines) we may express the resolving power of a spectroscope numerically. Thus, to separate the D lines requires a heavy flint glass prism with a base of about four-tenths of an inch; a prism of the same glass with a base of two inches would therefore have a resolving power of five. The resolving power of a prism is greater in the upper part of the spectrum than in the lower.

With compound prisms the crown glass must first be reduced to its equivalent in flint glass, allowing for the greater dispersive power of the latter, before applying the rule; the exact relation depends upon the kinds of glass used, but roughly, we may take one inch of flint glass as equivalent to two of crown.

The inferiority of the direct-vision prism in respect to resolving power can now be correctly appreciated. To take a real example, I have a large direct-vision prism made of five prisms, three of crown and two of flint glass arranged in the manner already described. On one side are the bases of the flint glass prisms, measuring together four inches; on the other side are the three bases of crown glass, with a total length of six inches. Taking the six inches of crown glass as equivalent to three of flint, there is a difference of one inch of flint glass between the opposite sides, so that the whole combination is only equivalent in resolving power to a simple flint glass prism with a base of one inch, and is decidedly its inferior in brightness.

In my first article I referred to the advantage of knowing how to change the dispersion of a prism by displacing it slightly from the position of minimum deviation, and we are now prepared to understand the exact nature of the change. As the thickness of glass traversed by the rays of light is very little affected by a slight displacement of the prism, the resolving power remains the same, and we have a change of dispersion unaccompanied by a change of purity. When the dispersion is increased by rotating

* Professor Schuster's definition.

the prism, the lines in the spectrum are broadened, as if the original spectrum had been viewed with a higher magnifying power; but with this important difference,—that whereas in the latter case the width of the spectrum would apparently be increased, in the former it remains unchanged. Rotation of the prism produces in fact a *horizontal* magnification of the spectrum, which with respect to brightness is more advantageous than enlargement with an eyepiece. Sir David Brewster made a telescope by combining two crossed achromatic prisms, which those who are curious about the matter will find described in his Treatise on Optics.

Hitherto we have supposed that the light coming through the slit diverges sufficiently to cover the whole of the collimator lens, as it always will do it the source of light is a flame close to the slit, but in practice cases will arise when the whole lens is not covered. When we point the colimator directly at the Sun, the rays from opposite limbs pass through the slit in straight lines and diverge at an angle of about half a degree, (the Sun's angular diameter), so that the spot of light on the collimator covers only half a degree as seen from the slit. With a collimator ten inches long the illuminated part of the lens is less than a tenth of an inch in diameter,* and all the rest of it might as well be covered up, for the light from the sky around the Sun is too faint to need consideration. Most of the optical power of the instrument is wasted.

In this case the *effective* aperture of the spectroscope is about a tenth of an inch. The observer, in order to get the benefit of the full power of his instrument, must see that the effective aperture is as great as the real aperture, that is, that the collimator lens is filled with light. Some small instruments exhibited at Chicago were intended to point directly to the Sun, as they were equatorially mounted and carefully balanced, but the necessity of observing the above condition had been overlooked.

In order to utilize the whole aperture when the collimator is directed to the Sun, we may place a lens in front of the slit, so as to form an image of the Sun on the slit-plate. The angular aperture of the lens must at least equal that of the collimator lens, that is, they must both subtend the same angle as seen from the slit, otherwise the collimator lens will not be completely illuminated. The brightness of the spectrum is then independent of the

* As the slit has considerable length, the illuminated part of the collimator is really a band half a degree wide, but the resolving power is the same as if the slit were indefinitely short.

size of the image lens, a large lens giving no greater brightness than a small one. In astronomical observations the image lens is the object-glass of the telescope to which the spectroscope is attached.

Although the brightness of the spectrum is independent of the dimensions of the image lens, the breadth of the spectrum is not. The greater the focal length of the lens, the larger will be the image of the Sun on the slit plate. If the diameter of the Sun's image is a quarter of an inch, each monochromatic image of the slit will be a quarter of an inch long, and hence the spectrum will be a quarter of an inch wide, for the open parts of the slit not covered by the solar image are too feebly illuminated to give a spectrum of appreciable brightness. Practically, therefore, the focus of the image lens should not be too short, say not less than twelve or fourteen inches.

A new advantage gained by the use of the image lens is the power it gives of observing the spectrum of each individual part of the source of light. Thus, if a sunspot on the solar image is brought within the jaws of the slit, its spectrum will appear in the eyepiece. Of course the solar image would have to be pretty large to give a spot-spectrum broad enough for observation. A spectroscope provided with an image lens is sometimes called an analyzing spectroscope. In the laboratory the image lens is useful when the source of light is very small, an electric spark, for instance, or when there would be danger of burning the slit by bringing it too close to a flame.

For measuring the positions of lines in the spectrum various devices are used. Fixed cross-wires in the eyepiece may be brought into coincidence with the lines, and the positions of the telescope read off on a graduated circle, or for short intervals a micrometer eyepiece may be used. A common method is to place a finely divided scale, usually obtained by photography, in such a position that it will be reflected from the surface of the prism next to the telescope and appear in contact with the spectrum seen in the eyepiece. The scale must be in the principal focus of a collimating lens, in order that the rays striking the reflecting surface may be parallel. The small spectroscopes used in chemical laboratories are usually furnished with this device.

For small instruments probably the most accurate method of determining the position of a line is by direct comparison with the solar spectrum or with other well-known lines. For this purpose a small reflecting prism called a comparison prism is placed over part of a slit, and the spectra of the two sources of light can be seen together, one formed by rays entering the slit directly, and the other by rays reflected into it by the comparison prism. It is then quite easy to determine the place of an unknown line among the lines of the solar spectrum, and hence its wave-length.

The practical matters to which I have devoted this article are those which should most carefully be borne in mind by the observer. They are not absolutely necessary to a good understanding of the results which the spectroscope has accomplished, but they are of importance in actual spectroscopic work. The spectrum of a body is seldom obtained by pointing a spectroscope at it in an off-hand manner, and as some of my readers are themselves supposed to be using small instruments, and hence to be interested in knowing how results are obtained, as well as what the results are, I hope these details about instruments and methods may not be amiss.

THE HEAVENLY BODIES.

DANIEL KIRKWOOD.

In the variety of their magnitudes and motions the heavenly bodies present an indefinite series for study and description. The great and small are there. Of the former we may name our system's source of light, surpassing in volume more than a million times the world which we inhabit, and whose scenery has occupied the attention of a thousand generations. Our initial number opened with a brief detail of facts. The small planets revealed became still more minute as discovery advanced, till some were found whose diameters were not greater than ten or twelve miles. But among the satellite rings, whose magnitudes are indefinitely minute we soon weary in the contemplation. Leaving in imagination our native system, we find in telescopic revelations, suns surpassing in magnitude and splendor the orb of day itself. Let us study, in brief, some of the creations thus revealed.

I.

Sirius and its Companion.

In beauty and grandeur what scenery can surpass the winter's midnight sky? In view of its splendors who has not asked, which is the greatest of these distant orbs? Is it stationary or in motion? If moving is it approaching the Earth, or receding from it, and at what rate? Which radiates the greatest quantity of light, and what is its amount compared with that of the Sun? In what system is found the largest satellite or companion star? Some of these questions, within the memory of persons still living, were thought to transcend man's loftiest efforts. The story of their solution forms one of the most brilliant chapters in the records of human progress.

Of the numerous efforts to find the annual parallax of Sirius, perhaps none is entitled to greater confidence than that of Maclear, or Abbe's rediscussion of Maclear's results in the *Monthlv Notices of the Royal Astronomical Society*, Vol. XXVIII, p. 6. This value is twenty-seven one hundredths of a second of arc, corresponding to the distance 761,704 times that of the sun from the earth, or seventy-one millions of millions of miles. Light, moving at the rate of 186,000 miles in a second, is more than twelve years in passing from Sirius to the Earth.

The proper motion of this star has been known since the time of Halley. Within the last sixty years, however, irregularities have been observed, such as might result from the disturbing action of a neighboring star. These anomalies, detected by different astronomers, suggested the theory of an undiscovered satellite. In 1862 this predicted companion was brought to light by Alvan G. Clark, Esq., of Cambridgeport, Mass. Since that date, therefore, Sirius and its disturbing attendant have been known and observed as a binary system.

MASS AND ELEMENTS OF THE BINARY.

The apparent semi-axis of the companion's orbit is 8″.53; hence with the adopted parallax the real semi-axis, in astronomical units, is 31.6 In other words, the mean distance of the satellite from the centre of Sirius is 2,939,000,000 miles—slightly greater than the distance of Neptune from the sun. With the calculated eccentricity—0.591—the least distance apart is found to be 13 astronomical units, or, 1,209,000,000 miles. The mass of Sirius is twice that of the companion, and at least fourteen times that of the sun. Other values of the parallax make the mass still greater.

LIGHT—VOLUME—DENSITY.

The intrinsic light of Sirius is 83 times that of the sun. Assuming, then, that their surfaces have equal luminosity, the diameter of Sirius is 9.1 times that of the Sun, or, 7,826,000 miles. The volume is 755 times greater than the Sun's and as the mass is but

14 times greater, the mean density is 0.018, that of the Sun being unity.

The study of this wonderful system has led to remarkable results. While the mass of Sirius is only twice that of the satellite, its light is twelve thousand times greater. Can this difference be due to the more rapid cooling of the lesser body? If so, as the mass of the star is seven times greater than that of the Sun, the age of the binary must be vastly greater than that of the solar system. If, Sirius, therefore, is the centre of a multiple cluster, any smaller members may have advanced so far in the process of cooling as to have lost entirely their native light—a condition to which the satellite discovered by Clark may be gradually approaching.

Dr. Huggins, of London, though not the first to suggest the use of the spectroscope in determining the motion of stars in the line of sight, was the first to reduce the suggestion to practice. His results are well known to astronomers. In the case of Sirius, as might have been expected of a body moving under the influence of a disturbing cause, the rate has been variable. Without entering into details, it may be remarked that very careful measurements have indicated a recession of from twenty to twenty-five miles per second.

The mass of a binary star can be determined only when its distance is known. These distances have not been found except for about thirty stars. The question, therefore, what star has the greatest quantity of matter, can receive no definite answer except in regard to those of known parallax. So far as measured, Sirius has undoubtedly the greatest mass as well as the greatest brightness, intrinsic and apparent. Its companion, moreover, is the largest satellite yet recognized.

Origin of the Binary.

The relations of this satellite to Sirius suggest a modification of the nebular hypothesis. The least distance between the two members is 13 millions of miles; the greatest, 50 millions. At the former, the apparent diameter of Sirius as seen from the *comes* is about 22′; at the latter 5′ 30″. This cometary eccentricity, as well as that of many other binaries, could hardly have originated in circular rings. It seems rather to indicate the primitive formation of two distinct nuclei in the same nebula. According to Laplace the planets of the solar system had their origin in circular rings abandoned at the Sun's equator.

SHOOTING STARS.

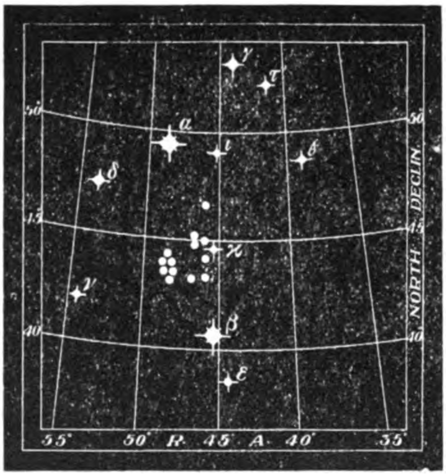
How to Observe Them and What They Teach Us.

W. F. DENNING, BRISTOL, ENGLAND.

V.—RADIATION AND DURATION OF METEOR SHOWERS.

The radiation of meteors is far from being precisely uniform in character, for different systems appear to exhibit peculiarities of distinct type. While some radiants are diffused over areas of 3, 5, or 7 degrees others are so limited that they may justly be termed *points*. We have already referred to the Andromedes of Biela's comet as supplying a very pronounced instance of indefinite radiation. The precise cause of this has not perhaps been settled but Professor Newton believes the explanation is to be found in "the glancing of meteors on entering the air. The meteoroid is probably a fragmentary body of irregular form and the burning off of the solid fragments as soon as burning begins makes them move in straight lines thereafter. The curvature of path otherwise should continue through the whole length of the luminous tracks. This glancing is not confined to the Biela meteors, it was true of the Leonids and still more so of the Perseids. It is reasonable to assume that it is true of all shooting stars." Many will be disposed to accept his ingenious explanation, but the writer would note that the radiants of the Leonids and Perseids are far more sharply defined than that of the Andromedes. It is extremely probable that the scattered radiation often ascribed to the former showers is an apparent effect only, brought about by including the meteors from closely neighboring systems and by errors in recording the path directions of the various meteors observed. At Bristol the radiants of the Leonids and Perseids have been frequently seen as very exact and restricted centers presenting a wide distinction to the diffuse radiation of the Andromedes.

As to "duration of activity" this is another feature in reference to which future observation will furnish important evidence. We know that the Perseids maintain a continuous fall during more than a month, and that the Orionids are to be seen for about three weeks, while the Quadraulids, Lyrids, Leonids and Andromedes are each probably confined to a week's activity. Some other showers seem to be exceedingly fugitive, appearing only on a single night. But it must be acknowledged that with regard to the mass of feeble systems, the question as to their visible duration remains an open one. The difficulty of obtaining observations on many consecutive nights and of following up the work year by year, the frequent hindrances occasioned by moonlight, clouds and other causes, have prevented our gaining anything but a vague idea as to the operations of the really tenuous streams. Many of them apparently show a stationary radiant and a fitful activity during extended periods, but the cause remains an unsolved enigma. How shall we deal, for instance, with a shower which recurs again and again from a position between the stars α and β Persei and of which the following observations have been made at Bristol in the months of July, August and September:



Date.	Radiant. ° °	Date.	Radiant. ° °
1877 July 20	...47 + 45	1879 Aug. 21-23	...46 + 47*
1884 July 23-25	...48 + 43	1887 Aug. 30	...46 + 43
1886 Aug. 2-10	...48 + 43	1887 Sept. 12-24	...47 + 43
1888 Aug. 5-14	...48 + 44	1885 Sept. 15	...48 + 43
1877 Aug. 3-16	...46 + 45	1877 Sept. 15-16	...47 + 45
1893 Aug. 8-16	...48 + 44	1886 Sept. 22-30	...48 + 44
1884 Aug. 19-21	...46 + 44		

Do these various positions represent a number of different showers emanating curiously enough, from virtually the same place in the firmament, and are we in fact to consider the coincidences of radiation as purely accidental? Or, on the other hand,

* The position of this radiant was estimated from paths not registered and it is evidently 3° N. of the correct place.

are we justified in adopting the 13 radiants as forming a single shower with a duration of more than 2 months and a radiant fixed at the point 47° + 44°? If a display of this character can, by any combination of circumstances, be approved it would certainly do away with some of the complications and doubts now existing and permit us to cut down considerably the number of supposed radiants, as many of them must be duplicates of long-continuing showers. But theoretically stationary radiants of the nature indicated cannot be admitted, and Dr. Kleiber has shown that if meteor showers are formed by rings or ellipses then the latitude of their radiants must remain constant while the longitude increases proportionately with the time. In other words the radiant must travel eastward amongst the stars and uniformly in a circle parallel with the ecliptic. The Perseids follow this rule but the Orionids apparently furnish a striking departure from it, for their radiant remains absolutely fixed at 92° + 15° during the 21 nights from Oct. 9 to 29 inclusive. The radiants of $\alpha - \beta$ Perseids in the foregoing table are also immovable, and this observational fact can hardly arise from a deception. It is true that showers are so plentifully distributed over the celestial vault that in some cases they must supply a succession of radiants at nearly identical positions. But the number of supposed fixed radiants is so great and the data on which they rest so conclusive, that the chance grouping of different showers cannot be accepted as affording a sufficient explanation of them. So far as observations on this field permit a confident statement the writer would aver that the series of radiants representing a stationary shower are practically identical in position, and cannot therefore be induced by any arrangement of separate streams. The most careful observation at Bristol has failed to exhibit differences in position other than those obviously resulting from the trivial errors common to this work. There is a shower from the star η Aurigæ (74° + 41°) which, beginning at the Perseid epoch in August, is prolonged intermittantly through the remainder of the year and is still active in February according to several authorities.

Observers will find that the various peculiarities, connected with the radiation of meteors, require the most careful and patient study. The rapid shifting of the Perseid centre will be confirmed without difficulty but the visible behavior of the majority of other showers will, from their comparative feebleness, occupy more time and require a keener discernment. A vast number of meteor-paths, registered with the utmost accuracy, will be necessary before anything like a conclusive test can be applied. Indeed the work seems better suited to professional astronomers than to amateurs who can rarely find opportunity to devote their nights with steady persistency, year after year, to the settlement of intricate questions of the kind alluded to.

It is fortunate that the derivation of radiants is not wholly dependent upon one method or upon the efforts of a single observer. By pre-arranging simultaneous observations two persons at different stations may register a number of the same meteors and in every such case the pair of paths will be divergent from the radiant. Thus a single meteor accurately recorded at two places suffices to indicate a good radiant, whereas an isolated observer, in deducing a centre from his individual results, must gather at least 5 or 6 paths before a reliable position can be obtained. And there is always an element of doubt attached to the latter because the observer has no absolute proof that he has correctly apportioned the meteors to their various radiants. He is justified from the visible features of a meteor, in assigning the place of its radiant, but the evidence he possesses is not always conclusive. It is therefore impossible to avoid occasional error though the discrimination gained by experience will generally lead him aright. In the case of a double observation of a meteor its radiant is indisputable as it rests not upon an assumption but upon an observational fact. Of course the character of the two observations come in as an important factor, but we are only alluding to paths recorded by capable persons. for rough work in this department is of no value whatever. Observers have often concerted together for the contemporaneous watching of meteors with the view to determine their real paths in the atmosphere, but the writer has never heard that such watches were instituted for the main or sole purpose of detecting radiants. Yet they might be undertaken successfully, and indeed some such plan is really necessary for the detection of very feeble showers. The results that might be accumulated by two persevering observers working systematically would vastly exceed that accruing from independent effort, for one person watching the sky during 5 or 6 hours may scarcely obtain more than 5 or 6 radiants, but if he combines with another observer and the collective results are compared, it is probable 3 or 4 times as many radiants would be found and the latter, being positions proving themselves, would be of thoroughly trustworthy character.

VARIABLE STARS. III.

J. A PARKHURST.

The preceding article in this series gave the methods used for observing variables and recording the observations. The present article will tell how to reduce the observations and draw from them the facts sought in regard to the behavior of the stars.

When a variable has been observed by Argelander's method, at frequent intervals for a time, the observations themselves furnish values for the brightness of the comparison stars. These stars then form a "light scale" by means of which numerical values for the brightness of the variable at the time of each observation can be deduced; since we have from each observation a value of the brightness of the variable in terms of the brightness of one or more comparison stars. This will be best understood by having an actual example before us, and following the reductions step by step. I will use for an illustration my observations of 4557 S Ursæ Majoris, from May to December 1893, omitting for the sake of simplicity the comparisons of the comparison stars among themselves.

OBSERVATIONS OF 4557 S URSÆ MAJORIS.

1893	May	11	*d* 2 *v*, *v* 3 *f*.
		17	*d* 2 *v*, *v* 4 *f*.
		27	*d* 2 *v*, *v* 3 or 4 *f*.
	June	19	*f* 1 *v*, *v* 1 *g*.
	July	1	*h* 1 *v*, *v* 2 *k*.
		10	*h* 2 *v*, *v k* or *v* 1 *k*.
	Aug.	2	*m* 2 or 3 *v*, *n v* or *n* 1 *v*, *v* 3 or 4 *o*.
		11	*n v* or *n* 1 *v*, *v* 1 or 2 *o*.
		16	*n* 1 *v*, *v* 1 *o*.
		26	Moonlight, *v* not held.
	Sept.	2	*n* 2 *v*, *v o*, *v* 1 *p*.
		6	*v* about = *o*, faint, seeing bad.
		26	*v* about = *m*, difficult, moonlight.
	Oct.	7	*v m*, *v* 1 or 2 *n*, low.
		9	*l* 1 or 2 *v*, *v* 2 *m*, seeing good.
		22	*g* 2 *v*, *v* 3 or 4 *l*, *v* 3 *k*.
		30	*v* 3 *l*, *v g*, *f* 2 *v*, *v* 3 *k*.
	Nov.	2	*f* 1 *v*, *v* 1 *g*.
		10	*f v*, *v* 2 *g*, *d* 4 *v*
		17	*v* 3 *f*, *d* 3 or 4 *v*
		30	*v* 5 *f*, *d* 3 *v*
	Dec.	3	*v* 3 *f*, *d* 3 or 4 *v*.

First we will form the light scale. The observations of May 11, furnish a value for the interval in steps between the stars *d* and *f*. Since *d* is 2 steps brighter than *v* and *v* 3 steps brighter than *f*, it follows that *d* is 5 steps brighter than *f*. By taking the mean of all the intervals from the observations in which *v* is between *d* and *f* in brightness, a good value may be obtained. Selecting similar combinations from the observations of each date, we can get values for the step intervals between all the comparison stars used. Intervals found by subtraction are not so reliable, and should only be used whèn better ones are wanting. The work will stand as in the following table, in which all the intervals between *d* and *f* are ranged under the heading *d f*, and similarly for the intervals between the other stars

		d f
May	11	5
	17	6
	27	5.5
Nov.	10	4
	17	6.5
	30	8
Dec.	3	6.5
		7)41.5
		Mean *d* 5.9 *f*

		f g
June	19	2
Oct.	30	2
Nov.	2	2
	10	2
		4) 8
		Mean *f* 2.0 *g*

		g k
Oct.	22	5
	30	3
		2) 8
		Mean *g* 4.0 *k*

		h k
July	1	3
	10	2.5
		2) 5.5
		Mean *h* 2.8 *k*

		m n
Oct.	7	1.5

		m o
Aug.	2	6

		n o
Aug.	2	4
	11	2
	16	2
Sept.	2	2
		4)10
		Mean *n* 2.5 *o*

		n p
Sept.	2	3

		o p
Sept.	2	1

		l m
Oct.	9	3 5

		g l
Oct.	22	5.5
	30	3
		2) 8.5
		Mean *g* 4.3 *l*

		k l
Oct.	30	0.0

		f l
Oct.	30	5

		f k
Oct.	30	5

		d g
Nov.	10	6

It will be noticed that these intervals do not exactly agree among themselves. For instance we have the intervals *f* 2 *g* and *g* 4 *k* from which the interval *f* 6 *k* would result. But that interval observed directly was *f* 5 *k*. Since the value *f* 6 *k* depends on six observations while *f* 5 *k* depends on only one, by giving weights according to the number of observations the mean value *f* 5.9 *k* would result. The following method will be convenient to make use of all the above intervals, each with its proper weight, in forming the light scale.—Assign the arbitrary value 0 to the faintest star used; in this case $p = 0$. For the next brighter star, *o*, we find from the observation of Sept. 2, the interval *o* 1 *p*, hence $o =$

$p + 1.0 = 1.0$. For the next brighter star, n, we have from the above table,

$$n = p + 3.0 = 0.0 + 3.0 = 3.0$$

also
$$n = o + 2.5 = 1.0 + 2.5 = 3.5$$

These two values for n can be combined by multiplying each by the number of observations on which it depends, and dividing the sum of the products by the sum of the number of observations. Thus—

$$\begin{aligned} n &= p + 3.0 = 0.0 + 3.0 = 3.0 \times 1 = 3.0 \\ &= o + 2.5 = 1.0 + 2.5 = 3.5 \times 4 = 14.0 \\ &\qquad\qquad 5)\ 17.0 \\ &\qquad \text{Mean, } n = 3.4 \end{aligned}$$

By proceeding in this manner with each brighter star successively the scale values for all will be obtained. The following table shows all the work—

$$\begin{aligned}
p &= 0 \\
o &= p + 1.0 = 0.0 + 1.0 = 1.0 \\
n &= p + 3.0 = 0.0 + 3.0 = 3.0 \times 1 = 3.0 \\
&= o + 2.5 = 1.0 + 2.5 = 3.5 \times 4 = 14.0 \\
&\qquad 5)\ 17.0 \\
&\qquad \text{Mean, } n = 3.4 \\[6pt]
m &= n + 1.5 = 3.4 + 1.5 = 4.9 \times 1 = 4.9 \\
&= o + 6.0 = 1.0 + 6.0 = 7.0 \times 1 = 7.0 \\
&\qquad 2)\ 11.9 \\
&\qquad \text{Mean, } m = 6.0 \\[6pt]
l &= m + 3.5 = 6.0 + 3.5 = 9.5 \\
k &= l + 0.0 = 9.5 + 0.0 = 9.5 \\
h &= k + 2.8 = 9.5 + 2.8 = 12.3 \\
g &= k + 4.0 = 9.5 + 4.0 = 13.5 \times 2 = 27.0 \\
&\quad l + 4.3 = 9.5 + 4.3 = 13.8 \times 2 = 27.6 \\
&\qquad 4)\ 54.6 \\
&\qquad \text{Mean, } g = 13.7 \\[6pt]
f &= g + 2.0 = 13.7 + 2.0 = 15.7 \times 4 = 62.8 \\
&\quad l + 5.0 = 9.5 + 5.0 = 14.5 \times 1 = 14.5 \\
&\quad k + 5.0 = 9.5 + 5.0 = 14.5 \times 1 = 14.5 \\
&\qquad 6)\ 91.8 \\
&\qquad \text{Mean, } f = 15.3 \\[6pt]
d &= f + 5.9 = 15.3 + 5.9 = 21.2 \times 7 = 148.4 \\
&\quad g + 6.0 = 13.7 + 6.0 = 19.7 \times 1 = 19.7 \\
&\qquad 8)\ 168.1 \\
&\qquad \text{Mean, } d = 21.0
\end{aligned}$$

Light scale.

$$\begin{aligned} p &= 0 \\ o &= 1.0 \\ n &= 3.4 \\ m &= 6.0 \\ l &= 9.5 \\ k &= 9.5 \\ h &= 12.3 \\ g &= 13.7 \\ f &= 15.3 \\ d &= 21.0 \end{aligned}$$

We are now prepared to assign numerical values to the brightness of the variable at the time of each observation. Here again we must take the mean of slightly different values, for instance for May 11 we have $d\ 2\ v$, whence $v = 19.0$, also $v\ 3\ f$, whence

MAP OF THE

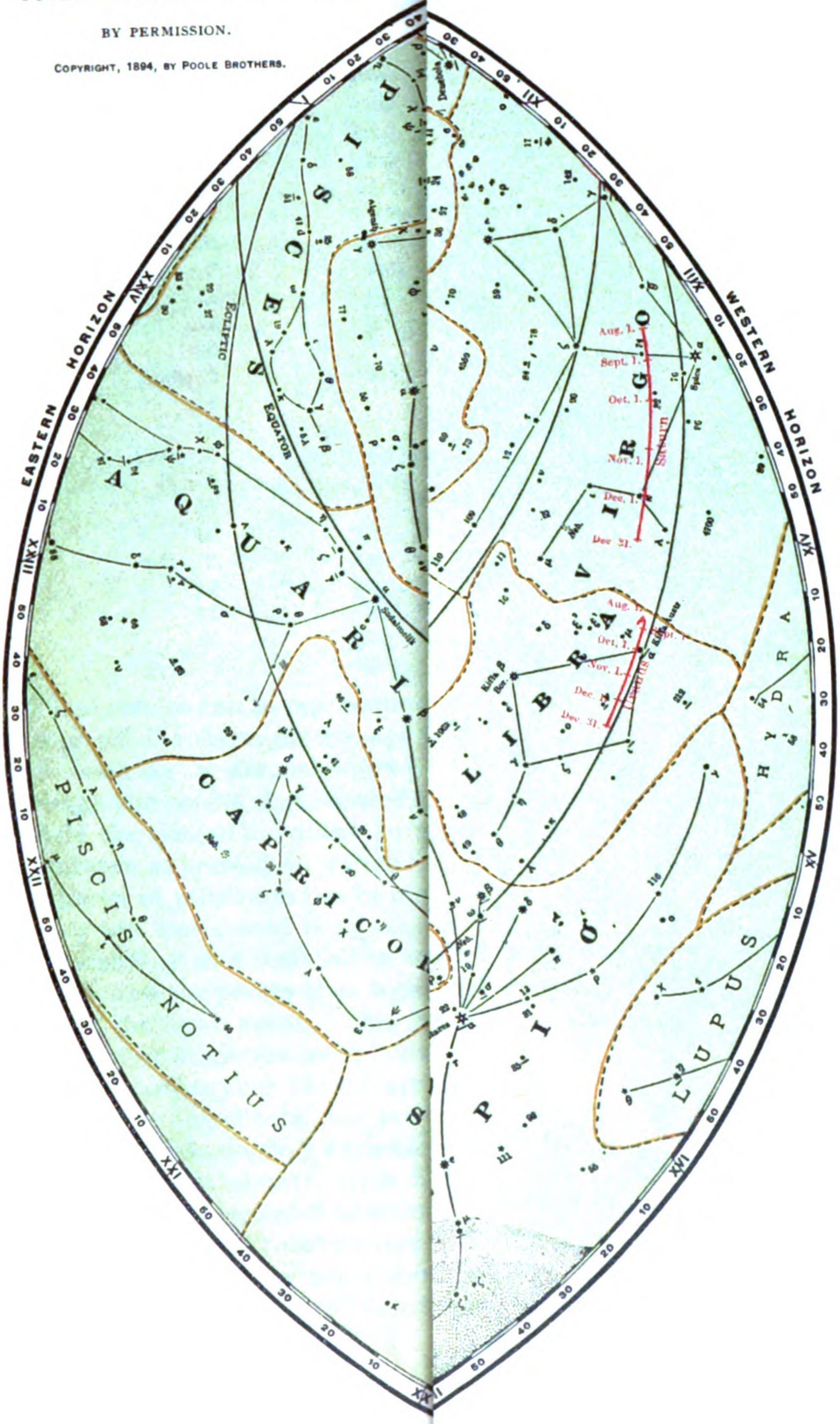
CONSTELLATIO

VISIBLE AUGUST 15,

AT 9 P. M.

REDUCED FROM SECTION OF POOLE BROTHERS' PLANISPHERE.

BY PERMISSION.



MAGNITUDE OF STARS.

to	1st Magnitude.	Stars underli
to	2nd ,,	double or m
....	3rd ,,	
....	4th ,,	
....	5th and under.	

Clusters and Nebulæ.

$v = 18.3$; the most probable value will be the mean of the two, or $v = 18.7$. Proceeding in this way with the observation of each date we have

Date.		Observed.	Mean.
1893 May	11	19.0, 18.3,	18.7
	17	19.0, 19.3	19.2
	27	19.0, 18.8	18.9
June	19	14.3, 14.7	14.5
July	1	11.3, 11.5	11.4
	10	10.3, 10.0	10.2
Aug.	2	3.5, 2.9, 4.5	3.6
	11	2.9, 2.5	2.7
	16	2.4, 2.0	2.2
	26		
Sept.	2	1.4, 1.0, 1.0	1.1
	6		1 ±
	26		6 ±
Oct.	7	6.0, 4.9	5.5
	9	8.0, 8.0	8.0
	22	11.7, 13.0, 12.5	12.4
	30	12.5, 13.7, 13.3, 12.5	13.0
Nov.	2	14.3, 14.7	14.5
	10	15.3, 15.7, 17.0	16.0
	17	18.3, 17.5	17.9
	30	20.3, 18.0	19.2
Dec.	3	18.3, 17.5	17.9

These results can be represented to the eye on squared paper by laying off the dates horizontally and the brightness vertically, and drawing a smooth curve passing as nearly as possible through the points thus located. This curve will show approximately the time of maximum or mirimum, and the corresponding brightness expressed in terms of the light curve. The time of maximum or minimum can be more accurately determined by bisecting the horizontal lines connecting corresponding points on the ascending and descending branches of the curve, drawing a line through the points thus located, and prolonging it till it intersects the light curve. This point of intersection will be the maximum or minimum as the case may be.

The accompanying charts are copies of small portions of the Durchmusterung charts, and are taken by the kindness of the author from Pickering's "Variable Stars of Long Period." They are two degrees square, with the variable near the centre enclosed in a small circle. The stars are all north of $+53°$ Decl. and therefore do not set to observers in northern and central United States. The following table shows their peculiarities; the data are taken from Chandler's "Second Catalogue of Variable Stars."

No.	Star Name	Place for 1900.0 R. A.			Decl.		Red-ness	Magnitude Max.	Min.	Period days.
		h	m	s	°	′				
107	T Cassiopeiæ	0	17	49	+55	14.3	7.3	7.0 – 8.0	11.0 – 11.2	445.0
432	S Cassiopeiæ	1	12	18	+72	5.1	6.7	6.7 – 8.6	< 13.5	610.5
793	T Persei	2	12	12	+58	29.5	4	8.2	9.3	Irreg.
814	S Persei	2	15	41	+58	7.8	5.0	8.5	13	"
1855	R Aurigæ	5	9	13	+53	28.4	6.5	6.5 – 7.8	12.5 – 12.7	460.6
2478	R Lyncis	6	53	3	+55	28.1	4.8	7.8 – 8.0	< 13	380.0
3825	R Ursæ Majoris	10	37	34	+69	18.0	1.6	6.0 – 8.2	13.2	302.1
4511	T Ursæ Majoris	12	31	50	+60	2.3	2.0	6.0 – 8.5	12.2 – 13	257.2
4557	S Ursæ Majoris	12	39	34	+61	38.4	3.2	6.7 – 8.2	10.2 – 11.5	226.1

The periods of all the above stars except R Aurigæ and R Lyncis are subject to variations, more or less irregular, ranging from 20 to 50 or more days above or below the period assigned. The laws governing these variations are not all well known, hence more observations are desired.

The table accompanying the plate gives the designation, place, and approximate magnitude (to the nearest unit) of Pickering's comparison stars for the variables charted. The comparison stars down to the 10th magnitude are lettered on the charts. It is an excellent plan for the observer to make about a three-fold enlargement of each chart in his note book, locating carefully thereon the comparison stars down to a magnitude below the limit of vision of his telescope. (See October POPULAR ASTRONOMY, page 91.)

FIRST OBSERVATIONS OF THE SUN AND MOON.

MARY E BYRD,*

I. QUESTIONS.

1. At what point on the horizon does the Sun set on some evening in January?

2. In eight or ten days can you detect a change in the sunset point? Is it moving north or south?

3. Five or six weeks after the January observation, how many degrees is this point from the west point?

4. If observations are made weekly, is the sunset point found moving uniformly along the horizon, or is the number of degrees passed over greater in some weeks than in others?

5. How do you account for the motion of the sunset point?

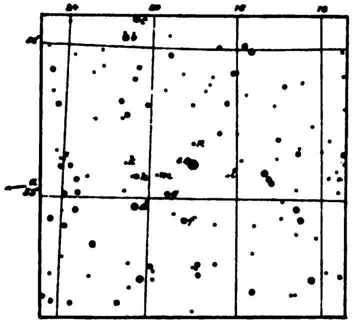
6. Can you find a time when for a few nights this point appears to be stationary?

7. When does the Sun set nearest to the south point?

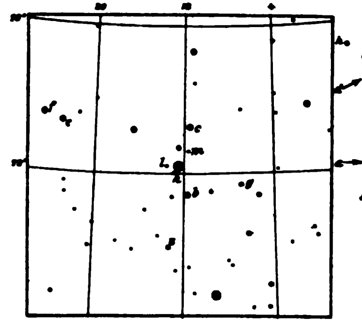
8. How many degrees is it then distant from the west point?

* Director of the Observatory at Smith College, Northampton, Mass.

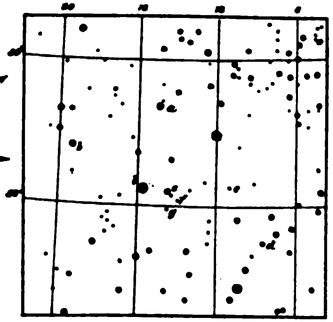
CIRCUMPOLAR VARIABLE STARS OF LONG PERIOD.



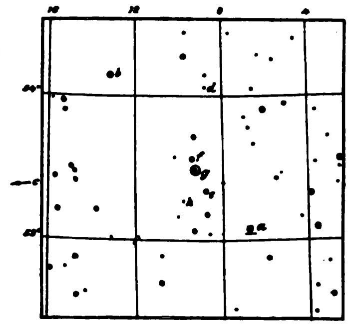
107 T CASSIOPEIÆ.
R.A. 0h 17m.8 DEC. + 55° 14'.



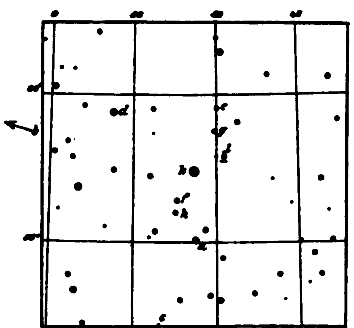
432 S CASSIOPEIÆ.
R.A. 1h 12m.3 DEC. + 72° 5'.



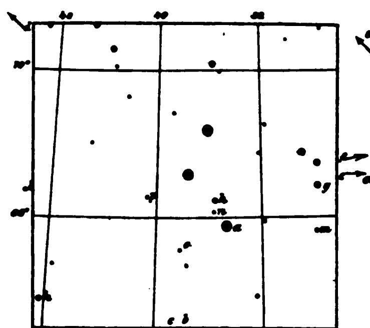
793 and 814, T and S PERSEI.
R.A. 2h 12m.2 DEC. + 58° 29'.
2h 15m.7 58° 8'.



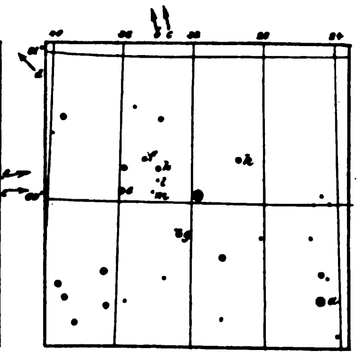
1855 R. AURIGÆ.
R.A. 5h 9m.2 DEC. + 53° 29'.



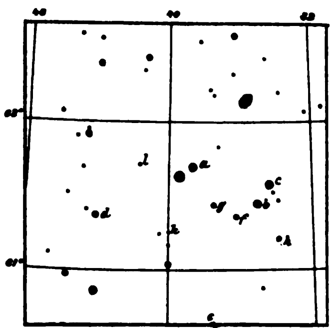
2478 R. LYNCIS.
R.A. 6h 53m.1 DEC. + 55° 29'.



3825 R. URSÆ MAJORIS.
R.A. 10h 37m.6 DEC. + 69° 18'.



4511 T URSÆ MAJORIS.
R.A. 12h 31m.9 DEC. + 60° 3'.



4557 S URSÆ MAJORIS.
R.A. 12h 39m.6 DEC. + 61° 39'.

9. Do the times of sunset vary uniformly from night to night?

10. How closely do the observed times of sunset agree with the almanac times?

. 11. If the setting point of the Sun is found, for example, to be ten degrees south of the west point on a certain evening, how far from the east point is it observed to rise on the preceding or on the following morning?

12. What is the noon altitude for one of these two days?

13. Having given the Sun's declination, how can you test the accuracy of this observation?

14. Can you detect any variation in the Sun's noon altitude in less than a week?

15. When the sunset point is moving south, how is the noon altitude changing?

16. When the sunset point is moving north, how is the noon altitude changing?

17. What is the noon altitude when greatest? When least?

18. At what times in the year are the greatest and least altitudes observed?

19. From these observations, how can you obtain approximately the angle between the ecliptic and the celestial equator?

20. From these observations how can you obtain approximately the latitude of the place?

21. Does the Sun ever pass through your zenith?

22. How accurately can you find apparent noon from two observations of the Sun, taken when it has the same altitude a little before and a little after meridian passage?

23. What is the difference between noon as shown by the clock and by the Sun on the noon mark?

24. Why do the noons not agree?

25. What constellation is seen in the west after sunset along the course which the Sun has just travelled?

26. From month to month do you find the same constellation there?

27. Do you always see the same constellation in the east, in the Sun's path just before sunrise?

28. What apparent motion of the Sun do these observations indicate?

29. Fixing the Sun's daily path with regard to the horizon by the points of rising, southing and setting, do you find a change in this path from month to month?

30. In what month is the path shortest and nearest to the horizon?

31. In what month is it longest and nearest to the zenith?

32. At what times in the year are the paths in a similar position with regard to the horizon?

33. Locating the Sun with regard to the horizon, what is its altitude and azimuth at a particular hour and minute?

34. How great is the change in these coördinates in an hour?

35. Which coördinate is changing the more rapidly at noon?

36. Two or three hours before sunset which is changing the more rapidly?

37. What is the hourly rate of the Sun's apparent motion?

38. Do you note any difference in the rate of this motion when it is an hour high and when it is half an hour high?

39. How long does it take the Sun to set, that is how long is the interval between the disappearance of the lower and upper limbs?

40. Does this interval vary in different months of the year?

41. Can you detect any difference in the size or form of the Sun when seen in different parts of the sky?

42. Is there any variation in the color of the Sun in one day, or from day to day?

43. Testing sunlight by its power to penetrate clouds, is there any difference in that which comes from the limb and from the centre of the Sun?

44. About the times of sunspot maximum if you look at the Sun through dark glasses can you see any spots?

45. What is the color of the Moon?

46. Are there variations in the color in one night?

47. Is the color different on different nights?

48. What is the appearance of the Moon when seen in broad daylight?

49. How do you describe the appearance which you designate as the "old Moon in the new Moon's arms?"

50. Do the dark and illuminated parts seem to belong to the same circle?

51. If not, which part belongs to the larger circle?

52. On a given evening what proportion of the disc is seen?

53. Is the bounding line between the light and dark portions smooth or broken?

54. At any particular time does the terminator form a convex or a concave boundary for the illuminated portion of the Moon? Can you lay down a general rule for different phases?

55. Viewed by the unaided eye, when, if ever, is the terminator a straight line?

56. Does the Moon appear full to the naked eye for three or four hours?

57. Which limb first becomes defective?

58. How are the dark markings located on the disc?

59. What proportional part of the visible disc do they occupy?

60. Does the color of the markings vary?

61. Do they change their position relatively to the limb, to the terminator, or to one another?

62. How would you prove that the Moon in all its phases is the same Moon?

63. When the Moon is full on any given evening, how does its time of rising compare with the time of sunset?

64. At what time does the Moon set on two or three successive nights?

65. How do these observed times agree with the almanac times?

66. Does the Moon rise and set every day?

67. In September or October can you find a time when the Moon stays above the horizon more than twelve hours? Less than twelve hours?

68. What marked peculiarity do you notice about the rising of the Moon when it is nearly full in September and October?

69. Where do you look for the Moon a few days before it is new?

70. How short a time before new Moon can you see the Moon?

71. How soon after new Moon can you see the Moon?

72. Why can you not see it at the instant of new Moon, or at least an hour or two after that time?

73. Which way do the horns of the new Moon point? Why?

74. When you see the crescent Moon in the East, which way do the horns then point? Why?

75. By means of the celestial globe and a disc of paper for the Moon, how accurately for a particular day and hour can you predict the direction in which the horns will point ?

76. Locating the Moon with regard to the horizon, what is the altitude and azimuth at a given hour and minute?

77. In how short a time are you sure of detecting a change in these coördinates ?

78. During a particular day, between what limits approximately do the altitude and azimuth of the Moon vary ?

79. At a given time, how many degrees is the Moon above or below the ecliptic ?

80. Measuring along the ecliptic how many degrees is it then east or west of the vernal equinox ?

81. Estimating distances directly from the celestial equator and vernal equinox, what is the Moon's right ascension and declination ?

82. How accurately can you obtain these coördinates by mapping the Moon with stars near it ?

83. Can you detect a change in these coördinates from night to night ? In a single night ?

84. On a given night in what constellation is the Moon ?

85. How do you reconcile the constellation in which the Moon is found in the sky with the place of the Moon as given in the *Old Farmer's Almanac?*

86. In what direction does the Moon appear to move ?

87. What is the hourly rate of the apparent motion ?

88. In what direction does the Moon move among the stars ?

89. What is the hourly rate of this motion ?

90. Through what constellations does the Moon pass in a given lunar month ?

91. Does it pass through the same constellations in different months ?

92. Fixing its path by bright stars, does the path vary from month to month ?

93. Fixing the Moon's path in reference to the horizon by the points of rising, southing and setting, do you find a change from night to night ? From month to month ?

94. How does the full Moon compare in size with the Sun ?

95. On a given day, does the Moon rise north or south of the sunrise point ?

96. On a given day, does the Moon set north or south of the sunset point ?

97. Is the meridian altitude of the Sun or the Moon greater on any particular day ?

98. If you fix the paths of the Sun and Moon by their points of rising, southing and setting, how do these paths compare on any given day ?

99. Having found the relative positions of these two paths for one day, will this position hold true for other days in different months ?

II.

SUGGESTIONS.

The preceding questions with few exceptions can be brought into two groups, one dealing with the position and motion of the Sun and Moon, the other treating of the physical characteristics of these bodies, their form, size, color and surface markings.

It is possible even without a telescope to do a little in studying the solar disc. One can at least put to the test his vague notions that the sun is not always of the same size, that it has been seen elliptical in outline and that its color varies all the way from dazzling white tinged with yellow to a dull, deep red. These winter days offer abundant opportunity to note how sunlight is affected by passing through cloud-layers of different thickness, and any one who watches the sun under a cloud for several days should obtain satisfactory proof for or against the text-book dictum that all parts of the sun are not equally bright. It is no objection whatever to such observations as these that they deal mainly with optical delusions and effects of the atmosphere. If one is ever to divine from appearances in the sky what belongs in very truth to a heavenly body and what must be traced to the observer and his surroundings, these tricks played by the air and our own eyes are precisely the very things to be investigated and it is well to begin with simple phenomena where the illusions stand out boldly.

In all observations connected with the Sun, spectacles with dark glasses are better than a piece of smoked glass held in the hand. The inexperienced observer gets a steadier view and both hands are left free. Two pairs of spectacles are needed when watching for sunspots and even then the glasses, unless they are very dark, must be smoked. The present year is a favorable time for finding spots on the Sun. There is a possibility any day that one may appear which is large enough to be seen without any magnifying power. During the past few months one of the students here has made a report of sunspots seen with the naked eye.

The sun is very bright and very far away. The Moon is our next-door neighbor and shows true neighborly kindness in being hospitable to every observer on the earth. Any one who has not made the experiment will doubtless be surprised to find out how much can be learned about the Moon's surface by simply looking at it. No matter how little is seen at first, it is only necessary to persevere and one by one details come out. A simple question is found to involve much more than appears at first sight. It needs more than a hasty glance to describe the ghost of a Moon which appears in broad daylight, looking like and yet unlike a little cloud.

All satisfactory study of the Moon's appearance must be accompanied by drawings of some kind. The poorest are usually better than none. In answering questions from 45 to 62 in the preceding list, as many as eight or ten sketches should be entered in the note-book in connection with the descriptions. No one should omit careful and repeated observation with the naked eye, although final tests will naturally be made, if possible, with an opera glass. If the glass magnifies three or four diameters, a genuine beginning can be made in selenography, and for that it would be hard to find a better guide than Chapter V, in *Astronomy with an Opera Glass*, by Serviss.

To be Continued.

GLASS FOR OPTICAL INSTRUMENTS WITH ESPECIAL REFERENCE TO TELESCOPE OBJECTIVES.

J. A. BRASHEAR.*

When the glass for the 36-inch objective of the Lick Observatory was under process of manufacture, and many failures had been made in obtaining the crown disc, a very successful glass maker in this country came to the writer and suggested that he could make such a disc without any difficulty. After a brief conversation with the gentleman as to his plans, it was clearly evident that the sum of his knowledge about optical glass was that it should be *transparent* and free from bubbles. Many persons, not conversant with the conditions demanded in a piece of glass suitable for making a high class telescope objective, consider that transparency and freedom from bubbles are the most important elements to consider, whereas a piece of glass may be as "clear as crystal" and without a bubble to mar its beauty, yet be worthless in an optical sense.

The history and development of the optical glass industry is indeed a very interesting story, but as its general facts have been written many times, it is best that we give our readers information of a kind that will be of practical value. They will, however, desire to know something of the methods of manufacture.

In making window glass, plate glass, table-ware glass, etc. the furnaces for melting the material are large enough to have from four to a dozen or more pots placed in them, and these pots are used until they break or are burned out, but in making optical glass but one pot is placed in a small furnace. Great care must be taken in the preparation of the pot as the oxide of iron and other impurities, often constituents of the clay used in the manufacture of pots for melting glass in, would ruin the finer grades of optical glass.

* Optician, Allegheny, Penn.

After the pot is brought up to a pretty high temperature the "batch" or material for the glass is placed in the pot and allowed to subside by the softening of the more easily melted materials, and again filled up, three fillings being usually required.

While the "batch" is melting we will give the composition of a few of the various glasses used in optical work.

Guinand and Fraunhofer used for the flint glass for objectives for telescopes,

100 parts silica,
106 parts red oxide of lead,
43 parts carbonate of potash.

Bontemps used

100 parts silica,
100 parts red oxide of lead,
21.5 parts carbonate of potash,
5 parts nitrate of potash.

A standard "batch" used in France and England contains:

100 parts silica,
105 parts red oxide of lead,
20 parts carbonate of potash.
5 parts nitrate of potash.

For denser flints more oxide of lead is used and for lighter, less of the oxide, and there are very many variations, formulæ for which the writer has received from the younger Feil, but which need not be repeated here.

For the crown glass the "batch" is composed of

100 parts silica,
41.64 parts carbonate of potash,
9.46 parts red oxide of lead.
9.46 parts slacked lime,
1.90 parts nitrate of potash.

Another formula is,

100 parts silica,
42.66 parts carbonate of potash.
21.66 slacked lime,
2.22 parts nitrate of potash.

In this latter formula the lead is left out entirely.

The optical glass manufactory of Jena has added many new kinds of flint and crown glasses which are now at the command of the optician, and Mr. Mantois of Paris has also made a number of new kinds during the past few years, but the standard flint and crown glasses for telescope objectives are practically those whose formulæ have been given above. Ordinary optical crown glass has an index of refraction for the D line of the spectrum of 1.51, but by the addition of baryta, this index has been increased to as high as 1.587.

Boro silicate flint glass has been made with an index for the D line as low as 1.55, while the dense yellow flint glass known as Faraday glass has an index for D equal to. 1.9626. But we must return to our glass melting furnace, and will find the "batch" melted and quite limpid. A "gathering" of it is now taken out on a rod called a punty, although a small pipe is frequently used so that the trial piece may be made something like the shape of a pear with a slight hollow blown in it. If the trial piece is found transparent and free from "seeds" which are imperfectly melted particles of silex or minute air bubbles, it is good enough for ordinary purposes for which glass is used in the arts, but for optical purposes it must now be stirred by a peculiar stirrer made of pot clay which is sometimes heated before being inserted in the pot. Our French optical glass makers call this stirrer Le Guinand, after the celebrated Guinand who first used this method of thoroughly mixing the glass. An iron bar called a crochet, bent at the end to insert in the clay stirrer, but which does not come in contact with the melted glass is put in an opening made for it in the Guinand and the glass is stirred thoroughly until it becomes so stiff by gradual cooling that it cannot well be stirred longer. For ordinary optical glass this one stirring usually suffices, but a second and even a third stirring is resorted to after the glass has been made softer by additional heating, if the highest grades of glass are desired.

This careful and prolonged stirring is one of the most difficult parts of the manipulation, as it usually requires two workmen to stand before the intensely heated furnace for two or three hours. When the stirrer is first introduced and the glass is limpid it can be moved around inside of the pot once a second, but at the close of the operation it requires five or six times as long to move it.

The stirrer must not touch the pot or some of the clay may be incorporated with the glass, and thus ruin it.

The purpose of this stirring is, to so thoroughly mix the glass that it will be as nearly equal in density throughout the mass as possible, and be free from striæ and other impurities that are, in part at least, eliminated in this way. After the final stirring, the next step is to thoroughly lute or stop every open place in the furnace so as to prevent any air from gaining admittance to it, and then a slow process of cooling goes on for from four to eight days, according to the size of the pot and the amount of material contained in it. This slow cooling is not for the purpose of annealing the glass in a perfect manner, but to save the glass from being shattered into small fragments. With the slowest cooling, it is always very uncertain whether or not large pieces, unbroken, can be secured, for if a lump is *cracked* in any way it can never be reunited to make a perfect disc; hence it is that as the discs of optical glass increase in size their cost increases greatly, and justly so. The writer has seen some very odd looking shapes in the original blocks at the factory of Mr. Mantois in Paris, from which one would think it impossible to make a disc suitable for a large objective, but we all owe a debt of gratitude to Guinand for the beautiful process which takes hold of this rough and unshapely piece of glass and fits it for the optician's handiwork.

And now let us follow the block as it goes through the processes which make it suitable for a lens.

A superficial examination determines whether it has such serious defects as would make it useless to carry the manipulation further. This preliminary examination causes many pieces to be rejected or set aside to be utilized for plates good enough for some uses such as cheap photo lenses, opera glasses, etc. If however, on close examination, it is found suitable for a high class lens, any serious defects are either ground off on a mill or sawed off with a soft iron saw, using sand or emery, or with a diamond saw, *i. e.*, a soft iron saw with diamond dust hammered in its edge. Some times it is found necessary to grind more than half way through a block of glass to cut out an imperfection and this may be done with safety, and indeed it is possible to grind almost through a block of glass and save it, but if the cut goes entirely through, it will never reunite without a flaw, whereas, when the cut is not through, the opening, with its surrounding rough surfaces will slowly rise to the top when the piece is softened in its secondary heating, which we will presently notice.

To be Continued.

FAITH IN THE INTEGRITY OF THE INTERSTELLAR MEDIUM.

DE VOLSON WOOD.*

That space is not void is conceded. That it is filled with a medium capable of transmitting light and heat is not questioned. This medium is believed to be uniform in density and elasticity,

* Stevens Institute, Hoboken, N. J.

but the exact nature of its constitution is unknown. Some believe it to be molecular like gas, while others question if its structure has been correctly defined. It makes no direct impression upon the senses, and is known only through effects produced; and yet, whatever be its nature, it is known to transmit a wave of light at the rate of 186,300 miles per second, there being, as a mean value, within the spectrum about 50,000 waves in an inch, or more than 60,000,000,000,000,000 in the distance passed over in one second. When it is considered that waves are transmitted through this medium in all conceivable directions with the same velocity, some faint conception may be had of its intense activity. The complicity of the waves is transcendent, for each shade of light has its own wave-length, there being about 36,000 waves to the inch in red light, and more than 64,000 in violet, and outside the visible spectrum there are less in number in one direction and more in the other. Every self-luminous body in the universe is imparting to this medium waves of these varying lengths, all travelling with a sensibly constant velocity. When it is considered that the countless number of stars and suns, scattered promiscuously throughout limitless space, are producing such waves radiating from each other in all possible directions, it would seem that, if they did not actually destroy each other, they would so interfere as to produce "confusion worse confounded" and the impressions upon the eye of an observer would be valueless. But, on the contrary, the scientist believes that this medium truly and faithfully transmits to the remotest space every wave imparted to it, preserving with the strictest integrity its individuality—except that planets and other solid bodies may destroy the waves they intercept.

A star ten or more years ago started a wave which just now, we will suppose, arrives at the Earth and writes its own record on some sensitized plates, though the star may be 6,000,000,000,000 miles away. From these impressions the physicist finds—perhaps—that the star is double, although the most powerful telescope had failed to divide it, that the two revolve about each other, and he determines their probable orbit, masses and velocities. Or, perhaps he finds, as in the remarkable star of 1892, that it changes from a star to a nebula in a few months. In all this, no question is raised in regard to the integrity of the record, nor whether in its long journey, any planet, sun, comet, meteorite or nebula has interfered to modify or in any way to corrupt the story it was commissioned to tell. What faith! But this is little more than the shadow of an illustration; for Herschel, the astronomer, thought it probable that we can see nebulæ from which it has taken light 300,000 years to reach the Earth, during which time the interstellar medium has been faithful in transmitting at the rate of more than 11,000,000 miles per minute the impulse committed to it, notwithstanding its path has been crossed and recrossed by other waves without number. Pen cannot adequately describe the transcendent properties of this wonderful medium called the "luminiferous ether," nor too highly exalt that faith which enables one to implicitly believe the truthfulness of the stories committed to him. One is led to exclaim with the Psalmist "Oh Lord! how manifold are thy works, in wisdom thou hast made them all."—*Science, Nov. 3, 1893.*

THE FACE OF THE SKY.

CHARLOTTE R WILLARD

At about seven o'clock February first a bright star may be seen rising a little north of the east point of the horizon. This is Regulus (α Leonis), the heart of the Lion, and is the brightest star in the zodiacal constellation Leo. On the twenty-first of August the sun passes just below this star. Preceding Regulus are five stars which with it form the Sickle, Regulus being at the end of the handle. Near the upper part of the Sickle is the point in the heavens from which the November meteors seem to radiate. The second star from Regulus (γ Leonis) is a fine double; the components are separated by about $3''$, and are of magnitudes 2 and 4; this is a binary with "period of 1,000 years or less."

Near the Sun's path and preceding Regulus by about 2½ hours is a hazy spot known as Præsepe or the Bee Hive in the constellation Cancer. An opera glass resolves this into a beautiful cluster.

A comparison of the colors of the bright stars now visible will be found interesting. Notice the contrast between the colors of Betelgeuse and Rigel by glancing quickly from one to the other. There is much to interest in the theory that the age of a star is indicated by its color.

About half way between Præsepe and Sirius is Procyon, the Little Dog Star, which is the only first magnitude star in the constellation Canis Minor. Its name signifies before the Dog, it rising a little earlier than Sirius. The motion of Procyon is evidently disturbed by an unseen companion, for which Mr. Burnham has in vain searched with the Great Lick Telescope.

"The Face of the Sky" occupies little space in the present issue, because of the large amount of matter to be presented on the phenomena for the year 1894. Those objects are mentioned which are appearing in the East and have not been noticed in preceding numbers.

Observatory on Mont Blanc.—We will soon give a picture of the Observatory on the summit of Mont Blanc, Switzerland, which is 15,780 feet above the level of the sea. It is the highest astronomical Observatory in the world, and has only recently been completed.

PHENOMENA DURING THE YEAR 1894.

H .C. WILSON.

Thinking that a general preview of the astronomical phenomena, which are to be expected during this year, would be of interest to our readers, we have prepared the following notes.

Eclipses.—There will be four eclipses, two of the Sun and two of the Moon, none of which will be of special interest. The first will be a *partial eclipse of the Moon* on March 21, beginning at $5^h 57^m$ A. M., and ending at $10^h 44^m$ A. M., central standard time. Only one-fourth of the Moon's diameter will be immersed in the Earth's shadow at the time of maximum eclipse.

The second will be an *annular eclipse of the Sun* beginning April 5 at $7^h 16^m$ P. M., and ending at $12^h 32^m$ A. M., April 6, central time. It will be visible as a partial eclipse in Asia, Alaska, and the eastern part of Europe. The path of the annular eclipse passes from the Indian Ocean across Hindostan, China, and Siberia, into Alaska.

The third will be a *partial eclipse of the Moon,* beginning Sept. 14 at $7^h 59^m$ P. M., and ending Sept. 15 at $1^h 04^m$ A. M. This will be visible throughout North and South America. The beginning will be visible in the western portions of Europe and Africa. Only 0.23 of the diameter of the Moon will be covered by the shadow at the middle of the eclipse.

The fourth will be a *total eclipse of the Sun,* beginning Sept. 28 at $9^h 1^m$ P. M. and ending Sept. 29 at $2^h 17^m$ A. M. central time. It will be visible mostly in inaccessible regions. The path of totality passes from Central Africa across the Indian Ocean to the south of Australia. As a partial eclipse it will be visible in the eastern part of Africa, Persia, Hindostan, the Indian Ocean, the southern part of Australia and one of the islands of New Zealand.

Transit of Mercury.—The planet Mercury will pass directly between the Earth and the Sun on Nov. 10, so that for over five hours it will be seen projected as a round black spot upon the disc of the Sun. The transit will begin at $9^h 55^m$ A. M., and end at $3^h 12^m$ P. M. central time. The accompanying diagram, Fig. 1, will indicate the course which Mercury is to take across the solar disc. This transit, which will be the last to occur during this century, will be visible throughout North and South America, and in the western parts of Europe and Africa. Before November we will give the necessary data for computing the times of the contacts for different localities.

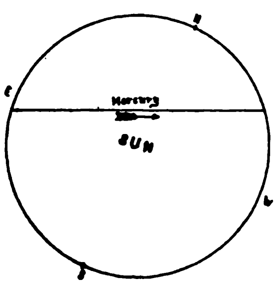


FIG. 1.

Occultations.—The usual number of occultations of stars by the Moon is to be expected. The lists of these for each month will be given one month in advance. We can, however, give only the data which apply to the occultations as seen from Washington, since these data are quite different for different localities, and the labor of calculating them for a sufficient number of points to make a general table even for the United States would be more than we can undertake. The Washington times will serve to call attention to the phenomena, but may be expected to be in error by many minutes, besides the difference in longitude for other places.

The Planets.—We have had the diagrams, Figs. 2 and 3, made in order to place before the eye of the reader the planets in their true places in their orbits, and relative positions with reference to the Earth and Sun. The circles represent the orbits of the planets, and their positions at the beginning and end of the year, and in some cases at the beginning of each month are marked upon the circles. It was impracticable to draw them all to the same scale, because of the enormous dimensions of the orbits of Uranus and Neptune.

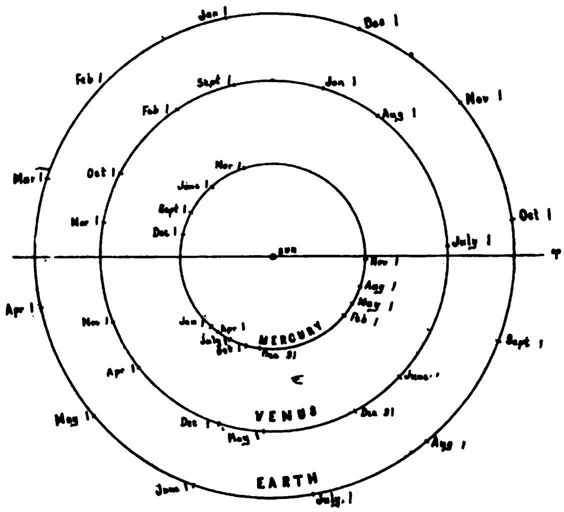


FIG. 2.—DIAGRAM SHOWING THE PLACES OF MERCURY, VENUS AND EARTH IN THEIR ORBITS DURING 1894.

At a glance one will see that Mercury makes a little more than four revolutions about the Sun, being seen from the Earth first on one side then on the other of the Sun. On Jan. 1 this planet as seen from the Earth, is to the right or west of the Sun. Toward the end of the month it will be behind the Sun, at superior conjunction. A few days before March 1 it will be at its greatest distance to the left or east of the Sun, and will therefore be visible in the evening just after sunset. About the middle of March Mercury will be in line between Earth and Sun, *i. e.*, at inferior conjunction, and invisible. A little study of the chart will show that we ought to expect to see Mercury as "evening star" in the latter part of February, the latter part of June and the middle of October, and as "morning star" about the middle of April, the first of August and the last of December.

In the same way we find that Venus will be "evening star" during January, but will pass between Earth and Sun in February, and after that will be "morning star," reaching her greatest distance to the right or west from the Sun in May. In November she will pass behind the Sun, becoming evening star again.

From Fig. 3 we see that Mars is just coming out from behind the Sun, and will not be in a very good position for three or four months yet, but that from July to the end of the year its position will be very favorable. Jupiter will be too close to the Sun for observation during May and June, and will be in best position in December. Saturn will be best seen in April and May, and will be invisible in

October. Uranus will be in best position in May and June, and Neptune in November and December. At the present time Mars, Saturn and Uranus are in that part of the sky which is visible in the morning, Jupiter and Neptune in the opposite region which is visible in the evening. Mars is rapidly leaving his companions behind, and at the end of the year will join Neptune and Jupiter.

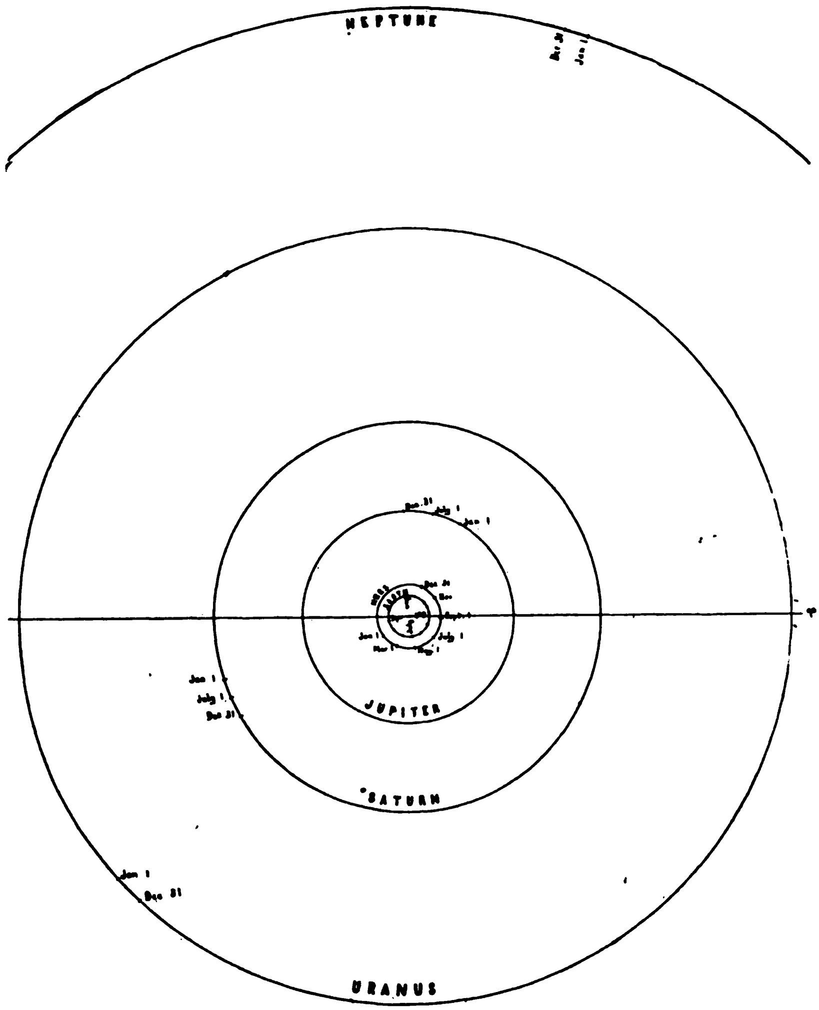


FIG. 3.—DIAGRAM SHOWING THE PLACES OF EARTH AND OUTER PLANETS IN THEIR ORBITS DURING 1894.

The chart, Fig. 4, shows the apparent paths which will be traced among the stars during the year by the planets Uranus and Saturn, and will enable the reader who is familiar with the constellations to identify the planets at any time.

Comets.—What new comets will be discovered of course we cannot predict, but two comets of short period are expected to return this year. The first, Tem-

pel II, the second comet of 1873, is due at perihelion April 20, and will be in good position for observation for several months after that time. It will be a telescopic comet. It was last seen in 1878, when it was observed for five months.

The second is Encke's periodic comet, which is not due at perihelion until Feb. 1895, but will be in best position for observation in December, 1894. This is also a telescopic comet, having a period of 3.3 years.

If the reader will refer to the plate of the Jupiter family of comets in the October number of POPULAR ASTRONOMY he will see the orbits of these comets and their relation to that of the Earth.

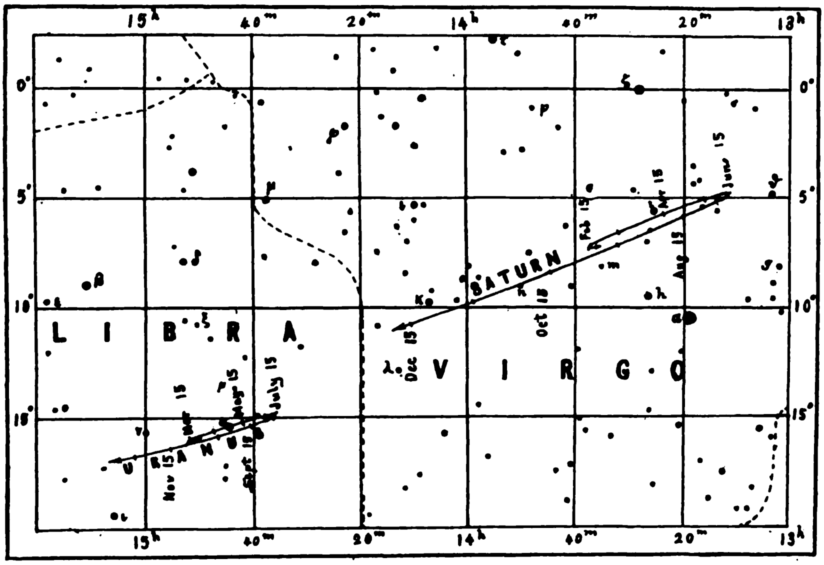


FIG. 4.—CHART SHOWING THE APPARENT PATHS OF SATURN AND URANUS AMONG THE STARS IN 1894.

The Phenomena of the Satellites.—The satellites of Mars are so small and faint that they are not likely to be seen by many amateurs. The most favorable time to make the attempt to see them will be in October when Mars is nearest the Earth.

The phenomena of Jupiter's four outer Satellites may be observed with a very moderate telescope. We will therefore give for each month the times of those phenomena which will be visible in the United States, and the configuration of the satellites at the most convenient hour for observation on each night. The diagram, Fig. 5, shows the apparent courses of the satellites around the planet for this year. The diagram gives the appearance seen in an inverting telescope. The vertical scale is made three times that of the horizontal scale in order to clearly separate the lines. Unfortuuately the arrows indicating the direction of motion have been omitted from the cut. It is easy, however, to remember that the motion in the upper half of each satellite orbit is toward the left, and in the lower half toward the right. It will be noticed that all the satellites except IV pass in front of the planet when going toward the left, and behind it when moving toward the right. Satellite IV barely skirts the upper and lower edges of the planet. The time when a satellite enters upon the right edge of the disc of

Jupiter is designated in the table on page 235 as *Tr. In.* (transit ingress); that when it leaves the left edge *Tr. Eg.* (transit egress). The time when the satellite coming from the left goes behind the planet is designated *Oc. Dis.* (occultation disappearance); when it emerges on the right *Oc. Re.* (occultation reappearance). When the satellite enters the shadow of the planet the designation is *Ec. Dis.* (eclipse disappearance); when it emerges from the shadow, *Ec. Re.* (eclipse reappearance). The shadow of the planet as seen from the Earth is sometimes projected toward the right, sometimes toward the left, and sometimes directly behind the planet, according to the position of the Earth with reference to the line passing through the Sun and Jupiter, so that the last mentioned phenomena occur in different apparent positions with reference to the planet at different times. In February the shadow of Jupiter will be projected toward the right, so that the eclipses all occur after the occultations and on the right side of the planet.

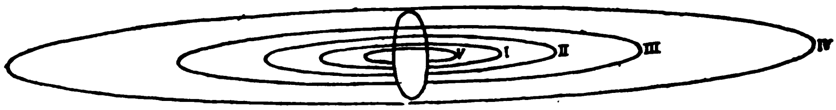


FIG. 5.—DIAGRAM SHOWING THE APPARENT COURSES OF THE SATELLITES OF JUPITER AROUND THE PLANET IN 1894.

The four diagrams at the top of page 234, marked *Phases of the Eclipses. etc.*, show where the observer should look for the disappearance and reappearance of each satellite. Satellite I is so near the planet that it enters the shadow while behind the planet, but reappears at the point marked r. Satellite II disappears in the shadow at d, very soon after emerging from occultation, and reappears at r. The third satellite is so far out that both the disappearance and reappearance of eclipses occur quite a distance to the right of the planet, and IV does not enter the shadow at all. When the shadow of a satellite crosses the disc of the planet it is seen as a round black spot entering on the right and passing off the left edge. The beginning of this phenomenon is designated *Sh. In.* (transit of shadow ingress), and the end *Sh. Eg.* (transit of shadow egress).

The configuration of Jupiter's satellites will be indicated, as for February on page 234, for a given hour of each night, the light disc representing the planet and the dots the relative positions of the satellites. The numerals indicate the numbers of the satellites, and also the direction of their motions. The latter is always from the dot toward the numeral. A light disc at the left side of the page indicates that the satellite, whose numeral is attached, is projected upon the face of the planet; a black disc on the right, that the satellite is invisible by occultation or eclipse.

Five of the satellites of Saturn are usually visible with a telescope of moderate power. As they are best seen when at their greatest distances to the right or left of the planet (elongations), we will give each month the times of the eastern elongations. The western elongations will occur just half way between the eastern; and the positions of the satellites at other times can be interpolated with the aid of a diagram which we will give in our next number. The rings of Saturn will be in good position for observation this year.

The satellites of Uranus and Neptune are too faint to be seen except with large telescopes.

PLANET NOTES FOR FEBRUARY.

Mercury will be "evening star" during February. During the first half of the month he will be close to the Sun, but in the latter part will be visible to the naked eye for a short time after sunset. He will be at greatest elongation, east from the Sun 18°, on the evening of Feb. 25. His greatest brilliancy will be attained on the evening of Feb. 21. Mercury will be ten degrees due south from Venus at 9^h 41^m P. M. Feb 8, central time.

Venus will be visible as evening planet for but a few days in February. On the 16th, at 3^h 04^m A. M., she will be at inferior conjunction, *i. e.*, between the Earth and Sun. Venus will be in conjunction with the crescent Moon, 11° north of the latter, at 3^h 03^m P. M. Feb. 6.

Mars will be visible in the southeast after 4^h A. M., but at too low an altitude for good observations in our latitude.

Jupiter will be at quadrature 90° east from the Sun Feb. 11, at 1^h 52^m A. M. He will be in excellent position for observation during the early part of the night. Jupiter will be in conjunction with the Moon, 4° 24′ north of the latter, Feb. 13 at 3^h 16^m A. M.

Saturn may be observed after midnight. Look toward the southeast in the constellation Virgo, about 5° northeast from the star Spica. The rings of the planet are easily seen with quite a small telescope. They are now turned at an angle of 14° to the line of sight, so that with telescopes of moderate power the divisions may be seen. Saturn's apparent motion among the stars during February will be westward. He will be in conjunction with the Moon, 4° north, at 8^h 02^m P. M. Feb. 23.

Uranus rises about midnight, and is in position for observation from 3 to 6 A. M. He is in the constellation Libra, about 1° 45′ east and 26′ south of the star α. Uranus will be at quadrature, 90° west from the Sun, Feb. 3 at 7^h 04^m P. M. He will be stationary in right ascension Feb. 18, and after that will move slowly westward. He will be in conjunction with the Moon, 3° 36′ north, at 9^h 58^m A. M. Feb. 25.

Neptune will be at quadrature, 90° east from the Sun, Feb. 29 at 2^h 36^m A. M. He will be in good position for observation during February. He is almost stationary in Taurus, a little more than one-third of the way on a straight line from ι to ε Tauri. There is no star of equal brightness, *i. e.*, 8th magnitude, within a radius of 1°.

Plate XI gives a photographic reproduction of a negative of a portion of the constellation Taurus, taken at Goodsell Observatory on the night of Nov. 17 by H. C. Wilson, with a 2½-inch camera. The camera was attached to the 8-inch photographic telescope, driven by clockwork, and corrected occasionally by the observer with a second telescope. The photograph was taken for the purpose of showing the place of Neptune with reference to the small stars, from which the amateur has difficulty to distinguish it. The planet is in the center of the plate near the point of the arrow. There is a diamond-shaped group of very faint stars which can only be seen with a magnifying glass, between the point of the arrow and Neptune. In order to enable the reader to identify the brighter stars we have marked upon the plate the Greek letters by which they are known, as well as the right ascension and declination lines. Toward the bottom of the plate is the familiar group of the Hyades with the bright red star Aldebaran (α). At the top of the plate are the bright stars ζ and β. The latter is photographically brighter than Aldebaran. The course of Neptune is diagonally across the plate. At pres-

PLATE XI.

Photograph of the region about Neptune in Taurus; taken with a 2½ inch camera at Goodsell Observatory, Nov. 7th, 1893; exposure 40 minutes.

ent the planet is near the feather end of the arrow, and moving very slowly toward the lower right hand corner of the plate. After March 20 it will move toward the upper left hand corner of the plate until Sept. 20, when it will be a little east and south of the star ι. After that time it will again move westward for a few months. We hope that this plate and the explanation will enable many amateurs to be sure that they have seen Neptune.

Planet Tables for February.

Date. 1894.	R. A. h m	Decl. ° '	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Feb. 5	21 41.7	− 15 51	7 41 A. M.	12 38.1 P. M.	5 35 P. M.
15	22 49.2	− 8 18	7 36 "	1 06.1 "	6 36 "
25	23 40.4	− 0 37	7 17 "	1 17.9 "	7 19 "
			VENUS.		
Feb. 5	22 11.8	− 3 43	7 19 A. M.	1 08.3 P. M.	6 57 P. M.
15	21 49.5	− 4 12	6 20 "	12 06.7 "	5 54 "
25	21 28.2	− 6 00	5 26 "	11 06.2 A. M.	4 46 "
			MARS.		
Feb. 5	17 35.5	− 23 28	4 09 A. M.	8 32.6 A. M.	12 56 P. M.
15	18 05.8	− 23 43	4 01 "	8 23.5 "	12 46 "
25	18 36.2	− 23 37	3 52 "	8 14.6 "	12 37 "
			JUPITER.		
Feb. 5	3 20.0	+ 17 34	11 00 A. M.	6 15.6 P. M.	1 32 A. M.
15	3 23 4	+ 17 49	10 22 "	5 39.6 "	12 57 "
25	3 28.0	+ 18 08	9 46 "	5 04.9 "	12 24 "
			SATURN.		
Feb. 5	13 37.0	− 7 19	10 56 P. M.	4 30.8 A. M.	10 05 A. M.
15	13 36.5	− 7 13	10 16 "	3 51.0 "	9 26 "
25	13 35.4	− 7 04	9 35 "	3 10.5 "	8 46 "
			URANUS.		
Feb. 5	14 51.7	− 16 02	12 51 A. M.	5 49.2 A. M.	11 47 A. M.
15	14 52.0	− 16 04	12 12 "	5 10.1 "	10 08 "
25	14 51.9	− 16 03	11 33 P. M.	4 30.7 "	9 28 "
			NEPTUNE.		
Feb. 5	4 37.8	+ 20 34	12 03 P. M.	7 33.0 P. M.	3 03 A. M.
15	4 37.6	+ 20 34	11 23 "	6 53.5 "	2 24 "
25	4 37.6	+ 20 35	10 41 "	6 14.2 "	1 44 "
			THE SUN.		
Feb. 5	21 17.8	− 15 45	7 15 A. M.	12 14.3 P. M.	5 14 P. M.
15	21 57.3	− 12 29	7 01 "	12 14.3 "	5 28 "
25	22 35.5	− 8 53	6 45 "	12 13.2 "	4 41 "

Phases and Aspects of the Moon.

		d	*Central Time.* h m
Apogee	Feb.	1	4 00 P. M.
New Moon	"	5	3 45 P. M.
First Quarter	"	13	4 43 A. M.
Perigee	"	17	3 18 P. M.
Full Moon	"	19	8 17 P. M.
Last Quarter	"	27	6 28 A. M.

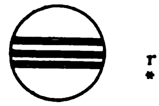
Occultations Visible at Washington.

Date 1894.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration. h m
Feb. 11	19 Arietis	6	6 49	76	8 02	226	1 13
12	ζ Arietis	5	11 13	97	12 07	237	0 54
16	c Geminorum	6	17 17	59	17 49	332	0 32
20	σ Leonis	4	9 55	152	10 58	277	1 03

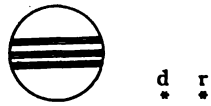
Jupiter's Satellites for February.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.

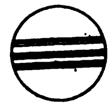


III.



II.

IV.



No Eclipse.

Configuration at 8^h for an Inverting Telescope.

Day.	West.		East.
1	3·	O	·1 2· ·4
2	.3 2· ·1	O	·4
3	·3 ·2	O	1· 4·
4	·1	O	·3 ·2 4·
5		O	1·2· 4· ·3
6	2.	O	4· 3. ·1●
7	4· 1·	O	3· ·2●
8	4· 3·	O	·1 2·
9	4· ·3 1·2·	O	
10	4· ·3 ·2	O	1·
11	·4 ·1	O	·2 ·3●
12	·4	O	1· 2· ·3
13	·4 2·	O	3· ·1●
14	·4 1··2	O	3·
15	3·	O	·4 ·1 2·
16	3· 1· 2·	O	·4
17	·3 ·2	O	·1 ·4
18	·1	O	·3 ·2 .4
19		O	1· 2· ·3 ·4
20	2· ·1	O	·3 4·
21	O 1· ·2	O	3· 4·
22	3·	O	·1 ·2 4·
23	O 2· 3· 1·	O	4·
24	·3 ·2 4·	O	·1
25	4· ·1 ·3	O	·2
26	4·	O	1· 2· ·3
27	4· 2· .1	O	3·
28	·4 ·2	O	1· 3·

New Asteroid 1893 AO.—This was discovered by Wolf at Heidelberg, on a photographic plate taken Nov. 6. Its position at 9^h 18^m Heidelberg M. T. was R. A. 2^h 19^m; Decl. $+ 11° 22'$. Daily motion $- 0.6^m$ in R. A. and $- 2'$ in Decl. Magnitude 13.

Elongations of the Satellites of Saturn.

(The western elongations will be found approximately half way between the eastern and other positions may be easily interpolated.)

MIMAS.

		h		
Feb.	3	6.7	A. M.	W
	4	5.3	"	W
	5	3.9	"	W
	6	2.5	"	W
	7	1.1	"	W
	11	6 9	"	E
	12	5.5	"	E
	13	4.1	"	E
	14	2.8	"	E
	15	1.4	"	E
	15	midn.		E
	20	5.7	"	W
	21	4.3	"	W
	22	3.0	"	W
	23	1.6	"	W
	24	12.2	"	W
Mar.	1	4.6	"	E

ENCELADUS.

Feb.	2	2.4	P. M.	E
	3	11.3	"	E
	5	8.2	A. M	E
	6	5.1	P. M.	E
	8	1 9	A. M.	E
	9	10 8	"	E
	10	7.7	P. M.	E
	12	4.5	A. M.	E
	13	1 5	P. M.	E
	14	10 3	"	E
	16	7.2	A. M.	E
	17	4 1	P. M.	E
	19	1.0	A. M.	E

ENCELADUS CONT.

		h		
Feb.	20	9 9	A. M.	E
	21	6.7	P. M.	E
	23	3.6	A. M.	E
	24	12.5	P. M.	E
	25	9.4	"	E
	27	6.3	A. M.	E
	28	3.1	P. M.	E

TETHYS.

Feb.	2	4.4	A. M.	E
	4	1.7	"	E
	5	11.0	P. M.	E
	7	8.3	"	E
	9	5.6	"	E
	11	2.9	"	E
	13	12.2	"	E
	15	9.5	A. M.	E
	17	6.8	"	E
	19	4.1	"	E
	21	1.4	"	E
	22	10.7	P. M.	E
	24	8.0	"	E
	26	5.3	"	E
	28	2.6	"	E

DIONE.

Feb.	1	3.1	P. M.	E
	4	8.8	A. M.	E
	7	2.4	"	E
	9	8.1	P. M.	E
	12	1.8	"	E
	15	7.4	A. M.	E

DIONE CONT.

		h		
Feb.	18	1.1	A. M.	E
	20	6 8	P. M.	E
	23	12.5	"	E
	26	6.1	A. M.	E
	28	11.8	P. M.	E

RHEA.

Feb.	3	7.7	A. M.	E
	7	8.0	P. M.	E
	12	8.4	A. M.	E
	16	8.8	P. M.	E
	21	9.2	A. M.	E
	25	9.6	P. M.	E

TITAN.

Feb.	4	6.0	P. M.	S
	8	12.9	"	E
	12	10.5	A. M.	I
	16	2.0	P. M.	W
	20	4 7	"	S
	24	11.2	A. M.	E
	28	9.5	"	I

HYPERION.

Feb.	2	6 6	P. M.	I
	8	3.2	A. M.	W
	12	12.8	P. M.	S
	17	4.7	"	E
	24	12 9	A. M.	I
Mar.	1	9.2	"	W

IAPETUS.

Feb.	28	1.0	A. M.	W
Mar.	19	9.9	P. M.	S

Phenomena of Jupiter's Satellites.

Central Time.

		h m			
Feb.	4	5 06	P. M.	III	Ec. Re.
		11 30	"	I	Oc. Dis.
	5	8 41	"	I	Tr. In.
		10 00	"	I	Sh. In.
		10 53	"	I	Tr. Eg.
		11 29	"	II	Tr. In.
	6	5 58	"	I	Oc. Dis.
		9 29	"	I	Ec. Re.
	7	5 22	"	I	Tr. Eg.
		5 49	"	II	Oc. Dis.
		6 42	"	I	Sh. Eg.
		8 13	"	II	Oc. Re.
		8 31	"	II	Ec. Dis.
		10 41	"	II	Ec. Re.
	9	5 49	"	II	Sh. Eg.
	11	7 25	"	III	Ec. Dis.
		9 09	"	III	Ec. Re
	12	10 36	"	I	Tr. In.
	13	7 54	"	I	Oc. Dis.
	14	6 24	"	I	Sh. In.
		7 18	"	I	Tr. Eg.
		8 25	"	II	Oc. Dis.
Feb.	14	8 37	P. M	I	Sh. Eg.
		10 49	"	II	Oc. Re.
		11 07	"	II	Ec. Dis.
	15	5 54	"	I	Ec. Re.
	16	5 51	"	II	Tr. Eg.
		6 05	"	II	Sh. In.
		8 27	"	II	Sh Eg.
	18	5 54	"	III	Oc. Dis.
		7 59	"	III	Oc. Re.
	20	9 51	"	I	Oc. Dis.
	21	7 00	"	I	Tr. In.
		8 19	"	I	Sh. In.
		9 14	"	I	Tr. Eg.
		10 33	"	I	Sh. Eg.
	22	7 50	"	I	Ec. Re.
	23	6 07	"	II	Tr. In.
		8 31	"	II	Tr. Eg.
		8 43	"	II	Sh. In.
	25	5 18	"	II	Ec. Re.
		10 01	"	III	Oc. Dis.
	28	8 58	"	I	Tr. In.
		10 15	"	I	Sh. In.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

		h m			h m			h m
Feb.	2	1 20 A. M.	Feb.	11	11 39 P. M.	Feb.	21	9 58 P. M.
		9 12 P. M.		12	7 31 "		22	5 50 "
	4	10 51 "		14	1 18 A. M.		23	11 38 "
	5	6 42 "		14	9 10 P. M.		24	7 29 "
	7	12 30 A. M.		16	10 49 "		26	1 16 A. M.
		8 21 P. M.		17	6 40 "			9 08 P. M.
	9	2 09 A. M.		19	2 28 A. M.		28	2 56 A. M.
		10 00 P. M.			8 19 P. M.			10 47 P. M.
	10	5 52 "		21	2 06 A. M.			

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

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

Feb.	1	9 A. M.
	6	8 "
	11	8 "
	16	8 "
	21	7 "
	26	7 "

ALGOL.

R. A. .... $3^h 1^m 1^s$
Decl. .... $+42° 32'$
Period .... $2d\ 20^h 49^m$

Feb.	11	6 A. M.
	14	2 "
	16	11 P. M.
	19	8 "

R. CANIS MAJORIS.

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

Feb.	3	7 P. M.
	4	10 "
	6	2 A. M.
	7	5 "
	11	6 P. M.
	12	9 "
	13	midn.
	15	4 A. M.
	20	8 P. M.
	21	11 "
	23	2 A. M.
	24	6 A. M.
	28	7 P. M.

S CANCRI.

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

Feb.	6	3 A. M.
	25	2 "

S ANTLIÆ.

R. A. .... $9^h 27^m 30^s$
Decl. .... $-28° 09'$
Period .... $0d\ 7^h 47^m$

Feb.	1	8 P. M.
	2	4 A. M.
	2	7 P. M.
	3	3 A. M.
	3	7 P. M.
	4	2 A. M.
	5	2 "
	6	1 "
	6	midn.
	7	"
	8	11 P. M.
Feb.	9	10 P. M.
	10	10 "
	11	9 "
	12	8 "
	13	8 "
	14	3 A. M.
	14	7 P. M.
	15	3 A. M.
	16	2 "
	17	2 "
	18	1 "
	18	midn.
	19	midn.
	20	11 P. M.
	21	10 "

S. ANTLIÆ CONT.

Feb.	22	10 P. M.
	23	9 "
	24	8 "
	25	8 "
	26	3 A. M.
	26	7 P. M.
	27	3 A. M.
	28	2 "

δ LIBRÆ.

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

Feb.	8	7 A. M.
	15	6 "
	22	6 "

U CORONÆ.

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

Feb.	7	9 P. M.
	14	7 "
	18	6 A. M.
	25	4 "

U OPHIUCHI.

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

Feb.	3	6 A. M.
	4	2 "
	8	6 "
	9	3 "
	14	3 "
	19	4 "
	24	5 "
	25	1 "

Variable Star Observers.—I have corresponded lately with the following persons who are observing variables or who wish to take up the work:—

J. D. Devor, 1st Nat'l Bank, Elkhart, Ind. .... 3-inch refractor.
Geo. M. Brace, High School, Bay City, Mich. .... 4-inch refractor.
J. C. Sanford, Marblehead, Mass. .... 4-inch refractor.
Mrs. M. B. Travis. Hampton, N. B. .... Field glass.
J. O. Tiffany, Attleboro, Mass. .... 6-inch refractor.
David Flanery, Memphis, Tenn. .... Opera glass.

H. A. PARKHURST.

Comparison Stars for Variables of Long Period.*

T Casiopeiæ.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
a..........	0	39.6	+54	41	6
b..........	0	21.2	+56	5	6
c..........	0	20.8	+56	13	7
d..........	0	20.6	+54	56	7
e..........	0	18.0	+55	15	8
f..........	0	18.3	+54	50	8
g..........	0	18.9	+55	2	8
h..........	0	20.5	+55	10	9
k..........	0	21.1	+55	14	9
l..........	0	16.1	+55	11	10
m..........	0	19.5	+55	10	10
n..........	0	18.0	+55	20	11
o..........	0	18.3	+55	20	12
p..........	0	17.7	+55	11	12
q..........	0	18.2	+55	16	13
r..........	0	17.7	+55	12	13
s..........	0	17.9	+55	13	14
t..........	0	18.0	+55	14	14
u..........	0	17.7	+55	12	14
w..........	0	17.8	+55	13	15
T..........	0	17.8	+55	14	var.

S. Casiopeiæ.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
a..........	0	41.6	+72	8	6
b..........	1	11.4	+77	52	7
c..........	1	11.2	+72	20	7
d..........	0	44.3	+73	1	8
e..........	1	23.2	+72	22	8
f..........	1	24.5	+72	24	8
g..........	1	7.0	+71	58	9
h..........	0	56.1	+72	50	9
k..........	1	12.7	+72	2	10
l..........	1	13.4	+72	4	10
m..........	1	11.6	+72	12	10
n..........	1	13.8	+71	52	11
o..........	1	12.8	+71	50	11
p..........	1	13.0	+71	59	12
q..........	1	14.4	+72	6	12
r..........	1	12.2	+72	0	12
s..........	1	12.9	+72	13	13
t..........	1	12.2	+72	6	13
u..........	1	11.8	+72	5	14
w..........	1	12.0	+72	5	14
x..........	1	12.9	+72	6	15
y..........	1	125.	+72	6	15
S..........	1	12.3	+72	5	var.

S and T Persei.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
a..........	2	15.1	+58	43	8
b..........	2	19.5	+58	25	8
c..........	2	14.6	+58	7	8
d..........	2	9.6	+57	45	9
e..........	2	11.4	+58	8	9
f..........	2	14.0	+58	2	9
g..........	2	14.3	+57	58	10
h..........	2	13.6	+58	2	11
k..........	2	15.9	+58	14	11
l..........	2	15.7	+58	9	12
m..........	2	15.6	+58	4	12
n..........	2	15.6	+58	0	12

S and T Persei Cont.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
o..........	2	15.4	+58	0	13
p..........	2	15.8	+58	10	14
q..........	2	15.9	+58	6	14
r..........	2	15.3	+58	6	14
s..........	2	15.6	+58	5	15
S..........	2	15.7	+58	8	var.
T..........	2	12.2	+58	29	var.

R Aurigæ.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
a..........	5	6.7	+53	6	6
b..........	5	13.2	+54	9	7
c..........	5	21.8	+53	20	7
d..........	5	8.9	+54	4	8
e..........	5	8.7	+53	22	8
f..........	5	9.5	+53	35	9
g..........	5	9.1	+53	29	9
h..........	5	9.8	+53	17	10
k..........	5	8.4	+53	23	10
l..........	5	9.8	+53	24	11
m..........	5	9.1	+53	20	11
n..........	5	8.3	+53	30	11
o..........	5	8.3	+53	19	12
p..........	5	8.9	+53	34	12
q..........	5	9.0	+53	29	13
r..........	5	9.7	+53	29	13
s..........	5	9.8	+53	28	14
t..........	5	9.5	+53	28	14
u..........	5	9.6	+53	28	15
R..........	5	9.2	+53	29	var.

R Lyncis.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
a..........	6	53.1	+54	59	7
b..........	7	3.3	+55	47	7
c..........	6	55.0	+54	19	8
d..........	6	56.9	+55	52	8
e..........	6	51.9	+55	53	9
f..........	6	53.9	+55	15	9
g..........	6	52.0	+55	45	10
h..........	6	54.0	+55	10	10
k..........	6	53.5	+55	30	10
l..........	6	51.6	+55	34	11
m..........	6	52.9	+55	32	11
n..........	6	51.8	+55	28	12
o..........	6	52.3	+55	33	12
p..........	6	52.6	+55	30	12
q..........	6	53.2	+55	32	13
r..........	6	52.7	+55	29	14
s..........	6	52.8	+55	30	14
t..........	6	53.1	+55	27	14
u..........	6	53.3	+55	32	15
R..........	6	53.1	+55	28	var.

R Ursæ Majoris.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
a..........	10	34.8	+68	57	6
b..........	10	38.2	+67	56	6
c..........	10	42.1	+65	40	6
d..........	10	56.8	+70	35	7
e..........	10	1.7	+69	10	7
f..........	10	14.5	+69	26	7
g..........	10	27.6	+69	13	8

* See Plate accompanying Mr. Parkhurst's article on Variable Stars.

R Ursæ Majoris *Cont.*

Des.	R. A. 1900 h	m	Dec 1900. °	′	Mag.
h	10	35.4	+69	8	8
k	10	48.5	+68	28	9
l	10	49.6	+69	6	9
m	10	27.7	+68	54	9
n	10	35.5	+69	4	9
o	10	38.1	+68	48	10
p	10	40.5	+69	9	10
q	10	40.5	+69	22	11
r	10	37.7	+69	21	11
s	10	37.0	+69	17	12
t	10	37.6	+69	15	12
u	10	36.7	+69	15	12
w	10	38.8	+69	18	13
x	10	38.2	+69	20	14
y	10	37.0	+69	19	14
z	10	37.9	+69	16	14
α	10	38.1	+69	19	15
R	10	37.6	+69	18	var.

T Ursæ Majoris.

Des.	R. A. 1900 h	m	Dec 1900. °	′	Mag.
a	12	25.4	+59	19	6
b	12	35.1	+61	26	7
c	12	34.5	+61	34	7
d	12	44.2	+61	22	8
e	12	35.9	+60	5	8
f	12	34.7	+60	18	8
g	12	32.8	+59	46	9
h	12	29.6	+60	17	9
k	12	34.0	+60	15	9
l	12	33.9	+60	10	10
m	12	34.3	+60	4	10
n	12	33.4	+59	52	10
o	12	33.9	+59	52	11

T Ursæ Majoris *Cont.*

Des	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
p	12	34.8	+60	8	12
q	12	31.3	+60	4	12
r	12	32.8	+59	58	12
s	12	34.2	+59	59	13
t	12	32.1	+60	0	14
u	12	33.1	+59	59	14
w	12	32.2	+60	1	14
x	12	32.5	+60	2	15
y	12	31.9	+59	59	15
T	12	31.9	+60	2	var.

S Ursæ Majoris.

Des	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
a	12	38.7	+61	42	6
b	12	35.1	+61	26	7
c	12	34.5	+61	34	7
d	12	44.2	+61	22	8
e	12	35.9	+60	5	8
f	12	36.4	+61	22	9
g	12	37.7	+61	25	9
h	12	33.8	+61	12	10
k	12	40.2	+61	15	10
l	12	41.7	+61	40	10
m	12	40.6	+61	33	11
n	12	40.6	+61	44	12
o	12	41.2	+61	33	12
p	12	41.7	+61	32	12
q	12	41.4	+61	36	13
r	12	37.5	+61	36	13
s	12	40.2	+61	39	14
t	12	40.4	+61	41	14
u	12	40.2	+61	41	14
w	12	40.1	+61	40	15
S	12	39.6	+61	38	var.

PRACTICAL SUGGESTIONS.

Persons interested are requested to remember this corner and to write briefly and frequently for it.

10. In the answer to S. G. S. in December issue it is stated "that a central 2-inch area of a high class objective should do better work than the whole of a 3-inch high class objective is utterly impossible. The only thing that it would indicate is that there is something wrong with the 3-inch objective."

This is explicit and satisfactory so far as it goes, but does not exhaust the query as the present writer interprets it and would be pleased to see it answered.

The following does better, but scarcely reaches the core, except possibly by implication. "Diaphragms will not improve a first class objective."

The point is this: Does the peripheral portion of the spherical surfaces of a high class objective do as good work as an equal area of the central portion of the same glass?

W. B. H.

11. Would an objective be rated first class if by using diaphragms—first an annular, then a central one—it is ascertained that the central portion of the glass, amounting to less than a third of the entire area, does better work than the remaining portion—the peripheral—constituting more than two thirds the area of the whole spherical surface?

W. B. H.

12. Inasmuch as celestial photography discloses the existence of myriads of stars too minute to be seen with the aid of the largest telescope, why is it that a 3½-inch refractor in the possession of the writer, gives a better or more distinct view of lunar scenery—craters in particular—than the best photographs, assuming as a fair sample the one taken at the Goodsell Observatory, and found in the frontispiece of POPULAR ASTRONOMY for September? W. B. H.

Answer. The great difference in the brightness of the features of the lunar surface makes it difficult, if not quite impossible, to biing out on the same negative, all the minute details that can be seen in a small telescope. If the exposure is timed for the mountains and bright table lands and streaks, then the details of the seas and valleys will be lost. If the exposure is made longer so as to get details in the darker portions, then the brighter parts will be over exposed and appear on the plate as simple patches of confused light. It is a difficult task to divide the time rightly between these extremes of light and shade and get the best results for both. If the photographer had either phase alone to deal with, he would quickly show us astonishing results in lunar photography as has already been done repeatedly in stellar exposures.

When the different parts of a landscape, for example, are so related that the brighter parts may be covered during a part of the time that the darker ones are exposed, the details of all parts of the view may sometimes be well secured in this way. It would be difficult to apply such a method to the Moon. The best results at Goodsell Observatory in photographing the moon were secured Dec. 22, 1893, when it was within a few minutes of the full and was passing the meridian and was also within nearly 15° of the zenith. The image was about 3¾ inches in diameter and the exposure was one-half second. The picture is an excellent one and will soon be reproduced for these pages.

12. An interested reader of these suggestions says, the answer by J. A. B. to query No. 5 was a revelation to him, and that he was glad to learn that solid eyepieces give nearly one "third more light" than the Huygenian ones do. He further adds that he is tempted to order two or three at once if they are not too expensive. Possibly J. A. B. will give the price of this kind of eyepiece.

GENERAL NOTES.

The publication will hereafter be issued before the first day of the month for which it is dated.

So many subscribers kindly responded to our request last month for the names of persons interested in astronomy that the request is continued. See first page of advertisements.

Optical Glass.—Mr. J. A. Brashear's series of articles on optical glass begins in this number. In our next he will present a number of illustrations showing how the great 40-inch disc belonging to the Yerkes telescope of the University of Chicago, was worked from the original lump of glass. The nine photographs were presented to Mr. Brashear by Mantois of Paris. They will make one of the most interesting plates yet published.

Variable Stars of Long Period.—The neat lithographic plate of variable stars of long period accompanying Mr. Parkhurst's article is furnished by kindness of Professor E. C. Pickering of Harvard College Observatory. Another like it will soon follow.

Professor Proctor's Monument.—Miss Mary A. Proctor, daughter of Professor Richard A. Proctor has recently furnished us with data for a sketch of his useful and very busy life. Beautiful plates will accompany the brief article.

Contributors will please bear in mind to make articles brief for space every month seems to be in good demand. From three to five printed pages is a fair average length for ordinary articles. The great variety desired for every issue is the reason for this request.

Visualizing the Earth's Motion.—In the December issue of POPULAR ASTRONOMY, Eliza A. Bowen shows how the Earth's *revolution* may be made manifest to the eye. The following is a simple method of rendering its *rotation*, also visible: Place on the floor of a room free from tremors and air currents, a good sized bowl nearly filled with water and sprinkle over the surface of the water an even coating of lycopodium powder, and across this make a narrow black line of pulverized charcoal. Place the bowl so that the black line shall coincide with a crack in the floor, or, if the room be carpeted, lay a stick upon the floor exactly parallel with the mark. After a few hours it will be found that the line is no longer parallel with the stationary object, but has moved from east to west proving that, during this interval, the Earth has moved from west to east.

The reason appears to me to be that the solid floor has with the Earth and bowl moved from west to east, and so has the water, also, but at a slower rate, as there is a slight inertia, of which the yielding liquid does not instantly partake, to be overcome. It will be seen that the line or charcoal mark always moved from east to west.

L. SWIFT.

Naked-Eye Observations of Jupiter.—When the Opposition of Jupiter has passed there remains much interesting work for the naked-eye observer in watching the proper motions of the planet so long as it is visible.

But he should be warned in regard to the apparent motion of the planet (I.) This is the daily apparent movement from the eastern to the western horizon, causing the planet to rise daily above the eastern horizon and to set behind the western, as do the Sun, Moon and stars. This apparent movement is due to the Earth's rotation upon its axis. (II.) This is the apparent motion from the eastern to the western horizon, detected by watching the planet for some weeks at the same hour of the night, thus throwing out the effect of the Earth's daily motion. This apparent motion is due to the Earth's revolution round the Sun. The fixed stars have the same apparent movement, except that Jupiter's real motion retards a little the apparent movement due to the Earth's revolution. All these movements to and from the horizon are to be disregarded.

The planet's real or proper motion, which is the chief object of attention is indicated by its change of place among the fixed stars. Whenever it crosses a line joining two other stars on the same or opposite sides of it, its motion becomes evident at once by the making or breaking of the line. It often forms with other stars, regular figures, triangles, diamonds, etc , and any variation in the regularity of the figure makes the movement quickly evident.

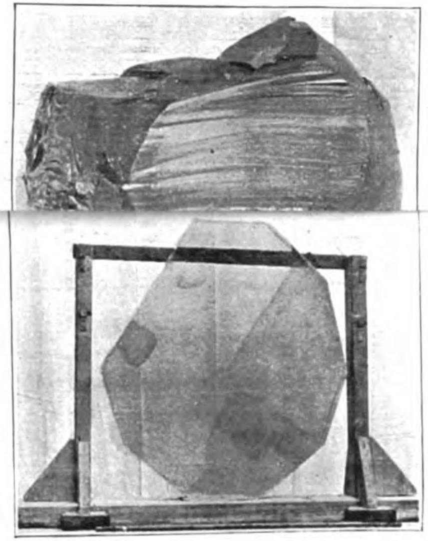
(III.) But the inexperienced observer will be surprised to find that Jupiter is now moving apparently west, not east. This is apparent, and lasts for sixty days before and sixty days after opposition, when the planet seems to become stationary for about two weeks, after which we can plainly see that it is moving eastward. This is an apparent movement precisely similar to that which takes place when a faster walker overtakes and passes a slower walker bound in the same direction as himself. It takes place near opposition only, because only then, the Earth and planet move towards the same quarter of the heavens. Their direction of revolution is always the same.

E. A. B.

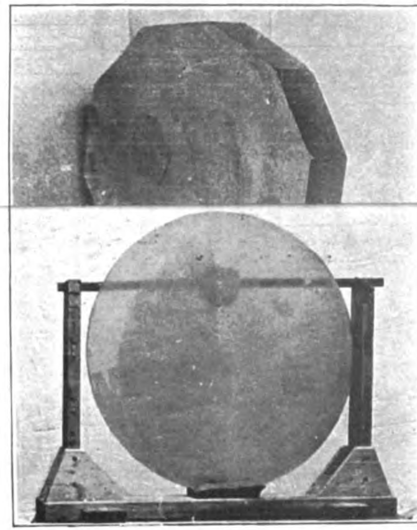
Errata in December number—
Page 165, line 15 from top, for β Cassiopeiæ, read B Cassiopeiæ.
Page 167, line 10 from bottom, for Nov. 1, read Nov. 16.

PLATE XIII.

No. 7.



No. 8.



No. 9.

PHOTOGRAPHIC HISTORY OF THE 40-INCH CROWN DISC OF YERKES TELESCOPE.

From photographs furnished by M. Mantois of Paris.

POPULAR ASTRONOMY, February, 1894.

Popular Astronomy.

Vol. I. FEBRUARY, 1894. No. 6

GLASS FOR OPTICAL INSTRUMENTS WITH ESPECIAL REFERENCE TO TELESCOPE OBJECTIVES.*

J. A. BRASHEAR.†

After all the imperfections that can be reached in the block of glass are ground out, it is then ready to be moulded into the proper shape.

Through the kindness of Mr. Mantois of Paris, I have the pleasure to present, in picture form,‡ a photographic history of the 40-inch crown disc for the Yerkes' telescope.

No. 1 shows the block of glass obtained unbroken from the pot on the 26th of January, 1888.

No. 2 shows the block after the gross imperfections had been sawn off. It was in this condition when I saw it later on in the year. It then weighed 240 kilos or about 525 pounds.

No. 3 shows the one side of the block after its first moulding into a decagonal or ten sided shape. No. 4 shows the opposite side.

After this moulding it was again polished and studied, and impurities detected that had to be ground away. The pictures 5 and 6 show opposite sides of the decagon after this second reduction of the material.

Nos. 7 and 8 show still further cutting and Fig. 9 the finished disc.

These manipulations required months of labor, with the result of producing a very fine disc, although it can be readily seen what a large amount of material had to be ground away before it was finally softened into disc form and annealed.

In the case of discs above six inches diameter the mould is so made as to give one side of the crown a convex curve and one side of the flint a concave curve of the approximate radius to be used in the final grinding and polishing; indeed in the case of large discs this is very necessary, as it allows a larger disc to be made of a certain weight of glass, as well as expedites the work of rough grinding.

* Continued from January Number, p. 224.

† Optician, Allegheny, Penn.

‡ See frontispiece opposite.

For moulding discs of considerable diameter, the mould is made in three parts; a flat bottom, and two half rings which are fastened together by a wire around the outside and set loosely on top of the flat base. The mould is then smeared over with gum arabic or other sticky substance and pulverized chalk dusted over the ring and bottom so that the softened glass will not adhere. This mould is now placed in a specially prepared furnace, the lump or block of glass placed in it and then covered over with a specially prepared cover so that the flame cannot reach it direct, as this would mean the destruction of the block of glass. The annealing furnace should be circular, if the disc is circular, but all the furnaces that I have seen are rectangular in shape except a small one built by Mr. Clark for softening down and annealing waste pieces of optical glass, but Mr. Feil and his successor, Mr. Mantöis, surround the mould with a circle of fire brick so as to allow for a symmetrical heating and cooling of the glass. The temperature of the furnace is now slowly and carefully raised, otherwise the block of glass would fly to pieces and be ruined. The temperature is raised only high enough to gently soften the glass until it drops down and fills up the mould. The cover can be raised from time to time to watch the progress of the softening and to tell when the disc is ready for the annealing. When the optical glass maker places his products in the highest class, the crown and flint for an objective are always made in the shape of *discs*, but a great deal of optical glass is made in rectangular plates in which case many can be annealed at once. In the case of discs, they are usually polished on the faces, examined carefully and if found satisfactory the glass maker warrants such discs to the purchaser, and if he is not satisfied with them they can be returned. Plates are polished on two opposite edges only, and after examination are placed in first and second classes. Third class pieces are not polished.

But to return to the annealing of the disc in the furnace. This is one of the most difficult of all the operations of the glass maker, for upon the successful annealing of a disc of glass depends much of its value for an objective. The simplest definition of annealing is that the conditions are such during the process of cooling that *every atom of glass may be permitted to assume a natural and unstrained condition with every one of its neighboring atoms.* If the glass is cooled so slowly that this condition is assured, we have a disc that quickly tells its own story when tested by proper optical means, but if the cooling be too rapid, or irregular, or one sided, the annealing is imperfect, the glass is left in a state of regular or irregular strain and is more or less unfitted for use in optical instruments.

As soon as the glass has softened down into the shape of the mould, the temperature may be brought down rapidly to within a certain limit which is perhaps not far from 1100 or 1200 degrees Fahrenheit, or say one or two hundred degrees above the point of incandescence. At this point the furnace must be closed tight, every avenue for the air to get in or out being luted with clay.

Then comes the difficult task of lowering the temperature so as to allow the particles of glass to arrange themselves *kindly* with one another. Various methods have been adopted; massive brick work in the construction of the annealing furnaces so as to allow of slow and regular cooling, automatic pyrometers which, attached to clock work, regulate the decrease of the temperature; annealing finally in massive copper moulds placed in the center of the furnace, etc., etc., but all having the same end in view, namely, a regular and slow cooling of the glass.

Quite often imperfections are found in the annealed discs which must be ground out, and the disc reannealed a second and even a third time, but in prolonged or repeated annealing, glass has a tendency to devitrify, *i. e.*, lose its transparency and become semi-opaque. The writer has seen some beautiful discs ruined in this way, one of which was about 30 inches in diameter. In annealing large discs this risk is very great, particularly when the process has to be repeated.

After the furnace has cooled down nearly to the temperature of the outside air, the discs or plates may be safely removed.

It would be impossible in the space at our command to go into the minutiæ of this subject, but we will be pleased to answer any inquiries through the columns of this journal.

In our next paper we will give the various methods of testing optical glass.

HOW TO FIND THE ORBIT OF A DOUBLE STAR BY A GRAPHICAL METHOD.

S. W. BURNHAM.

The graphical method of finding the elements of the orbit of a binary star has some very material advantages over any other. If measures of the angles and distances were absolutely exact, then the analytical method would be perhaps better than any other, because these positions could be represented by one, and only one ellipse which would mark the apparent path of the companion star. There would be no room for the exercise of the judgment of the investigator. He would have nothing to do but determine by direct and positive means, mathematically or otherwise, the ellipse which would exactly pass through the points found by observation. In practice this can never be done. All observations are more or less in error. Everything depends on the skill, and the experience of the observer. If he has devoted his life to the use of the micrometer in double star work, and made everything else in the line of observation with the telescope of secondary importance, then his measures are entitled to the greatest confidence, and to the highest weight. One set of measures by such an observer is of more value than the best that half a dozen observers can do who divide their time and interest in as many different subjects. It is hardly necessary to mention the names of the Struves and of Dembowski as most illustrious examples of devotion and consistency in following for a long series of years a single line of research. The value of such work will endure for all time. Baron Dembowski confined his attention wholly for thirty years to the measurement of double stars; and acquired a most remarkable skill in the use of the micrometer. In my judgment, no astronomer living or dead, can rank with Dembowski as an observer with this instrument. It is the reward, which comes from the efforts of one, perhaps naturally gifted for the work, who preferred to devote all his time and energies to one subject, and to the absolute exclusion of every other.

I do not wish to be understood as instituting any comparison as to the relative importance of this and other departments of astronomical research; but only to call attention to the importance of selecting at the outset some one line of practical work with the telescope, and then keeping that paramount to the end. In these days of remarkable progress and discovery, no astronomer, however zealous or gifted, can divide his energies in several different directions, and accomplish much in any one. The way to the front is a long one, and there is no royal road. A life-time is much too short.

These remarks are pertinent only by way of pointing out the fact that in finding the orbit of a double star, we have to deal with all sorts of material, and some of it of very indifferent quality. The value of the result will largely depend upon the exercise of sound judgment and common sense in deciding what to do with observations more or less inconsistent with each other.

No manipulation of figures by the use of elaborate mathematical formulæ, no application of the method of least squares, or other refinements of investigation will take the place of these qualities so necessary in the solution of other every-day problems. To proceed in this manner intelligently, it is necessary to have a certain familiarity with the skill, experience, instrumental facilities, etc., of the different observers, in order to give each measure used its proper bearing.

It should not be inferred from these remarks that double star measures are in any wise inferior to other observations with any instrument; but it must be borne in mind that the unavoidable errors, quantities so small that they are wholly insensible in themselves, bear a large ratio to the whole distance measured. The mean distance of the components of nearly every rapid binary known does not exceed 1″, and in many cases this quantity is less than 0″.5, and yet a distance of 0″.1, which can scarcely be appreciated with common powers even in the largest telescope, bears a very considerable relation to the whole.

The graphical method of finding the elements of the orbit, strictly speaking, has not been used until within the last half dozen years. Herschel devised a plan which he called by this name, and it has been varied and elaborated by other writers since that time. This method to some extent was a combination of the mathematical and the graphical, but it sacrificed, as the other so-called graphical methods have done, all the special advantages of the latter by the adoption of artificial positions for the real measures, and then building a superstructure upon that imaginary foundation. These artificial positions were obtained by laying down the angles and distances on square-ruled paper, and drawing what was called an interpolating curve through these positions, which when done with proper care was supposed to represent the real positions better than the measures themselves. Then these new positions, as thus corrected, were laid down and the apparent ellipse drawn, from which the various elements were determined by methods partly graphical and partly analytical. The objection to this and all similar plans is, that the basis upon which the whole investigation must necessarily rest, the actual measures themselves, is entirely lost sight of, and the subsequent steps may, and generally do, rest upon a more or less erroneous assumption. It is certain, it seems to me, that nothing can be better to deal with than the real observations as they were made, since one can then proceed intelligently with all the data before him. If it be true in any instance that the actual measures cannot be thus used to give the best result, it follows, as a matter of course, that it would be better not to use them at all.

It is necessary to have a considerable arc described by the measures in order to get even an approximate orbit. Under no circumstances will an arc of 90° be sufficient. One may as well guess at the period without making even a figure, upon the assumption that the angular motion will on the average continue to be the same for the whole revolution, as to go through the most elaborate analytical investigation. The fact is that a variety of ellipses, differing widely from each other in area, eccentricity, etc., and sometimes circles and other conic sections, will represent in these short arcs the best observations we ever have as well as, and not unfrequently better than, the particular ellipse found by the most laborious process. In other words, the problem is an indeterminate one, and, so far as any one can say from the given data, no one of several hypotheses is more likely to be correct than the others. Such cases should be left for astronomers of the future to deal with when the proper material has been furnished by observers. It is not often that even an arc of 180° is sufficient. The distances may be such that the limit of the apparent ellipse is well defined, but this is not often the case. As a rule we should have not less than 225° for the difference of the extreme position-angles, and in the projection of some orbits 270° is none too much. In all cases the arc must be large enough to define within very narrow limits the dimensions of the apparent ellipse.

The Measures.

All the measures should be carefully collected from original sources, and arranged in chronological order, with the name of the observer, and the number of nights of which each set is a mean. It is desirable to have this list complete, but it by no means follows that all the measures should be used. It will be obvious from an inspection of the tabular arrangement, even if the pair is an easy one, that some of the measures are erroneous, and too poor to be of any use. Generally speaking such observations will be where one would naturally look for them, in the work of comparatively inexperienced observers. Single observations—that is, measures on one night—are always to be regarded with suspicion, since they may be affected with accidental errors of reading the micrometer, etc. Each set of measures should be a mean of not less than three nights' observations. It goes without saying that the best result will be obtained by the use of the good material only. To attempt to divide up the errors, upon any theory of weights or otherwise among all the observations, good, bad and indifferent, simply because they happen to be on record, is illogical in theory, and unsound in practice. No double-star observer has ever lived, and probably never will, who has not made measures under some circumstances which any one acquainted with the subject would be justified in rejecting at once.

When two or more sets of measures in the same year are to be used, a simple mean is usually taken, and that used instead of the measures in detail. It is very important for a clear understanding of the diagram, that it should not be confused with unnecessary lines and positions.

The measures of the pair to be investigated having been collected, the next step is to lay the selected positions down on paper. This should be done on a scale sufficiently large so that they can be accurately put down, and the subsequent measurements made with all necessary exactness. In a general way the scale should be such that the major axis of the final ellipse will be at least eight or ten inches long. In close pairs, $0''.1$ would represent one or two inches. For this purpose a semi-circular protractor with arm and vernier reading to tenths of degrees or less will be necessary for the laying down of the position-angles; and a standard rule twelve or fifteen inches in length, divided into tenths, with a thin beveled edge, for laying down the distances. Having selected a sufficiently large sheet of plain drawing paper two lines are accurately drawn across it at right angles to each other, to represent the four quadrants, and the extremities of these lines are marked 0°, 90°, 180° and 270°. With the protractor accurately centered at the intersection of these lines, and the quadrants made to coincide, the several position-angles are laid down; and lastly the respective distances in close pairs to the nearest hundredth of a second, on these lines or their continuations. We now have a series of positions lying probably on both sides of any ellipse which can be drawn to represent them. The scale of distances used should be put on the drawing so that it may be reduced with the orbit if it should be desired to do this subsequently in the camera.

The Ellipse.

We now come to the most difficult part of the whole operation, and that is to draw the ellipse which shall represent the observations as perfectly as possible, giving due preference to those which under all the conditions are entitled to the most weight, and at the same time make the areas approximately proportional to the times.

At first sight this looks like a very hard thing to do, but with some practice in this direction, one can at the first attempt, from an inspection of the figure as a whole, fix the foci of the trial ellipse so that the subsequent changes will be small in amount. It is not necessary to actually draw an ellipse on the paper until the major axis and the eccentricity have been roughly determined by passing a point around where the boundary of the figure would be, and watching its path through the several positions.

I have experimented a great deal with all the devices for drawing ellipses, and will say briefly that so far as I know, no instrument has ever been made which is of any practical use for describing ellipses. All the appliances for this purpose are too limited in their application to be of any value. A practical ellipsograph should describe anything between a circle and a straight line, and with any value for the major axis up to the limit of the instrument.

I have found, therefore, that with some modification, the old-fashioned way of using some kind of cord and two fixed points to be better than anything else. If the ellipse is not very eccentric, a strong silk thread will answer the purpose if carefully used so as to make the tension uniform. If the ellipse is very elongated, a very fine wire, soft and thoroughly annealed, is much better, as it will not stretch or yield to any sensible extent. A very fine wire, such as is used in artificial flower making, I have found well adapted to this purpose. For one of the foci I use a fine needle which passes through a fixed loop in the wire just large enough to admit it. For the other focus, a sharp steel wire, with an eye through it which will be in the plane of the diagram when the needle is driven into the drawing board, is necessary. A small sewing-machine needle, which has an eye in just the right place, answers the purpose.

[*To be Continued.*]

ARCTURUS.

DANIEL KIRKWOOD.

With the exception of Sirius, Arcturus is the brightest star visible in our latitude. It is among the few stars mentioned in the Bible, (Job xxxviii: 32). The proper motions of the fixed stars were first discovered by Dr. Halley in 1717. All observers know the configuration of bright stars called the "Dipper." The handle forms a curve, which continued southward some twenty degrees, points out Arcturus. The parallax has been estimated at $0''.13$. The velocity through space is 375 miles per second,* or more than one million miles per hour. That the stars differ very greatly in their volumes cannot be doubted. Indeed we have good reasons for supposing our Sun to be a relatively small body in comparison with many of the giant globes to which our vision is nightly turned. Placed at the distance of Arcturus, its apparent magnitude would almost, if not entirely disappear from our unassisted sight. When we compare their spectra we find that of Sirius of the first; that of Arcturus of the second, or solar type. The small parallax found for Arcturus indicates a distance eleven million times that of the Sun from the Earth. But as the apparent magnitudes of the fixed stars vary inversely as the squares of the distances, the Sun placed at the distance of Arcturus would be diminished one hundred and twenty-one millions of millions of times. Assuming that the intrinsic brightness of the Sun and Arcturus is the same, and that the relatively greater brilliancy of Arcturus depends on its greater volume, we reach the astonishing conclusion that the bulk of Arcturus is one million times that of the Sun.

SUGGESTIONS TO AMATEURS.

LEWIS SWIFT

OTHER WONDERFUL NEBULÆ.

That mighty Nimrod of Astronomy, Sir William Herschel, hunted the sky over for the discovery of nebulæ, and found more than anyone either before or since his day. Armed with telescopes of his own construction, of far larger aperture than any previously made, he was enabled to thus achieve surpassingly greater success than had been attained by all other astronomers.

He divided the nebulæ and clusters into eight classes, a distinction still in vogue, as follows: Class (I) Bright; (II) Faint; (III) Very faint; (IV) Planetary; (V) Large. The other three sorts refer to clusters of varying degrees of resolvability. These five classes are sub-divided into round, irregular, elongated, annular and stellar nebulæ. Of class I, he discovered 288; of class II,

* Miss Clerke's System of the Stars, p. 345.

909; of class III, 984; of class V, 52; a total of 2,312 nebulæ and 197 clusters.

To the ancients, only about a half dozen visible to the naked eye were known, and the revised list of Messier reaching down to the year 1781, gives only 101 of these objects. But since Herschel's time, other observers, including his son, Sir John Herschel, have increased the number to nearly 8,000. Dreyer's New General Catalogue, published five years ago, contains the places and description of 7,840 nebulæ and clusters.

Besides the above named astronomers, D'Arrest, Auwers, Marth, both the Rosses, Stephan, Stone, Swift, Tempel, and many others have been persistent workers in this department. Of those who have discovered one hundred and over (excluding clusters) are Sir John Herschel with 1454; Swift, 900; Marth, 600; Stephan, 455; D'Arrest, 440; the Rosses, 255; Leavenworth, 253; and Stone, 100.

Though like the stars they are very unequally distributed, yet not a constellation is devoid of them, many being crowded with nebulæ. Virgo contains over 500, while the Northern Crown has only about a half-dozen.

The Milky Way, which contains nine-tenths of all the visible stars, has very few nebulæ, the most remarkable of which are the Swan or Horseshoe or Omega, right ascension $17^h\ 15^m$, declination south $16°\ 15'$; the Trifid, R. A. $17^h\ 55^m$, Decl. — 23°; Dumbbell, R. A. $19^h\ 54^m$, Decl. north 22° 23′. The Crab nebula, R. A. $5^h\ 27^m$, Decl. + 21° 56^m, though not in the Milky Way is quite near it. This is number one of Messier's Catalogue, and its rediscovery by him on Sept. 12, 1758, while examining a comet, induced him to embody in a catalogue all nebulæ visible with his small telescope, resulting in a list of 101, though many of these are, in reality, clusters.

The Crab nebula as seen with large telescopes is in shape, a very singular object, showing radials suggestive of the claws of a crab, from whence its name. It has never been resolved into stars as has been alleged.

But of all the nebulæ visible from this latitude, none save that of Orion, are to me so interesting as the Trifid and the Swan, both of which I commend for examination to the owners of small telescopes. Radiating from the Center of the Trifid are three black channels dividing it into three nearly equal parts. In one of the rifts near its center is a star seen double by Sir William Herschel, and as triple by Sir John, but which is really quadruple. Mr. South, on July 11, 1823, with his five-foot equatorial, measured the star so curiously situated "where three ways meet," but strangely missed the nebula which forms so striking an appendage to it. Adjoining it on the north is another nebula larger than the Trifid though much fainter, a test object, both for aperture and keenness of vision, for users of small telescopes, whom it is well to advise

> "If at first you don't succeed,
> Try, try again."

The Trifid was observed by Messier on June 5, 1764, and is number 20 of his Catalogue, indicated thus, M. 20. In Sir John Herschel's General Catalogue of Nebulæ, it is number 4355, and number 6514 in Dreyer's New General Catalogue. Sir William Herschel, who first observed it on July 12, 1784, thought of it as three separate nebulæ which he registered as follows: "Class V, 10, 11, 12," remarking, "Three nebulæ joined form a triangle, very faint and of great extent. In the middle is a double star." On May 26, 1786, he again viewed it and considering it then as one body, assigned it to Class IV, number 41, with this notice: "A double star with extensive nebulosity of different intensity. About the double star is a black opening resembling the nebula in Orion in miniature."

In neither catalogue does he give the position of the attached large nebula, nor does he mention it in his "remarks." Neither does Sir John in his notes on the Trifid nebula, continued down to 1833, make the slightest allusion to it though it has a pretty bright star near its center. The conclusion is, therefore, irresistible that not either of the Herschels ever saw it, and yet in both the General and the New General Catalogues it is figured as 9 of Class V. According to Auwers' synopsis of Sir William's numbers with dates of discovery and their several classes, V, 9 is given as having been discovered on May 22, 1784. The perplexing question here arises, how could he have seen this very faint nebula on May 22, 1784, and not have detected in the same field the very much brighter Trifid until May 26, 1786? This mysteriousness is my excuse for the occupation of so much space in its discussion. It was no doubt discovered in 1839 by H. L. Smith and E. P. Mason.

Some five or six years since I observed a luminous filament of the most delicate spider-line fineness stretched across its northwest cleft reminding me of one of the cables of the New York and Brooklyn suspension bridge with the difference that there was no depression from shore to shore. Owing however to electric street lights, no opportunity has since presented itself for re-observing it.

How feebly can one's imagination form, or his faltering pen convey an idea of the vastness of volume of most of the nebulæ which even small telescopes reveal as discs, when the most powerful glass can raise none on a single star! They are too vast to be conceived of or expressed in figures. Take, for instance, the one we have been considering, the Trifid nebula, and it is small in comparison with some others, and if we allow it to be as distant as the nearest stars (a reasonable supposition) and of a size that would fill the orbit of Neptune, or 5,600,000,000 miles in diameter, it would still appear with our most powerful instruments only as a very minute disk, yet with a high power it fills the entire field of view.

Although we know nothing of their distances and magnitudes, we are sure that they shine by inherent light. In our ignorance we are left to mere conjecture as to the ultimate destiny of such vast accumulations of gaseous matter, which most of them, doubtless, are. Perhaps the most reasonable supposition is that they are suns and planets in process of formation after a manner analogous to that of our own Sun and his planetary family "in the beginning."

ROCHESTER, N. Y., DEC. 21, 1893.

FIRST OBSERVATIONS OF THE SUN AND MOON.*

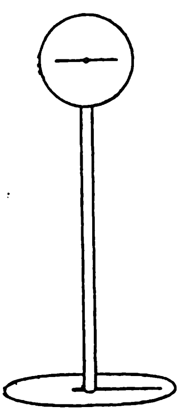
MARY E. BYRD.

The motion of the heavenly bodies would be far simpler if we could see in the sky one motion at a time instead of the resultant of several motions. As far as naked-eye astronomy is concerned, the Sun stands still. The motions which he seems to have are only those of the Earth transferred. Now if the Earth had but the motion of rotation, it would simply turn over and over in the same place in space and cause the Sun to appear above the eastern horizon, cross the meridian and disappear in the west. The Sun's path would be practically the same from day to day as long as the observer remained stationary. If, on the other hand, the Earth stopped rotating but moved on as usual in its orbit, keeping the same inclination to the ecliptic, the fixed observer would have the Sun above the horizon half the year, and

* Continued from January Number, p. 221.

its azimuth and altitude would change slightly from month to month. Taking things as they really are, we have in the westward movement of the Sun across the heavens, the effect mainly of the Earth's rotation, the changes in the noon altitude and in the points of rising and of setting must be referred to the orbital motion of the Earth, and the cycle of these changes should be completed in a year. Analogous to these motions of the Sun are the daily and monthly motions of the Moon. The former is, of course, apparent and due, as in the case of the Sun, to the Earth's turning on its axis; the latter presents itself in actual observation both in the eastward motion of the Moon among the stars, and in the constant shifting of the diurnal path where it intersects the horizon and crosses the meridian. This shifting is far more marked than that shown by the Sun as the period is only one-twelfth as long. It is not surprising that the monthly motion though real, presents itself under the same guise as the apparent annual motion of the Sun. For to the unaided eye, the phenomena are the same, whether the Earth goes around the Sun or the Sun around the Earth.

At whatever point we attack the problem of motion by actual observation, one thing is clear, the diurnal paths of the Sun and Moon must be located with reference to the horizon by the points of rising, southing and setting. The necessary angles in altitude and azimuth may be determined in various ways. The following involves no apparatus whatever. Take from a common almanac the time of apparent noon, and at that instant fix by permanent marks the position of the shadow. The direction of the shadow gives a rough meridian line which prolonged north and south intersects the horizon respectively in the north and south points. The celestial meridian may be described as the circle in the sky passing through these points and through the zenith. When the Sun in its daily journey comes to this circle, it is said to south, to transit or to cross the meridian; and its distance above the plane of the horizon is meridian altitude or noon altitude. In order to determine its value for a particular day, face the Sun on the meridian, decide whether it is about half the distance from the horizon to the zenith or only about a third. Then correct the 45° or 30° by dividing these angles into tenths. The observer must guard against making the distance too large near the horizon and too small at the zenith. When sunset points are to be located, stand on the meridian line facing west and stretch out the arm at right angles to the body. The line prolonged from the arm fixes approximately the west point from which the position of the setting point is determined by measuring on the horizon the angle between these points. When this angle is large an auxiliary line aids in making a more accurate measure as, for example, if two trees or other objects are chosen so that the line passing through them cuts the horizon near the setting point. Then the distance between the intersection of the line and the point gives a constant angle which can be estimated a number of times on different days and the mean taken. From the intersection to the reference line small angles are easily measured in terms of the Sun's own diameter. These methods may, in general, be employed for sunrise and for the rising and setting of the Moon. But those who become interested in watching any heavenly body will soon be dissatisfied with mere eye estimates. In finding meridian altitudes it is some help to hold the forefingers in front of the face, one vertical and the other pointed toward the body in the sky. Pencils and rulers are better than fingers, and a better way still is to lay a ruler on the side of a wall nearly in the meridian line and measure with a protractor the angle between the edges of the wall and ruler, thus finding the zenith distance. Any one who has a gnomon can determine the zenith distance at noon by measuring the height of the vertical shaft and the length of its shadow at noon, and then computing the required angle by plane trigonometry. One student whom I know has lately made an adjustable quadrant out of a yard stick and a strip of whalebone. It is hardly comparable to Tycho Brahe's famous quadrants but its measures are better than guesses and the owner claims for it the especial merit that it is not confined to the plane of the horizon but can be used in measuring angles anywhere in the sky. The accompanying diagram gives an idea of an inexpensive instrument made of wood which a number of students have found very convenient. As nearly as was possible from a brief description, it was made like one devised by Professor W. A. Rogers of Colby University. He gave it no name but we call it the circles. A vertical shaft about five feet in height carries at the top a vertical circle fifteen inches in diameter and at the bottom a horizontal pointer placed as nearly as possible in the same plane. Both circle and pointer can be brought into any vertical plane of the horizon, as the upright shaft turns in an aperture cut in the center of the horizontal cir-



cle. The latter circle about thirty inches in diameter is graduated from 0° to 360° so that azimuth is reckoned in true astronomical fashion from the south point through the west and north points around the complete circle. The circles may be readily transformed into a gnomon by removing the upright support and vertical circle and inserting instead a shaft with a sharp tapering point of such height that the long noon shadows of summer will just reach the circumference of the horizontal circle. A large flat stone makes a good base for the instrument. One method of fixing a meridian line on the stone is to draw a chalk line north and south with the help of a compass, allowance being made for the difference between the magnetic meridian and the true meridian. If the ends of this line are cut in the stone, a permanent meridian line is secured.

The manner of using the circles is as follows. Place them so that the line between 0° and 180° lies north and south; by means of a carpenter's level, see that the vertical shaft is approximately vertical and the horizontal circle approximately level, take hold of the shaft and move it around until the plane of the vertical circle produced includes the desired object; keeping the eye still in this plane place it also in line with the pointer in the plane, move the pointer until it is in line with the object, then clamp. The readings designated on the circles by the pointers give directly the altitude and azimuth of the object. In the evening if there is neither moonlight nor twilight an assistant should hold a bulls-eye lantern behind the upper circle so that its light falls on the end of the pointer.

A number of measures are made satisfactorily at night without any instrumental help. Select two stars somewhere near the space to be measured and about the same distance above the horizon. Let the line joining the two stars be the unit of measure in which the required distance is expressed. The value of this line in degrees is easily found in two ways sufficiently accurate for naked-eye work. Find on the celestial globe the stars chosen, measure the distance between them on a narrow strip of paper and then, as all great circles in the same sphere are equal, take from the celestial equator the number of degrees corresponding to the measured space. Or, if the mean right ascensions and declinations of the stars are known for the year, the following formula will give the number of degrees between them.

$$D = \sqrt{(\Delta\delta)^2 + (\Delta\alpha)^2 \cos^2\delta}$$

where δ is the mean declination of the two stars and $\Delta\delta$ and $\Delta\alpha$

are respectively the differences in declination and right ascension of the two stars.

Suppose, for example, that the line selected is the one between α and γ Pegasi; by measurement on the globe, it equals 16°.6. By the second method the result is a little more accurate, as is shown by the following:

α Pegasi	R. A. $= 22^h\ 59^m$	Decl. $= +\ 14°\ 37'$	$14°\ 37'$
γ Pegasi	$0\ 08$	$14\ 35$	$14\ 35$
	$\Delta\alpha = -1\ 09 = -17°.25$	$\Delta\delta = 02' = 0°.03$	$\delta = 14\ 36$

$$D = \sqrt{(0°.03)^2 + (-17°.25)^2 \cos^2 14°.36} = 16°.7$$

Every one who makes observations, even if they are little more than guesses, wishes to know what degree of accuracy they possess. All angular measures referring to the Sun's diurnal path are easily tested on the celestial globe. Adjust the globe so that it gives the aspect of the heavens for the time of observation. The position of the Sun corresponds to the date of the month marked on the ecliptic. Its altitude is found by laying off on a strip of paper the vertical distance between the Sun and the metal plate which represents the horizon. On the latter plate from the foot of the vertical circle measure to the nearest cardinal point, east, south or west. As described above, the two coördinates are readily expressed in degrees. In order to apply this method to the Moon, it is only necessary to know its right ascension and declination for the time of observation. Meridian altitudes of either the Sun or Moon may be checked by taking out for the day the declination given on page 6 or page 7 of *The Connecticut Almanac*. There is a typographical error in the heading of the first table, the year should be 1893. A very simple calculation furnishes the required test. As an illustration, on November 7, 1893, according to a student's observation made with the circles, the altitude of the Sun at noon was 32°. For that date the *Almanac* declination is — 16° 30′. This combined with the colatitude of the place, 47° 41′, gives the Sun's altitude as 31° 11′. *The Connecticut Almanac* is computed for New Haven but no interpolation is necessary in case of the Sun even for a place whose longitude differs by several hours.

No problems connected with apparent motion are more interesting than those which deal with the rate of this motion. At the instant when the Sun is on the meridian, its path is parallel to the horizon. An hour before and an hour after meridian passage, imagine vertical circles passed through the Sun and prolonged to the horizon. Since the downward curvature of the path is small between these two positions, the arc intercepted on the horizon gives approximately the number of degrees passed over by the Sun in two hours. Making use of this method for the Moon, five students during the past October observing independently with the circles, obtained hourly rates for the Moon varying from 13¼° to 14¼°.

Another method applicable to the Moon is best described by giving an outline of an actual observation. The student stood on one of the Observatory steps from which point the Moon was seen toward the southeast, a short distance above a white birch tree. In the sky not far away was the square of Pegasus. The line between α and γ was taken as the measuring line and the Moon's distance above the tree estimated to be a certain part of this unit. An hour later the student looked again from the same position, the same part of the measuring line was laid off above the tree and the Moon put back in imagination in the place it first occupied and, finally, the interval between this imaginary Moon and the real Moon in the sky was estimated in terms of the measuring unit. This way of obtaining the apparent hourly rate of the Moon's motion involves, of course, the error of assuming the motion to be in a great circle; for so short a time, however, the error is small compared with the probable error of observation.

No mention has thus far been made of observations for finding the motion of the Moon among the stars, nor for determining its latitude and longitude, right ascension and declination. Any student, however, who has put into practice a few of the foregoing suggestions will have no difficulty in making such applications and modifications as these problems demand. A few hours of genuine study of the heavenly bodies is better than much reading. The royal road of astronomy does not lie in a library, it is out of doors under the open sky.

CONSTELLATION STUDY.

WINSLOW UPTON.

IV.

The preceding articles of this series have discussed the general plan of constellation study which is recommended. It remains to take up the several constellations in turn and give suggestions for learning their leading features, as far as this can be done on a printed page. For at this point it is necessary to pass from a written description to the sky itself, and use such aids as star atlases may supply.

A word here regarding star atlases will not be out of place, for a good star atlas is indispensable to a thorough study of the constellations, and almost as necessary for the merest outline study of them. A number of excellent atlases can be purchased, each having special advantages, and some better adapted for one purpose than another. Individual preferences of course vary, and the opinions of the writer accordingly may not agree with those of others. Among the atlases available for the student the following are standard works: Argelander's Uranometria Nova and Heis' Atlas Cœlestis. These are the authoritative charts of the astronomer and thoroughly reliable. The former is nearly an ideal chart for the student who wishes to carry the study to some detail, or to have a standard atlas for reference, as it gives all the stars visible to the naked eye, and also contains the boundaries of the constellation areas and the outlines of the historical figures with sufficient distinctness for use, but not with undue prominence. Klein's star atlas and Proctor's larger atlas give more stars and the plates are therefore somewhat crowded, which is at first an embarrassment. The historical figures are omitted in these atlases. For a more general study less comprehensive works such as Proctor's Half Hours with the Stars, Burritt's Atlas to his Geography of the Heavens, Young's Uranography, are to be recommended, but the student is likely to outgrow them if he is persistent in the study. Burritt's Atlas has the advantage of large pages, but the historical figures are rather too prominent for their importance in the science of today. Besides atlases, the charts known as planispheres which can be set for any given hour are quite useful. Among those now in the market is Poole Bros.' Celestial Planisphere, which is very serviceable. It gives the brighter stars with the leading clusters and nebulæ, and like Young's Uranography has guiding lines which are a help in tracing the configurations. The constellation boundaries are given but not the historical figures, though the latter are given in the accompanying Handbook. The chart which is published in this number of POPULAR ASTRONOMY is a reproduction of a portion of Poole's Planisphere, and may be referred to in reading the remainder of this article.

In taking up the constellations in turn let us recall the classification adopted in the earlier articles of this series. We are to imagine the heavens divided into four lune-shaped areas, the boundaries of which are the equinoctial and solstitial colures. Then for convenience we are to take from each of these four sections the part in the vicinity of the pole and make a circumpolar map. Our five divisions are the circumpolar map and the four divisions thus decapitated. Were we to discuss all the constellations of the southern sky we should need a circumpolar map around the south pole corresponding with that around the north pole. We will first notice the constellations around the north pole and then those of the four sections, according to the list given in the second article of this series. Before doing this we should note how the four divisions of the sky are placed at the time of observation. To do this we should trace the line of the equinoctial colure. and imagine the solstitial colure drawn at right angles to it, intersecting it at the pole star. If it is in the evening of some night in February, the solstitial colure will run not far east or west of the meridian, and the first division of the sky will lie west of it and the second east of it. The third and fourth divisions are below the horizon except near the pole. If the observer faces the north for the circumpolar groups the first division lies above the pole west of the meridian (or more strictly west of the solstitial colure, which will only momentarily coincide with the meridian in the diurnal motion of the heavens), the second division lies above the pole east of this line, the third division is below the second and the fourth below the first. The bowl of the "Dipper" is in the second and its handle in the third division.

Constellations North of the Zenith, as seen in Northern Latitudes.

Cassiopeia. The line drawn from δ Ursæ Majoris to the Pole Star, if prolonged an equal distance passes through β Cassiopeiæ. δ Ursæ Majoris is the star marking the junction of the handle and bowl of the Dipper. The area called Cassiopeia is on the opposite side of the pole from the part of Ursa Major in which is the handle of the Dipper. The characteristic figure of Cassiopeia is a quadrilateral and two additional stars the line connecting which is nearly parallel with one of the sides of the quadrilateral. The figure made is somewhat like a chair, the four stars of the quadrilateral forming the body and the two other stars the back. There is a third star in the prolongation of the line representing the back of the chair which makes the chair a high-backed chair as some see it. The stars are conspicuous, with the exception of the one lettered κ where the knee of a person would come when sitting in the chair. A person thus sitting would face Draco. While this group is called Cassiopeia's Chair, the ancients did not represent the queen sitting in the chair; the stars which make the shape of the chair are a part of the figure of the royal lady, whose feet are towards the pole. The quadrilateral of stars is in the upper part of the body and the head is represented in the sky by a few faint stars just south of the quadrilateral. There are many faint stars visible to the naked eye besides those named, and the Milky Way passes through the quadrilateral of stars.

Camelopardalis. This name was given by Hevelius in the 17th century to the large area immediately following Cassiopeia, as the heavens rotate. The name is sometimes written Camelopardalus or Camelus. There are no stars in this area brighter than the fourth magnitude. The head of the giraffe is drawn near the pole star between it and the extremity of the tail of Draco. It is possible to trace a winding line of faint stars near the boundaries of the area, as shown on the chart of stars published in this number of POPULAR ASTRONOMY, but it requires a clear sky to do this.

Ursa Major. This large area contains the conspicuous stars of the Dipper and certain other stars around which the outlines of a bear may be drawn. The handle of the Dipper forms the tail of the bear and is out of all proportion to the size of that appendage in nature. Heis in his Atlas draws the diminutive tail of the terrestrial bear in addition to the gorgeous attachment required by the stars. The bowl of the Dipper is in the body of the animal. The head is marked by a group of small stars which may be found by prolonging the line connecting the upper stars of the bowl, α and δ. Three of the paws are marked each by a pair of stars which is a curious feature of this constellation. They may be found in this way: Prolong towards the south, that is away from the pole, the two pairs of stars forming the sides of the bowl of the Dipper, α, β and δ, γ. These lines converge to a bright star lettered ψ. This star is at the vertex of a triangle whose other vertices are two of the pairs, the two at which the hind paws of the bear are drawn. They are lettered ν, ξ and λ, μ respectively and are represented on the chart, which shows another way to find them. The third pair, lettered ι, κ and marking the position of one of the four paws may be readily found by prolonging the line δ, β of the Dipper, passing through the bright star θ on the way. There is a fourth pair of stars which might have represented the other fore paw had not the astronomer Hevelius in giving the name Lynx to a vacant space between the groups Ursa Major and Auriga of Ptolemy's list included them in the new constellation. The Dipper and the three pairs of stars above named are the characteristic features of the constellation and with the group constituting the head of the bear show the extent of space covered by it.

Ursa Minor. The seven leading stars of this constellation form the "Little Dipper" which can be readily traced by starting with the pole star, which is at the end of the handle, and following the rather faint curved line of stars to the four forming the bowl of the dipper. This is illustrated on the chart. If there is any difficulty in finding this figure, another way is to notice the line connecting the pole star with the end of the handle of the Great Dipper, the star η Ursæ Majoris. The two stars β and γ of Ursæ Minoris lie a little out of this line not quite half-way from the pole star. When these are found the construction of the rest of the figure from the four faint stars between these two stars and the pole star is not difficult. As in the case of the Great Bear, the handle of the Dipper is the tail of the Little Bear, and the bowl part of its body.

Draco. This winding constellation is a good example of the snake-like figures which can be readily formed among the stars, and which are almost the only configurations bearing any resemblance to the objects suggested by their names. A quadrilateral of stars forms the head of the figure. Its position is close to the solstitial colure,—the arc which is nearest the winter solstice, or the XVIII hour circle. In February evenings this is the part of the colure which extends from the pole towards the north horizon. The head of Draco is 25° from the pole, and therefore may not be readily detected unless the sky is clear near the horizon. When found, the winding line of stars marked on the chart can be readily traced, passing between the two dippers. It is sometimes easier to begin at the tail of the dragon and trace the line towards the head. In this case the star which marks the intersection of the line drawn from the "pointers" of the Great Dipper to the pole star with the dragon, lettered λ, is a good one to begin with. The star α Draconis, which is nearly in the line connecting the pole star with the end of the handle of the Great Dipper, is the star which was the nearest bright star to the pole at the time of the building of the great pyramid. In tracing the figure of the dragon it will be noticed that at the turning points where folds of the dragon are usually drawn there are groups of small stars.

Cepheus. This constellation lies between the head of Draco and the constellation Cassiopeia. A large part of its area is devoid of prominent stars. Its characteristic figures are a group of stars at the southernmost limit of the area, where the head of the king is drawn, and a broken line of three third magnitude stars further north near the center of the area. The former group consists of a variable star, one of the fourth magnitude, and one of the fifth magnitude, forming a triangle with several very faint stars adjacent. The easternmost of the triangle (at the left when the group is seen below the pole), lettered δ, is the variable star and one of the best known in the sky. It fluctuates between the fourth magnitude and the fifth every five days. The broken line of stars referred to embraces the only conspicuous stars in the constellation. The two southernmost form a line with the pole star, very much as the pointers of the Dipper, and the third makes an obtuse angle of about 130° with this line.

These six constellations occupy the greater part of the area within 40° of the northern pole of the sky. Three other constellations, Perseus, Auriga, and Lynx have a large part of their area within this circumpolar region, but their most conspicuous stars are farther south, and they will be treated with the constellations which culminate south of the zenith in northern latitudes.

The following table contains the approximate positions of the leading stars in each constellation. It is given for use in charting the stars, as suggested in the third article of this series.

APPROXIMATE POSITIONS OF THE LEADING STARS IN THE CIRCUMPOLAR CONSTELLATIONS.

CASSIOPEIA.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
β	2.4	0 4	58 36
κ	4.2	0 27	62 23
α	2.2	0 35	56 0
γ	2.3	0 51	60 10
δ	2.8	1 19	59 37
ε	3.6	1 47	63 11

CAMELOPARDALIS.

(No Bright Stars.)

URSA MAJOR.

o	3.4	8 22	61 3
ι	3.2	8 52	48 26
κ	3.7	8 57	47 33
θ	3.2	9 26	52 8
λ	3.6	10 11	43 25
μ	3.1	10 16	42 0
β	2 6	10 56	56 55
α	2.0	10 58	62 18

URSA MAJOR. Cont.

Name.	Magnitude.	Right Ascension.	Declination.
ψ	3.1	11 4	45 3
ξ	4.8	11 13	32 6
ν	3.8	11 13	33 39
γ	2.6	11 49	54 15
δ	3.4	12 10	57 35
ε	1.8	12 49	56 30
ζ	2.6	13 20	55 26
η	2.0	13 44	49 49
		URSA MINOR.	
α	2.2	1 17	88 46
β	2.1	14 51	74 34
γ	3.2	15 21	72 11
ζ	4.5	15 48	78 6
η	5.0	16 20	75 59
ε	4.5	16 56	82 12
δ	4.3	18 7	86 37
		DRACO.	
λ	4.1	11 26	69 54
κ	3.8	12 29	70 20
α	3.6	14 2	64 51
ι	3.4	15 23	59 19
θ	4.2	16 0	58 49
η	2.8	16 23	61 44
ζ	3.3	17 8	65 51
β	3.0	17 28	52 22
ν	4.8	17 30	55 14
ψ	4.8	17 45	72 12
ξ	3.9	17 52	56 54
γ	2.4	17 54	51 30
φ	4.2	18 22	71 17
χ	3.7	18 23	72 42
δ	3.2	19 12	67 29
ε	3.9	19 48	70 1
		CEPHEUS.	
α	2.6	21 16	62 10
β	3.4	21 27	70 1
δ	3.7 — 4.9	22 25	57 54
γ	3.4	23 35	77 4

VARIABLE STARS. IV.

J. A. PARKHURST.

The worst foe to accuracy in variable star work is a preconceived notion of what the star is going to do. Too much emphasis cannot be placed on the caution against this source of error. The work should be approached in a "judicial frame of mind" and the observer must train himself to record just what he sees, nothing more or less. With this end in view it is better not to make the reductions explained in the January number till the star has certainly passed a maximum or minimum, nor to learn from the ephemeris when the maximum or minimum ought to occur, except barely enough to be prepared for observation. For this reason POPULAR ASTRONOMY gives the times of minima of the Algol stars only to the nearest hour, though for most of them the predictions can be made very much closer.

The principal facts in regard to the period of variables are given concisely in what are termed their elements. These consist of 1st, the epoch; 2d, the length of period. The time of the first well determined maximum is generally taken as the epoch, and if the period is regular the time of any other maximum can be found by multiplying the length of period by the number of periods elapsed since the epoch and adding the product to the time of the epoch. For example Chandler's elements for 107 T Cassiopeiæ are—

$$1871 \text{ March } 31 + 445.0 \text{ E},$$

in which E represents the number of periods elapsed since the epoch.

It is not always possible to represent a star's variation by so simple an expression as the above. In some cases a star's period will gradually shorten till it is about five-sixths the usual length, then lengthen till it is as much longer than the average, thus showing that there is a secondary cause at work with the principal one, their varying combination giving different lengths of period. This can often be represented in the elements by what is called a "sine term." For example the elements of 5237 R Boötis are—

$$1858 \text{ June } 8 + 223.4 \text{ E} + 10 \sin (10° \text{ E} + 80°).$$

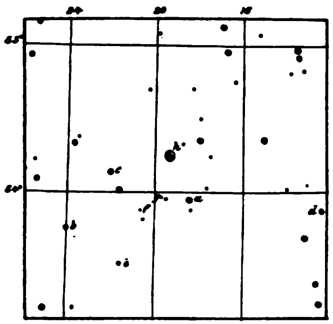
As the value of the sine varies from + 1 to — 1 the last term can have values from + 10 to — 10 and the period will vary from 233.4 to 213.4 days.

There is a progressive lengthening or shortening in the case of some variables which can be represented by terms containing the second or third power of E while other stars defy any number of terms to follow their idiosyncrasies.

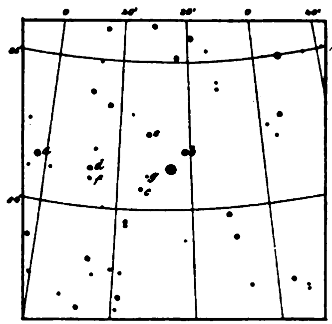
IDENTIFYING THE VARIABLE.

If the observer has a telescope provided with finding circles he will have no difficulty in picking up the fields charted in this and preceding numbers, and with attention he will be able to identify the variables. If he has no finding circles the operation will not be so easy and some suggestions may be helpful. First

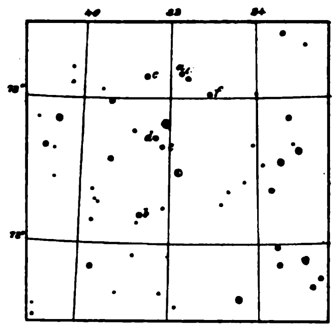
CIRCUMPOLAR VARIABLE STARS OF LONG PERIOD.



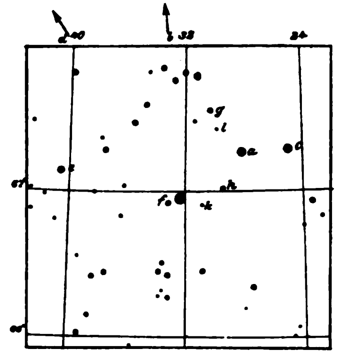
5157 S BOOTIS.
R.A. 14^h 19^m.5 DEC. +54°16′.



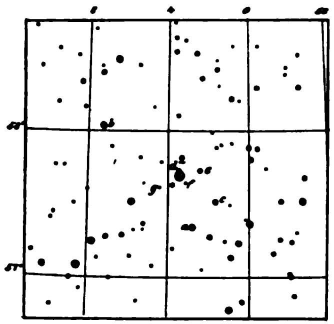
5190 R CAMELOPARDI.
R.A. 14^h 25^m.1 DEC. +84°17′.



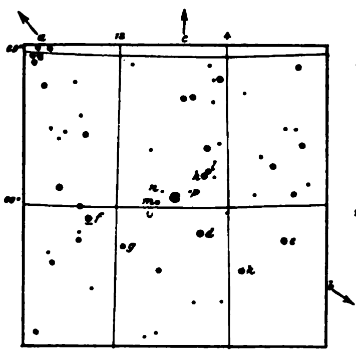
5948 R URSÆ MINORIS.
R.A. 16^h 31^m.3 DEC. +72°29′.



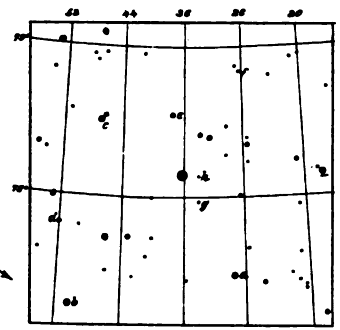
5955 R DRACONIS.
R.A. 16^h 32^m.4 DEC. +66°58′.



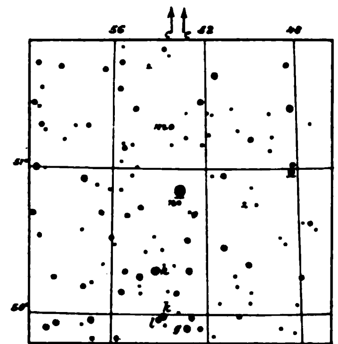
7220 S CYGNI.
R.A. 20^h 3^m.4 DEC. +57°42′.



7609 T CEPHEI.
R.A. 21^h 8^m.2 DEC. +68°5′.



7779 S CEPHEI.
R.A. 21^h 36^m.5 DEC. +78°10′.



8600 R CASSIOPEIÆ.
R.A. 23^h 53^m.3 DEC. +50°50′.

make an enlarged copy of the chart for each variable, locating carefully the stars charted and also the comparison stars from the lists in the January and February numbers, down to a magnitude a little below the limit of vision of the telescope used. Locate the variable on the star atlas by means of its given Right Ascension and Declination, and note its relation to the nearest naked-eye stars which can be identified. In most cases the telescope can be pointed at the sky within a degree or so of the proper direction. A little careful sweeping will now suffice to find and recognize some part of chart, and so on to the variable, *provided* that three facts are known: 1st. How faint stars one can expect to see. The table given in the October number, page 91 will settle that point. 2d. Which is north in the sky and on the chart. 3d. How large a portion of the chart will be included in the field of view. To settle this last point it will be well to draw a circle on the chart with the variable as a center and the breadth of the field of view as a diameter. This will show just what can be seen when the telescope is correctly pointed on the variable. Most of the difficulty beginners find in locating variables will come from neglecting some of these three points, but by taking them into account a little practice will enable the observer to locate the variables readily without finding circles.

The list of comparison stars for the variables charted opposite page 216 in the January number, is on page 237.

The plate accompanying this article is the companion to that published in the January number and is generously contributed by Professor E. C. Pickering of Harvard College Observatory.

The plate and the list of comparison stars are taken from Pickering's "Variable Stars of Long Period."

The principal facts in regard to the variables are given in the following table, taken from Chandler's "Second Catalogue of Variable Stars."

Star No.	Name	Place for 1900.0 R A h m s	Decl ° ′	Redness	Magnitude Max.	Magnitude Min.	Period days.
5157	S Boötis...............	14 19 32	+ 54 15.9	2.8	7.7 — 8.5	12.5 — 13.2	274.0
5190	R Camelopardalis	14 25 6	+ 84 17.1	2.1	7.2 — 8.6	11.8 — 13.5	269.5
5948	R Ursæ Minoris...	16 31 18	+ 72 28	3.2	8.6 — 9.0	10.5	Irreg.
5955	R Draconis	16 32 23	+ 66 57.8	2.0	6.5 — 8.7	12 — 13	245.6
7220	S Cygni................	20 3 24	+ 57 41.9	5.1	8.8 — 11.3	< 14.5	322.8
7609	T Cephei	21 8 13	+ 68 5.0	6.3	5.2 — 6.8	9.5 — 9.9	383.3
7779	S Cephei...............	21 36 28	+ 78 10.3	9.1	7.4 — 9.2	11.5	484
8600	R Cassiopeiæ.......	23 53 19	+ 50 49.9	6.5	4.8 — 7.0	9.7 — 12	429.0

The period of S Boötis is undergoing a progressive shortening; that of R Camelopardalis has irregularities whose law is not yet established. The periods of S Cephei and R Cassiopeiæ alternately lengthen and shorten.

Most of the variables charted in the January and February numbers will be visible in February with a two-inch telescope. The brightest of the list will probably be numbers 8600, 5955, 5190, 5157, 107, 4511, 793, 814, 1855. Three inches aperture will show 7609, and 5157; five inches will show 7779, 4557 and 3825, while six inches or more will be required to see 7220, 2478 and 432.

MARENGO OBSERVATORY,
Marengo, Ill. 1894, Jan. 8.

DOES THE LUMINIFEROUS ETHER SERVE AS A MEDIUM FOR THE TRANSMISSION OF THE FORCE OF GRAVITATION?

DE VOLSON WOOD.

In the January number of POPULAR ASTRONOMY, page 199, I find the statement: "This ether apparently does not gravitate, but it may, notwithstanding, be the medium by which the influence of gravitation, as well as of light, heat, and electricity, is propagated." The suggestion that the luminiferous ether transmits the force of gravity, is comparatively frequent; but according to recognized laws, it is physically impossible for the same medium to transmit both light and the force of gravity. The reasoning is simple. Including the effect due to the compression produced by a wave, the velocity with which a wave is transmitted in an elastic medium is

$$v = \sqrt{\frac{\gamma E}{D}}$$

where E is the measure of the elasticity and D the density—or mass in unity of volume—and γ the ratio of the specific heat at constant pressure to that at constant volume whose value is 1.4 nearly. In my article on the luminiferous ether in the London *Philosophical Magazine* for November, 1885,* I determined that, according to the data at hand,

$$E = \frac{4}{10^9} \text{ and } D = \frac{2}{35 \times 10^{24}}$$

per cubic foot. These values give

* Republished in Van Nostrand's Science Series, No. 85.

$$v = 187500 \text{ miles}$$

per second. The observed value is

$$v = 186300 \text{ miles per second.}$$

Considering the fact that the value of $\gamma = 1.4$ is entirely arbitrary in regard to the ether, the result rather confirms the analysis. The particular point we desire to make is this—that a medium of fixed elasticity and density can transmit a wave with only one velocity, and that if it does transmit a wave with any other velocity either the elasticity or density, or both, must be changed. It is believed that the ether is practically uniform in regard to elasticity and density throughout space; and this idea is confirmed by the analysis in the article above referred to. Such being the case, the velocity of a wave in the ether will not differ very largely from 186300 miles per second; certainly no cause is known why it should be twice or three times that value. But La Place found that if the force of gravitation, if propagated by an elastic medium, must have a velocity exceeding a hundred millions times that of light (*Mech. Celeste,* B. X, ch. 8). It is then physically impossible for gravity to be propagated by the luminiferous ether. If gravity is propagated by an ether, it must be one peculiar to itself, which we may call the "gravitation ether" in which the ratio of E to D as far transcends that for the luminiferous ether, as that ratio for the ether transcends its value for atmospheric air.

If the luminiferous ether be molecular and subject to the force of gravitation, it will not be drawn to the centres of force so as to leave void spaces, for as I showed in my article the force of repulsion between the particles will so counteract gravitation as to leave it of practically uniform tension throughout space.

SHOOTING STARS.

How to Observe Them and What they Teach Us.

W. F. DENNING.

VI. The August Perseids.

Having touched upon some of the observational features of shooting stars it is now proposed to give a little space to the description of three of the leading showers, namely, the Perseids of August and the Leonids and Andromedes of November. The former of these will form the subject of the present paper and though the Perseid system cannot, it is true, boast of such abundant and brilliant displays as the Leonids and Andromedes it compensates for this in its more frequent appearance. Every year as the anniversary of St. Lawrence (August 10) comes round the Perseids return more or less plentifully and the observer who attentively watches them is always amply repaid for his trouble. No doubt variations affect the visible strength of the stream from year to year, but it is invariably sufficiently pronounced to merit observation and sometimes so rich and striking as to attract popular notice.

The Perseids form one of the oldest meteor groups of which we are cognizant, for its observed returns apparently date back to the ninth century when several displays were historically recorded as having occurred in the latter part of July. Quetelet's catalogue contains seven instances of the shower's apparition between A. D. 811 and 841, but in the ensuing centuries it seems to have rarely met with the recognition it deserved and it was not till the latter part of the 18th century that it received special notice. It then began to be more systematically observed though its features in detail still awaited study. The earlier observations appear to have simply consisted in noting that on about August 10th meteors were much more numerous than usual, and occasionally something was added as to their general directions relatively to the points of the compass. That the bulk of the meteors exhibited radiation from a centre in Perseus does not appear to have been clearly apprehended until a third of the present century had passed away and more serious attention was accorded to the subject of meteors. After the great display of Leonids in 1833 interest in these phenomena was however much intensified and the facts showed them to possess an important significance. The necessity of recording the apparent paths of individual meteors and other features of their appearance was then realized, and Heis, Herrick, Schmidt and others became the successful pioneers in this complicated field of astronomy.

One of the earliest observers to determine the Perseid radiant was G. C. Schaeffer of New York who in 1837 and 1838 placed it at 55° + 60°. In late years it was more accurately fixed by Greg, Herschel, Twining and others at 45° + 57°. Schiaparelli's discovery in about 1866 that the orbit of the Perseids and of Tuttle's Comet (III 1862) presented an agreement so close that their physical identity was to be inferred, gave another stimulus to this department and greatly encouraged the efforts of observers.

The Perseids were long known to possess a very durable activity, with maximum on about August 10, and Le Verrier pointed out that the radiant point ought to become displaced in position on succeeding evenings. This was not however detected until 1877 though Greg found the radiant an elongated one extending from Perseus to Cassiopeia. A numerous series of observations at Bristol in 1877 clearly proved that the radiant had a motion to the eastward, a fact which was amply corroborated in subsequent years when the rate and direction of this motion were determined with greater precision. On July 19 the point of radiation is at 19° + 51°, whereas on August 10 it is at 45° + 57° and its R. A. increases at the rate of little more than 1° daily. The following diagram will exhibit the approximate path of the radiant between July 19 and August 17.

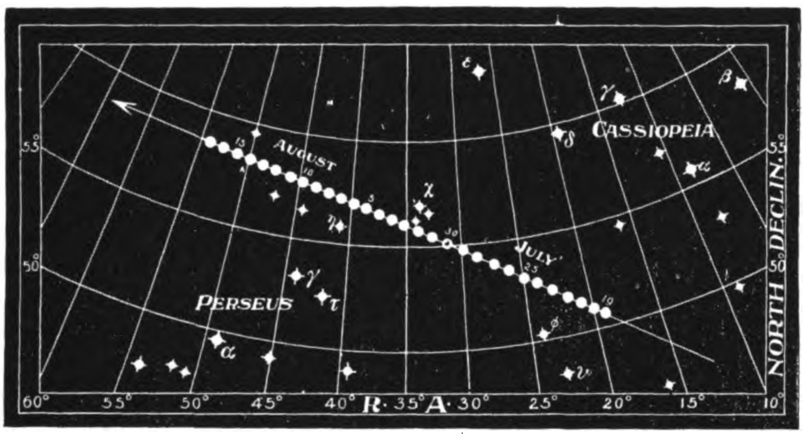


FIG. 5. PATH OF THE PERSEID RADIANT JULY 19 TO AUGUST 17.

The shower is probably visible before July 19 and after August 17 but for present purposes these limiting dates are adopted as the observations indicating a still longer duration are perhaps too scanty to be conclusive.

There are a considerable number of minor showers in simultaneous operation with the Perseids and they have served to introduce complications and to give the Perseid radiant a diffuse character not really belonging to it. When the meteors in this region are severally apportioned to their proper centres the focus of the Perseids often comes out with remarkable definiteness. There are certainly more than 100 distinct meteor streams in active play on about August 10 (say between August 5 and 15) and the radiant positions of many of the more prominent of these have been ascertained in a satisfactory manner. In the following table 72 of them are enumerated, but it must be understood that they comprise a proportion only of the aggregate of co-Perseid showers and that in some cases the positions may require correction as they represent extremely weak showers:

METEORIC RADIANTS VISIBLE AUGUST 5-15.

° °	° °	° °	° °
3 + 27	49 + 30	104 + 79	304 − 13
4 − 2	54 + 71	104 + 34	310 + 77
7 + 11	55 + 84	134 + 77	311 + 62
8 + 53	61 + 39	186 + 74	312 + 15
9 + 34	61 + 48	213 + 53	315 + 48
19 + 29	61 + 60	215 + 76	320 + 31
20 + 58	63 + 22	242 + 49	320 + 11
23 + 36	70 + 51	250 + 55	320 − 12
25 + 42	70 + 65	255 + 37	331 + 49
28 + 72	74 + 41	264 + 62	332 + 71
30 + 36	76 + 74	270 + 20	333 + 10
31 + 49	77 + 32	271 + 48	333 + 27
32 + 18	78 + 57	284 − 12	334 + 57
38 − 13	87 + 34	291 + 70	340 − 13
40 + 28	87 + 15	292 + 53	343 + 12
41 + 23	92 + 57	296 ± 0	347 ± 0
43 + 39	96 + 71	296 + 86	350 + 51
48 + 44	98 + 43	302 + 24	351 + 38

It will be noticed that nearly all of these showers are in the northern hemisphere. There are undoubtedly a great number of others in the southern hemisphere but the quest of meteor radiants has never been adequately pursued in this part of the firmament. In fact the southern heavens may be said to offer a rich and comparatively unexplored field and it is hoped the day is not far distant when some thoroughly competent observer will make it the theatre of his labors.

The following diagram may be useful as indicating the places of 34 radiants in the same general region as the Perseids between Aug. 5—15. No doubt there are many additional ones, but these are probably the best. It will be interesting to find whether these subordinate systems continue active in future years and whether they offer a regular annual display like the Perseids.

With regard to the hourly number of meteors visible at the August epoch this varies in different years but at the end of July, early in August, and between August 13 and 25, a single observer may generally count 20 an hour. From observations at Bristol some years ago the writer constructed the diagram annexed which shows the horary rate of all meteors and of Perseids between July 25 and August 19. It will be seen on inspection that the numbers increase and decline very suddenly near the date of the maximum. At the end of July there is a marked rise in the total number of meteors which is not due to the Perseids but to a specially active shower of Aquarids revealed by observations in 1878.

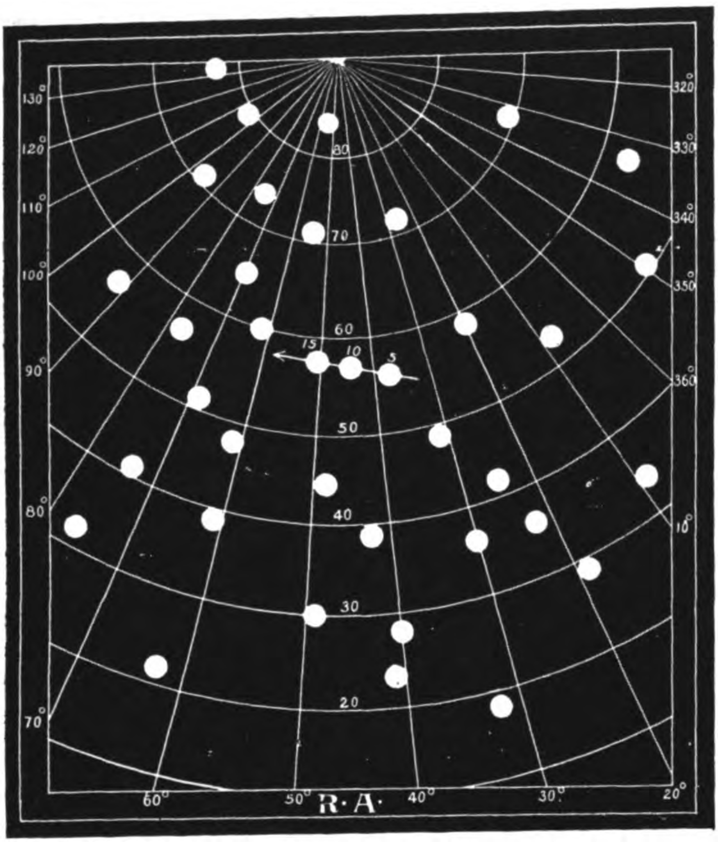


FIG. 6. PERSEID AND CONTEMPORARY RADIANTS IN SAME REGION BETWEEN AUGUST 5 AND 15.

From carefully observed tracks the radiant may always be determined within a probable error of 2 degrees. To show how closely the positions obtained by different observers may agree we quote the following results obtained in 1879 and 1880, at the time of the Perseid maxima:—

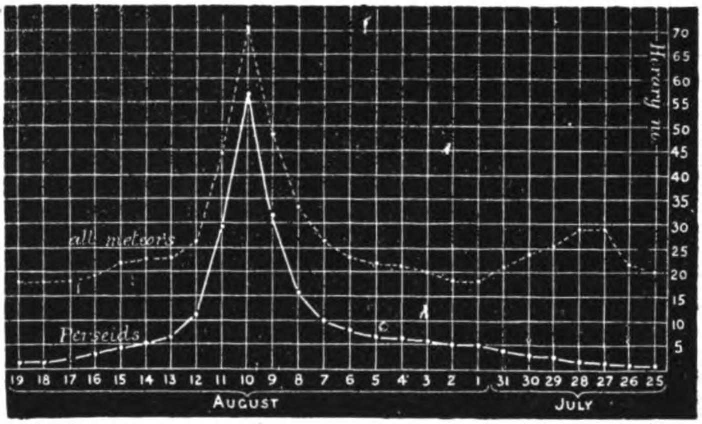


FIG. 7. DIAGRAM EXHIBITING HORARY NUMBERS OF ALL METEORS AND PERSEIDS. JULY 25–AUG. 19.

Observer.	1879 Aug. Radiant.		1880 Aug. Radiant.	
	°	°	°	°
G. L. Tupman..........................	45	+ 51	44	+ 51
H. Corder.................................	45	+ 57	45	+ 58
E. F. Sawyer............................	44½	+ 57	44¾	+ 51¼
W. F. Denning.........................	46	+ 58	44	+ 56

There are some other circumstances in connection with the Perseids which we might have noticed but the objeet has merely been to outline some of the facts and to give a few details which may invite comparisons by future observers. It is by fair comparison and criticism that the truth is evolved and continued observation, while affording the means of detecting errors, also furnishes the corroboration often necessary to render doubtful features certain. We hope that many of the future spectators of this fine shower will do so with a keen regard to details so that all its traits of appearance may be fully elucidated. That the display will always command appreciative observers cannot be doubted for a moment, for apart from the abundance of its meteors and their occasional splendor, the shower comes at the most attractive season of the year when the nights are getting suitably dark and the observer can remain out of doors for hours together without any of theinconveniences attached to the winter season.

THE NEED OF A FREE ASTRONOMICAL OBSERVATORY.

FLORENCE ARMITAGE.

Why among all the noble achievements for the benefit of the masses in this enlightened age, have not the promoters of education and science established a *free* Observatory for the study and advancement of that most grand, elevating and enlightening science, Astronomy?

As vice is mostly due to ignorance and narrow-mindedness, would it not be achieving a great purpose if the ignorant be aroused to the fact that this Earth is but one body, and that a very small one of many, flying through space; and that our short life here is not given us to live for the gratification of worldly pleasures but for perfecting the mind in so far as we are able, and that the more highly educated the more capable the mind of realizing what boundless omnipotence rules the universe including all the starry host?

What can teach this better than Astronomy?

Some scoff at religion and demand *proof* of the existence of supreme power. What can illustrate perfection of might as the wonderful laws which govern the universe? Not night or day, weeks, months, years or centuries fail. Supremely and silently all was and is. What can more grandly illustrate the existence of supreme perfection and unchangeableness?

We *can* and *must* have a building in the city of New York where telescopes may be erected, the people assembled and those of learning teach the elements of Astronomy.

Consider what wonders might be revealed if many assisted in unraveling the mysteries of time and space.

Money should be raised to perfect this plan and it rests with scientists and the noble minded to do this great work.

By the co-operation of the readers of POPULAR ASTRONOMY, subscriptions might be started immediately for a site, buildings and instruments.

John Tyndall, the eminent physicist, died at Haslemere, England, Dec. 4, 1893. Few men of science have been more widely or favorably known than he. He was born Aug. 21, 1820, at Leighlin Bridge near Carlow, Ireland. In January–February *Physical Review* will be found a good brief note giving a sketch of Professor Tyndall's life and work. A fine small portrait makes the frontispiece of the same number.

PLANET NOTES FOR MARCH.

H. C. WILSON.

Mercury during March will be passing between the earth and the Sun, as may be seen from the diagram in our last number, page 228. For the first two or three days the planet will be visible in the evening just after sunset. In order to see it one must look toward the west, just a little above the horizon. On March 14, 2^h 18^m A. M., Mercury will be in conjunction with the Sun, and after that time it will be morning planet.

Venus will be morning star and rapidly come out from the rays of the Sun. She will increase rapidly in brilliancy so that none can mistake her, greatest brilliancy being attained on the 22nd of March. Venus will be in conjunction with the waning moon, 12° 28′ north, March 4 at 9^h 39^m P. M. Central time.

Mars rises about 4 o'clock in the morning and is at such a southern declination that there will be little opportunity for observation of this planet in northern latitudes during March. It is in the constellation Sagittarius and moving eastward. Mars will be in conjunction with the Moon, 4° 44′ north, March 1 at 11^h 29^m P. M. and again March 30 at 11^h 38^m P. M.

Jupiter will be in good position for observation in the early evening. The position of this planet among the stars is shown upon the Poole Bros.' map at the end of this number. Jupiter will be in conjunction with the Moon, 4° 40′ south, March 11 at 2^h 40^m P. M.

Saturn rises in the evening and will be in good position for observation after midnight. For the position of this planet in the constellation Virgo see the chart in our last number. Saturn will be in conjunction with the Moon, 4° 24′, north, March 23 at 3^h 01^m A. M.

Uranus is in the constellation Libra, southeast from Saturn (see chart page 230), and may be observed after midnight. Uranus will be in conjunction with the Moon, 3° 39′ north, at 6^h 12^m P. M., March 24.

Neptune will be in good position for observation during the early evening in March. The position of this planet in Taurus is shown on Poole Bros.' map at the end of this number. We are sorry that, by the process used in reproducing the photograph of the Neptune region (Plate XI in our last number), more than two-thirds of the stars shown in the photograph were lost, thus destroying to a large extent its value to the amateur who might use it as a means of finding the planet.

The asteroid *Juno* is in the constellation Libra about 5° northeast of the star β. It is making the turn of the loop in its apparent path and after the middle of the month will move westward.

Planet Tables for March.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
1894.	h m	° ′	h m	h m	h m
Mar. 5	23 51.8	+ 2 33	6 44 A. M.	12 57.6 P. M.	7 11 P. M.
15	23 27.0	+ 0 02	5 50 "	11 53.7 A. M.	5 57 "
25	23 06.7	− 4 33	5 09 "	10 54.1 "	4 40 "

VENUS.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Mar. 5	21 20.5	− 7 36	4 54 A. M.	10 27.0 A. M.	4 00 P. M.
15	21 25.0	− 8 59	4 24 "	9 52.0 "	3 20 "
25	21 42.5	− 9 23	4 04 "	9 30.3 "	2 56 "

MARS.

Mar. 5	19 00.6	− 23 16	3 42 A. M.	8 07.5 A. M.	12 33 P. M.
15	19 31.0	− 22 32	5 31 "	7 58.5 "	12 26 "
25	20 01.0	− 21 27	3 16 "	7 49.1 "	12 22 "

JUPITER.

Mar. 5	3 32.4	+18 25	9 18 A. M.	4 37.8 P. M.	11 58 P. M.
15	3 38.7	+18 49	8 43 "	4 04.8 "	11 27 "
25	3 45.8	+19 15	8 09 "	3 32.6 "	10 57 "

SATURN.

Mar. 5	13 34.1	− 6 54	9 02 P. M.	2 37.8 A. M.	8 14 A. M.
15	13 32.0	− 6 40	8 19 "	1 56.3 "	7 33 "
25	13 29.5	− 6 24	7 36 "	1 14.6 "	6 53 "

URANUS.

Mar. 5	14 51.5	− 16 01	10 57 P. M.	3 55.0 A. M.	8 53 A. M.
15	14 50.8	− 15 58	10 16 "	3 14.9 "	8 13 "
25	14 49.8	− 15 53	9 36 "	2 34.6 "	7 33 "

NEPTUNE.

Mar. 5	4 37.8	+20 35	10 13 A. M.	5 43.0 P. M.	1 13 A. M.
15	4 38.2	+20 37	9 34 "	5 04.1 "	12 35 "
25	4 38.9	+20 39	8 55 "	4 25.5 "	11 56 P. M.

THE SUN.

Mar. 5	23 05.0	− 5 51	6 31 A. M.	12 11.5 P. M.	5 52 P. M.
15	23 42.2	− 1 55	6 13 "	12 08.9 "	6 05 "
25	0 18.7	+ 2 01	5 55 "	12 05.9 "	6 17 "

Phases and Aspects of the Moon.

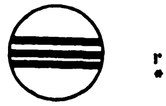
	Central Time. d	h m
Apogee	Mar. 1	10 06 A. M.
New Moon	" 7	8 18 A. M.
First Quarter	" 14	12 28 P. M.
Perigee	" 16	11 18 P. M.
Full Moon	" 21	8 11 A. M.
Last Quarter	" 29	2 28 A. M.
Apogee	" 29	6 42 A. M.

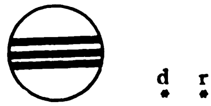
Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

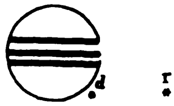
	h m		h m		h m
Mar. 1	6 39 P. M.	Mar. 12	10 46 P. M.	Mar. 22	9 06 P. M.
3	12 26 A. M.	13	6 38 "	23	4 58 "
3	8 18 P. M.	15	12 25 A. M.	24	10 46 "
4	4 10 "	15	8 17 P. M.	25	6 37 "
5	9 57 "	16	4 09 "	26	12 25 A. M.
6	7 49 "	17	9 56 "	27	8 17 P. M.
7	11 36 "	18	5 48 "	28	4 08 "
8	7 28 "	19	11 35 "	29	9 56 "
9	3 19 "	20	7 27 "	30	5 47 "
10	9 07 "	21	3 19 "	31	11 35 "
11	4 59 "				

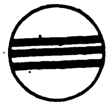
Jupiter's Satellites for March.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. 

III. 

II. 

IV.  No Eclipse.

Configuration at 7h for an Inverting Telescope.

Day.	West	East.
1	·4 3· O	2 ·1●
2	·43· 1· O	2·
3	·3 ·2 ·4 O	·1
4	1· ·3 O	·4 ·2●
5	O	1· 2 ·3 ·4
6	2· ·1 O	·3 ·4
7	·2 O	1· 3· ·4
8	O	·2 4·
9	O 1· 3· O	2· 4·
10	·3 2· O	·1 4·
11	·31· O	4· ·2●
12	4O·	·1 ·3 2·
13	4· ·12· O	·3
14	4· ·2 O	1· 3·
15	4· ·1 O	3· ·2
16	4· 3· O	1· 2·
17	·4 ·3 2· O	·1●
18	.4 ·3 1· ·2O	
19	·4 O	·3·1 2·
20	1· ·4 2· O	·3
21	·2 O	1· 4 3·
22	·1 O	3· ·2 4·
23	3· O	1· 2· ·4
24	3· 2· O	·4 ·1●
25	·3 ·21· O	4·
26	O	·3 ·1 ·2 4·
27	O2· .1 O	·3 4·
28	·2 O	·1 4· 3·
29	·1 4·O	·2 3·
30	4· 3· O	1· 2·
31	4· 3· 2· ·1 O	

Phenomena of Jupiter's Satellites.

Central Time.

	h	m			
Mar. 1	12	13	P. M.	III	Tr. In.
	2	21	"	III	Tr. Eg.
	5	28	"	III	*Sh. In.
	6	18	"	I	*Oc. Dis.
	7	28	"	III	*Sh. Eg.
	9	45	"	I	*Ec. Re.
2	3	27	"	I	Tr. In.
	4	44	"	I	Sh. In.
	5	41	"	I	*Tr. Eg.
	6	57	"	I	*Sh. Eg.
	8	48	"	II	*Tr. In.
	11	13	"	II	Tr. Eg.
	11	21	"	II	Sh. In.
3	1	44	A. M.	II	Sh. Eg.
	12	47	"	I	Oc. Dis.
	4	14	P. M.	I	Ec. Re.
4	9	57	A. M.	I	Tr. In.
	11	12	"	I	Sh. In.
	12	10	P. M.	I	Tr. Eg.
	1	26	"	I	Sh. Eg.
	3	03	"	II	Oc. Dis.
	5	28	"	II	Oc. Re.
	5	37	"	II	*Ec. Dis.
	7	54	"	II	*Ec. Re.
5	2	12	A. M.	III	Oc. Dis.
	4	20	"	III	Oc. Re.
	7	17	"	I	Oc. Dis.
	7	29	"	III	Ec. Dis.
	9	17	"	III	Ec. Re.
	10	43	"	I	Ec. Re.
6	4	26	"	I	Tr. In.
	5	41	"	I	Sh. In.
	6	40	"	I	Tr. Eg.
	7	55	"	I	Sh. Eg.
	10	10	"	II	Tr. In.
	12	35	P. M.	II	Tr. Eg.
	12	40	"	II	Sh. In.
	3	03	"	II	Sh. Eg.
7	1	46	A. M.	I	Oc. Dis.
	5	12	"	I	Ec. Re.
	10	56	P. M.	I	Tr. In.
8	12	10	A. M.	I	Sh. In.
	1	09	"	I	Tr. Eg.
	2	23	"	I	Sh. Eg.
	4	24	"	II	Oc. Dis.
	6	49	"	II	Oc. Re.
	6	55	"	II	Ec. Dis.
	9	12	"	II	Ec. Re.
	4	25	P. M.	III	Tr. In.
	6	34	"	III	*Tr. Eg.
	8	16	"	I	*Oc. Dis.
	9	29	"	III	*Sh. In.
	11	30	"	III	Sh. Eg.
	11	41	"	I	Ec. Re.
9	5	25	"	I	Tr. In.
	6	39	"	I	*Sh. In.
	7	39	"	I	*Tr. Eg.
	8	52	"	I	*Sh. Eg.
	11	32	"	II	Tr. In.
10	1	57	A. M.	II	Tr. Eg.
	1	59	"	II	Sh. In.
Mar. 10	4	22	A. M.	II	Sh. Eg.
	2	46	"	I	Oc. Dis.
	6	10	"	I	*Ec. Re.
11	11	55	"	I	Tr. In.
	1	08	P. M.	I	Sh. In.
	2	08	"	I	Tr. Eg.
	3	21	"	I	Sh. Eg.
	5	45	"	II	*Oc. Dis.
	8	10	"	II	*Oc. Re.
	8	14	"	II	*Ec. Dis.
	10	31	"	II	Ec. Re.
12	6	25	A. M.	III	Oc. Dis.
	8	35	"	III	Oc. Re.
	9	15	"	I	Oc. Dis.
	11	29	"	III	Ec. Dis.
	12	39	P. M.	I	Ec. Re.
	1	18	"	III	Ec. Re.
13	6	25	A. M.	I	Tr. In.
	7	37	"	I	Sh. In.
	8	38	"	I	Tr. Eg.
	9	50	"	I	Sh Eg.
	12	54	P. M.	II	Tr. In.
	3	18	"	II	Sh. In.
	3	19	"	II	Tr. Eg.
	5	41	"	II	*Sh. Eg.
14	3	45	A. M.	I	Oc. Dis.
	7	08	"	I	Ec. Re.
15	12	54	"	I	Tr. In.
	2	05	"	I	Sh. In.
	3	08	"	I	Tr. Eg.
	4	19	"	I	Sh. Eg.
	7	07	"	II	Oc. Dis.
	9	32	"	II	Oc. Re.
	9	32	"	II	Ec. Dis.
	11	49	"	II	Ec. Re.
	8	41	P. M.	III	*Tr. In.
	10	15	"	I	Oc. Dis.
	10	51	"	III	Tr. Eg.
	1	30	A. M.	III	Sh. In.
16	1	37	"	I	Ec. Re.
	3	32	"	III	Sh. Eg.
	7	24	P. M.	I	*Tr. In.
	8	34	"	I	*Sh. In.
	9	38	"	I	*Tr. Eg.
	10	48	"	I	Sh. Eg.
17	2	16	A. M.	II	Tr. In.
	4	36	"	II	Sh. In.
	4	42	"	II	Tr. Eg.
	7	00	"	II	Sh. Eg.
	4	45	P. M.	I	Oc. Dis.
	8	06	"	I	*Ec. Re.
18	1	51	"	I	Tr. In.
	3	03	"	I	Sh. In.
	4	08	"	I	Tr. Eg.
	5	16	"	I	Sh. Eg.
	8	29	"	II	*Oc. Dis.
19	1	07	A. M.	II	Ec. Re.
	10	42	"	III	Oc. Dis.
	11	15	"	I	Oc. Dis.
	12	53	P. M.	III	Oc. Re.
	2	35	"	I	Ec. Re.

Mar. [illegible]	[illegible]	"	[illegible]	[illegible]
	[illegible]	"	[illegible]	[illegible] Re.
2[illegible]	[illegible] A. M.		[illegible]	[illegible] In.
	[illegible]	"	[illegible]	Sh. In.
	[illegible]	"	[illegible]	[illegible] Eg.
	[illegible]	"	[illegible]	Sh. Eg.
	[illegible] P. M.		[illegible]	[illegible] In.
	[illegible]	"	[illegible]	*Sh. In.
	[illegible]	"	[illegible]	*[illegible] Eg.
	[illegible]	"	[illegible]	*Sh. Eg.
2[illegible]	[illegible] A. M.		[illegible]	[illegible]
	[illegible]	"	[illegible]	[illegible] Re.
2[illegible]	2 [illegible]	"	[illegible]	[illegible] In.
	[illegible]	"	[illegible]	Sh. In.
	[illegible]	"	[illegible]	[illegible] Eg.
	[illegible]	"	[illegible]	Sh. Eg.
	[illegible]	"	[illegible]	[illegible]
	2 [illegible] P. M.		[illegible]	[illegible] Re.
2[illegible]	12 [illegible] A. M.		[illegible]	[illegible]
	12 [illegible]	"	[illegible]	[illegible] In.
	[illegible]	"	[illegible]	[illegible] Eg.
	[illegible]	"	I	[illegible] Re.
	[illegible]	"	[illegible]	Sh. In.
	7 [illegible]	"	[illegible]	Sh. Eg.
	[illegible] P. M.		I	[illegible] In.
	10 [illegible]	"	I	Sh. In.
	11 [illegible]	"	I	Tr. Eg.
24	12 4[illegible] A. M.		I	Sh. Eg.
	[illegible]	"	II	Tr. In.
	7 14	"	II	Sh. In.
	7 2[illegible]	"	II	Tr. Eg.
	[illegible]	"	II	Sh. Eg.
	[illegible] 4[illegible] P. M.		I	*Oc. Dis.
	10 [illegible]	"	I	Ec. Re.
2[illegible]	[illegible]	"	I	Tr. In.
	4 [illegible]	"	I	Sh. In.
	[illegible]	"	I	*Tr. Eg.
	7 12	"	I	*Sh. Eg.
	11 14	"	II	Oc. Dis.
Mar. 2[illegible]	3 44 A. M.		[illegible]	[illegible] Re.
	[illegible] P. M.		[illegible]	[illegible] Dis.
	3 1[illegible]	"	[illegible]	[illegible] Dis.
	4 31	"	[illegible]	[illegible] Re.
	[illegible]	"	[illegible]	[illegible] Re.
	[illegible]	"	[illegible]	*[illegible] Dis.
	[illegible]	"	[illegible]	[illegible] Re.
2[illegible]	[illegible] A. M.		[illegible]	[illegible] In.
	[illegible]	"	[illegible]	Sh. In.
	[illegible] P. M.		[illegible]	[illegible] Eg.
	[illegible] 41	"	[illegible]	Sh. Eg.
	4 3[illegible]	"	[illegible]	*[illegible] In.
	[illegible]	"	[illegible]	*Sh. In.
	[illegible]	"	[illegible]	*[illegible] Eg.
	[illegible]	"	[illegible]	Sh. Eg.
28	[illegible] 4[illegible] A. M.		I	Oc. Dis.
	[illegible]	"	I	Ec. Re.
29	4 [illegible]	"	I	Tr. In.
	5 [illegible]	"	I	Sh. In.
	[illegible]	"	I	Tr. Eg.
	[illegible]	"	I	Sh. Eg.
	[illegible] 3[illegible] P. M.		II	Oc. Dis.
	5 [illegible]	"	II	Ec. Re.
30	2 [illegible] A. M.		I	Oc. Dis.
	5 [illegible]	"	III	Tr. In.
	5 2[illegible]	"	I	Ec. Re.
	7 3[illegible]	"	III	Tr. Eg.
	9 31	"	III	Sh. In.
	11 35	"	III	Sh. Eg.
	11 24 P. M.		I	Tr. In.
31	12 25 A. M.		I	Sh. In.
	1 38	"	I	Tr. Eg.
	2 35	"	I	Sh. Eg.
	7 50	"	II	Tr. In.
	9 52	"	II	Sh. In.
	10 16	"	II	Tr. Eg.
	12 16 P. M.		II	Sh. Eg.
	8 45	"	I	*Oc. Dis.
	11 57	"	I	Ec. Re.

Note.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc. denotes occultation; Tr., transit of the satellite; Sh., transit of the shadow; * Visible at Washington.

A Partial Eclipse of the Moon will occur on March 21. It will not, however, be visible in the United States except in the extreme western part just as the Moon is setting. It will be visible in Alaska, the Pacific Ocean and Asia. At the middle of the eclipse 0.248 of the Moon's diameter will be obscured. The following are the elements of the eclipse as given by the *American Ephemeris*:

Greenwich mean time of opposition in right ascension March 21, $1^h\ 27^m\ 17^s.1$.

Sun's right ascension	$0^h\ 03^m\ 24^s.38$	Hourly motion	$9^s.10$
Moon's right ascension	12 03 24 .38	Hourly motion	120 .73
Sun's declination	$0°\ 22'\ 10''.1$N	Hourly motion	$0'\ 59''.2$N
Moon's declination	0 36 09 .5N	Hourly motion	16 29 .3S
Sun's equa. hor. parallax	8 .6	Sun's semi-diameter	16 02 .9
Moon's equa. hor. parallax	58 10 .5	Moon's " "	15 50 .4

TIMES OF THE PHASES:

	Gr. Mean Time. h m	Central Time. h m	Pacific Time. h m
Moon enters penumbra	March 21, 11 57.4 A. M.	5 57.4 A. M.	3 57.4 A. M.
Moon enters shadow	1 25.3 P. M.	7 25.3 "	5 25.3 "
Middle of the eclipse	2 20.6 "	8 20.6 "	6 20.6 "
Moon leaves shadow	3 15.7 "	9 15.7 "	7 15.7 "
Moon leaves penumbra	4 43.7 "	10 43.7 "	8 43.7 "

Elongations of the Satellites of Saturn.

[In the diagram the points marked 0 are those of eastern elongation of the several satellites. Their positions at intervals of one day after eastern elongation are indicated by the symbols 1*d*, 2*d*, etc.]

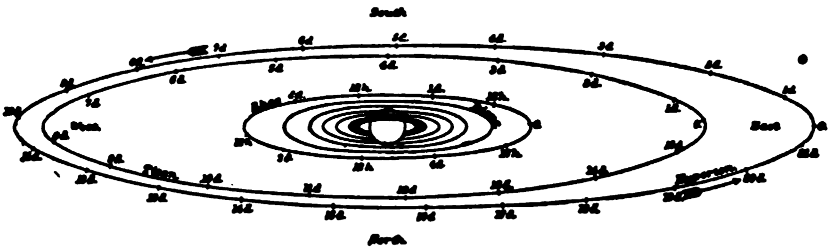


DIAGRAM OF THE APPARENT ORBITS OF SATURN'S SATELLITES.

MIMAS.

		h		
Mar.	2	3.2	A. M.	E
	3	1.8	"	E
	4	12.4	"	E
	4	11.0	P. M.	E
	9	4.8	A. M.	W
	10	3.4	"	W
	11	2.0	"	W
	12	12.6	"	W
	12	11.3	P. M.	W
	18	3.6	A. M.	E
	19	2.3	"	E
	20	12.9	"	E
	20	11.5	P. M.	E
	21	10.1	"	E
	26	3.8	A. M.	W
	27	2.5	"	W
	28	1.1	"	W
	28	11.7	P. M.	W
	29	16.3	"	W

ENCELADUS.

Mar.	1	12.0	midn.	E
	3	8.9	A. M.	E
	4	5.8	P. M.	E
	6	2.7	A. M.	E
	7	11.5	"	E
	8	8.4	P. M.	E
	10	5.3	A. M.	E
	11	2.2	P. M.	E
	12	11.1	"	E
	14	7.9	A. M.	E
	15	4.8	P. M.	E
	17	1.7	A. M.	E
	18	10.6	"	E
	19	7.5	P. M.	E

ENCELADUS CONT.

		h		
Mar.	21	4.3	A. M.	E
	22	1.2	P. M.	E
	23	10.1	"	E
	25	7.0	A. M.	E
	26	3.9	P. M.	E
	28	12.7	A. M.	E
	29	9.6	"	E
	30	6.5	P. M.	E
Apr.	1	3.4	A. M.	E

TETHYS.

Mar.	2	11.9	A. M.	E
	4	9.2	"	E
	6	6.5	"	E
	8	3.8	"	E
	10	1.1	"	E
	11	10.4	P. M.	E
	13	7.7	"	E
	15	5.0	"	E
	17	2.3	"	E
	19	11.6	A. M.	E
	21	8.9	"	E
	23	6.2	"	E
	25	3.5	"	E
	27	12.8	"	E
	28	10.1	P. M.	E
	30	7.4	"	E

DIONE.

Mar.	3	5.5	P. M.	E
	6	11.2	A. M.	E
	9	4.8	"	E
	11	10.5	P. M.	E
	14	4.2	"	E
	17	9.9	A. M.	E
	20	3.5	A. M.	E

DIONE CONT.

		h		
Mar.	22	9.2	P. M.	E
	25	2.9	"	E
	28	8.6	A. M.	E
	31	2.2	"	E

RHEA.

Mar.	2	9 9	A. M.	E
	6	10.3	P. M.	E
	11	10.7	A. M.	E
	15	11.1	P. M.	E
	20	11.5	A. M.	E
	24	11.8	P. M.	E
	29	12.2	"	E

TITAN.

Mar.	4	12.9	P. M.	W
	8	2.8	"	S
	12	9.9	A. M.	E
	16	7 4	"	I
	20	10.9	"	W
	24	12.9	P. M.	S
	28	7.9	A. M.	E
Apr.	1	5.4	"	I

HYPERION.

Mar.	5	6.7	P. M.	S
	10	10.7	"	E
	17	7.3	A. M.	I
	22	2.5	P. M.	W
	26	11.8	"	S
Apr.	1	4.0	A. M.	E

IAPETUS.

Feb.	28	1.0	A. M	W
Mar.	19	9.9	P. M.	S
Apr.	9	9.0	A. M.	E

Occultations Visible at Washington.

Date 1894.		Star's Name.	Magnitude.	IMMERSION Washington M. T.	Angle f'm N pt.	EMERSION Washington M. T.	Angle f'm N pt.	Duration.
				h m	°	h m	°	h m
Mar.	16	λ Cancri	6	14 47	62	15 20	340	0 33
	18	37 Leonis	6	15 49	57	16 14	1	0 25
	20	β Virginis	4	10 52	173	11 49	269	0 57

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time]

U CEPHEI.

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

Mar.	3	7 A. M.
	5	7 P. M.
	8	6 A. M.
	10	6 P. M.
	13	6 A. M.
	15	6 P. M.
	18	6 A. M.
	20	5 P. M.
	23	5 A. M.
	25	5 P. M.
	28	5 A. M.

ALGOL.

R. A................$3^h\ 1^m\ 1^s$
Decl................$+40°\ 32'$
Period............$2d\ 20^h 49^m$

Mar.	6	4 A. M.
	9	1 "
	11	10 P. M.
	14	7 "
	17	3 "
	20	12 noon
	23	9 A. M.
	26	6 "
	29	3 "

λ TAURI.

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

Mar.	1	3 P. M.
	5	2 "
	9	1 "
	13	noon
	17	11 A. M.
	21	9 "
	25	8 "
	29	7 "

R CANIS MAJORIS.

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

Mar.	1	10 P. M.
	3	1 A. M.
	4	5 "
	5	8 "
	6	11 "
	7	2 P. M.
	8	6 "
	9	9 "
	10	12 midn.
	12	3 A. M.
	13	7 "
	14	10 "
	15	1 P. M.
	16	4 "
	17	8 "
	18	11 "

R CANIS MAJ., CONT.

20	2 A. M.
21	5 "
22	9 "
23	12 noon.
24	3 P. M.
25	7 "
26	10 "
28	1 A. M.
29	4 "
30	8 "
31	11 "

S CANCRI.

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

Mar.	6	1 P. M.
	16	1 A. M.
	25	1 P. M.

S ANTLIÆ.

R. A.............. $9^h\ 27^m\ 30^s$
Decl...............$-28°\ 09'$
Period........... $0d\ 7^h\ 47^m$

Mar.	1	5 P. M.
	2	12 midn.
	3	11 P. M.
	4	11 "
	5	10 "
	6	9 "
	7	9 "
	8	8 "
	9	7 "
	10	7 "
	11	6 "
	12	5 "
	13	12 midn.
	14	12 "
	15	11 P. M
	16	11 "
	17	10 "
	18	9 "
	19	9 "
	20	8 "
	21	7 "
	22	7 "
	23	6 "
	24	5 "
	25	5 "
	26	12 midn.
	27	11 P. M.
	28	11 "
	29	10 "
	30	9 "
	31	9 "

δ LIBRÆ.

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

Mar.	1	5 A. M.
	3	1 P. M.
	5	9 "
	8	5 A. M.
	10	1 P. M.
	12	9 "
	15	5 A. M.
	17	12 noon
	19	8 P. M
	22	4 A. M.
	24	12 noon
	26	8 P. M.
	29	4 A. M.
	31	11 "

U CORONÆ.

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

Mar.	4	1 A. M.
	7	12 noon
	10	11 P. M.
	14	10 A. M.
	17	9 P. M.
	21	7 A. M.
	24	6 P. M.
	28	5 A. M.

U OPHIUCHI.

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

Mar.	1	2 A. M.
	2	10 P. M.
	3	6 "
	4	2 "
	5	10 A. M.
	6	6 "
	7	2 "
	7	11 P. M.
	8	7 "
	9	3 "
	10	11 A. M.
	11	7 "
	12	3 "
	12	11 P. M.
	13	8 "
	14	4 "
	15	12 noon
	16	8 A. M.
	17	4 "
	17	12 midn.
	18	8 P. M.
	19	4 "
	20	1 "
	21	9 A. M.
	22	5 "
	23	1 "

U OPHIUCHI CONT.	
Mar. 23	9 P. M.
24	5 "
25	1 "
26	9 A. M.
27	6 "
28	2 "
28	10 P. M.
29	6 "
30	2 "
31	10 A. M.

Y CYGNI.

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

Mar. 2	2 P. M.
4	2 A. M.
5	2 P. M.
7	2 A. M.
8	2 P. M.
10	2 A. M.
11	2 P. M
13	2 A. M.
14	2 P. M.

Y CYGNI CONT.	
Mar. 16	2 A. M.
17	2 P. M.
19	2 A. M.
20	2 P. M.
22	2 A. M.
23	2 P. M.
25	2 A. M.
26	2 P. M.
28	1 A. M.
29	1 P. M.
31	1 A. M.

Test Objects for Small Telescopes.

[From Clark and Sadler's "Star Guide."]

Name of Objects.	R. A. h	m	Decl. °	′	Distance ″	Position Angle. °	Magnitudes.		Aperture of telescope
				DIVIDING TESTS.					
14 Orionis...........	5	02	+ 8	20	1.15	203	5.8	6.0	4
4 Lyncis..............	6	12	+ 59	25	0.95	101	6.2	7.5	5
Σ 1333.................	9	11	+ 35	56	1.69	42	6.7	7.0	3
OΣ 229................	10	42	+ 41	42	0.84	330	6.5	7.5	6
Σ 1606.................	12	05	+ 40	32	1.21	338	6.2	7.0	4
Cor. Bor. I.........	15	14	+ 27	15	1.22	308	5.6	6.1	4
μ^2 Boötis............	15	20	+ 37	47	{ 0.78	104	6.5	7.8 }	6
					{ 108.4	172	4.5	}	
λ Ophiuchi..........	16	25	+ 2	14	1.65	44	4.4	5.4	3
OΣ 313................	16	29	+ 40	21	0.99	152	7.0	7.6	5
Cephei 83......	20	59	+ 56	13	1.62	349	6.4	6.8	3
				DEFINING TESTS.					
ψ^2 Orionis...........	5	21	+ 2	59	2.66	324	5.4	9.0	4
42 Orionis...........	5	30	− 4	55	1.73	218	5.5	9.2	6
κ Leonis	9	18	+ 26	41	{ 3.36	205	5.1	10.1 }	6
					{ 10.	65		11.5 }	
49 Leonis	10	29	+ 9	14	2.39	158	6.2	8.4	3
84 Virginis..........	13	37	+ 4	07	3.56	234	5.7	8.0	3
6 Serpentis..........	15	15	+ 1	08	2.28	13	4.7	9.4	6
η Draconis..........	16	22	+ 61	46	5.26	142	2.8	9.0	4
68 Herculis.........	17	13	+ 33	14	4.41	62	5.1	10.1	5
70 Ophiuchi........	18	00	+ 2	32	2.05	20	4.3	6.2	3
60 Cygni.............	20	57	+ 45	42	2.71	165	5.5	9.5	5
				SPACE-PENETRATING TESTS.					
40 Cassiopeiæ	1	29	+ 72	27	53.3	237	6.0	10.9	5
λ Geminorum ...	7	12	+ 16	45	9.5	33	3.5	9.8	3
θ Cancri.....	8	25	+ 18	29	60.8	60	5.5	10.4	4
δ Cancri.....	8	38	+ 18	37	42	113	5.0	11.8	6
υ Ursæ Maj........	11	12	+ 33	43	7.0	147	3.5	9.6	3
ρ Boötis.............	14	27	+ 30	52	53	334	3.6	11.7	6
5 Ursæ Min.........	14	28	+ 76	12	56.4	129	4.8	10.5	4
5 Serpentis..........	15	13	+ 2	13	10.7	38	4.8	10.0	3
54 Ophiuchi........	17	29	+ 13	15	21.6	75	6.0	11.0	5
110 Herculis........	18	41	+ 20	26	{ 61.2	96	5.0	12.0 }	6
					{ 44.7	92		11.0 }	

Meteor.—On the evening of December 30th, a meteor of unusual interest was observed by two Des Moines men. It was first seen a little west of south, at an altitude of about 35°. It appeared to move slightly east of north, and stopped in the northwest, at a somewhat lower altitude than it started. The first appearance was of a bright silvery hue, resembling a streak of lightning. The luminous train remained visible while they walked more than three blocks—fully five minutes.

W. A. C.

Comparison Stars for Variables of Long Period.*

S Boötis.

Des.	R. A. 1900 h	m	Dec. 1900 °	'	Mag.
a	14	18.6	+ 53	59	7
b	14	24.0	+ 53	45	8
c	14	22.3	+ 54	10	8
d	14	12.4	+ 53	56	9
e	14	21.5	+ 53	32	9
f	14	21.0	+ 53	55	10
g	14	19.8	+ 54	1	10
h	14	18.9	+ 54	21	11
k	14	22.4	+ 54	17	11
l	14	21.7	+ 54	13	12
m	14	19.4	+ 54	20	12
n	14	19.8	+ 54	11	12
o	14	19.3	+ 54	19	13
p	14	19.3	+ 54	23	14
q	14	19.1	+ 54	18	14
r	14	19.5	+ 54	10	14
s	14	19.9	+ 54	17	15
S	14	19.5	+ 54	16	var.

R Camelopardi.

Des.	R. A. 1900 h	m	Dec. 1900 °	'	Mag.
a	15	1.6	+ 84	20	8
b	14	21.4	+ 84	24	8
c	14	32.3	+ 84	10	9
d	14	46.8	+ 84	17	9
e	14	31.2	+ 84	34	10
f	14	45.8	+ 84	14	10
g	14	30.8	+ 84	15	11
h	14	28.8	+ 84	23	11
k	14	17.8	+ 84	29	12
l	14	31.3	+ 84	21	12
m	14	22.5	+ 84	16	13
n	14	13.3	+ 84	12	13
o	14	18.8	+ 84	17	14
p	14	24.2	+ 84	11	14
q	14	26.5	+ 84	12	14
r	14	26.6	+ 84	14	15
R	14	24.9	+ 84	17	var.

R Ursæ Minoris.

Des.	R. A. 1900 h	m	Dec. 1900 °	'	Mag.
a	16	31.3	+ 73	9	8
b	16	35.2	+ 72	11	8
c	16	34.8	+ 73	9	9
d	16	33.6	+ 72	44	9
e	16	33.2	+ 72	40	10
f	16	28.7	+ 73	1	10
g	16	34.9	+ 72	46	10
h	16	33.6	+ 72	22	11
k	16	34.9	+ 72	20	11
l	16	31.0	+ 72	14	12
R	16	31.3	+ 72	29	var.

R Draconis.

Des.	R. A. 1900 h	m	Dec. 1900 °	'	Mag.
a	16	28.1	+ 67	16	7
b	16	34.0	+ 68	13	7
c	16	25.0	+ 67	16	7
d	16	42.9	+ 68	17	8
e	16	40.8	+ 67	9	8
f	16	33.2	+ 66	55	8

R Draconis Cont.

Des.	R. A. 1900 h	m	Dec 1900 °	'	Mag.
g	16	30.2	+ 67	34	1
h	16	29.6	+ 67	1	9
k	16	31.0	+ 66	56	09
l	16	29.9	+ 67	27	10
m	16	31.4	+ 67	6	10
n	16	32.8	+ 66	49	11
o	16	32.4	+ 66	48	12
p	16	34.2	+ 66	59	12
q	16	32.6	+ 66	55	12
r	16	33.5	+ 66	57	12
s	16	33.3	+ 66	50	13
t	16	34.2	+ 67	1	14
u	16	32.6	+ 66	56	14
w	16	32.6	+ 66	59	14
x	16	32.6	+ 67	0	15
R	16	32.4	+ 66	58	var.

S Cygni.

Des.	R. A. 1900 h	m	Dec 1900 °	'	Mag.
a	20	2.6	+ 57	20	8
b	20	7.0	+ 58	2	8
c	20	1.4	+ 57	32	9
d	20	3.5	+ 57	43	9
e	20	2.3	+ 57	44	10
f	20	3.0	+ 57	40	10
g	20	4.3	+ 57	37	10
h	20	3.6	+ 57	32	11
k	20	3.8	+ 57	36	11
l	20	3.6	+ 57	40	11
m	20	3.5	+ 57	48	12
n	20	3.6	+ 57	49	13
o	20	3.6	+ 57	45	13
p	20	3.5	+ 57	39	14
q	20	2.8	+ 57	47	14
r	20	3.6	+ 57	43	14
s	20	3.8	+ 57	41	15
t	20	3.6	+ 57	43	15
S	20	3.4	+ 57	42	var.

T Cephei.

Des.	R. A. 1900 h	m	Dec 1900 °	'	Mag.
a	21	40.5	+ 70	50	5
b	20	41.9	+ 66	18	6
c	21	5.8	+ 71	2	6
d	21	0.4	+ 67	51	7
e	21	0.4	+ 67	47	7
f	21	14.3	+ 67	56	8
g	21	11.9	+ 67	44	8
h	21	6.1	+ 68	12	8
k	21	3.7	+ 67	35	9
l	21	5.7	+ 68	15	9
m	21	10.0	+ 68	1	10
n	21	9.1	+ 68	8	10
o	21	6.6	+ 68	8	10
p	21	7.2	+ 68	4	10
q	21	7.6	+ 68	12	11
r	21	6.4	+ 68	2	12
s	21	10.7	+ 68	12	12
t	21	9.7	+ 68	14	12
T	21	8.2	+ 68	5	var.

* See Plate accompanying Mr. Parkhurst's article on Variable Stars.

S Cephei.

Des.	R. A. 1900 h	m	Dec. 1900 °	′	Mag.
a	21	29.9	+77	30	7
b	21	50.9	+77	18	8
c	21	47.1	+78	34	8
d	21	52.7	+77	52	9
e	21	37.8	+78	37	9
f	21	28.7	+78	53	9
g	21	34.3	+78	1	10
h	21	34.3	+78	11	10
k	21	40.7	+78	11	10
l	21	42.2	+78	13	11
m	21	36.2	+78	4	12
n	21	39.1	+78	13	12
o	21	35.0	+78	8	12
p	21	37.5	+78	14	13
q	21	38.8	+78	4	14
r	21	37.8	+78	11	14
s	21	37.4	+78	10	14
t	21	37.7	+78	10	15
S	21	36.5	+78	10	var.

R Cassiopeiæ.

Des.	R. A. 1900 h	m	Dec. 1900 °	′	Mag.
a	23	32.6	+45	56	4
b	23	35.5	+43	46	4
c	23	53.9	+55	12	5

R Cassiopeiæ Cont.

Des.	R. A. 1900 h	m	Dec. 1900 °	′	Mag.
d	0	5.1	+45	31	5
e	23	52.1	+55	9	6
f	23	56.3	+49	25	6
g	23	53.1	+49	53	7
h	23	54.5	+50	17	7
k	23	54.2	+49	58	8
l	23	54.3	+49	57	8
m	23	53.9	+51	16	9
n	23	53.5	+50	46	9
o	23	53.0	+50	41	10
p	23	54.1	+50	52	10
q	23	53.8	+50	45	10
r	23	53.3	+50	50	11
s	23	54.1	+50	48	11
t	23	53.1	+50	54	12
u	23	53.5	+50	48	12
w	23	53.2	+50	53	12
x	23	53.7	+50	54	13
y	23	53.4	+50	51	13
z	23	53.3	+50	52	14
α	23	53.4	+50	49	14
β	23	53.2	+50	49	15
R	23	53.3	+50	50	var.

Errata in January number:

Page 236, last line, for H. A. Parkhurst read J. A. Parkhurst. Page 237 for Casiopeiæ read Cassiopeiæ. Page 237, S Cassiopeiæ star c for Decl. 77° 52′ read Decl. 71° 52′. Page 237 S Cassiopeiæ star y for R. A. 1^h 125^m read 1^h 12.5^m. Page 237 3rd line from top for Decl. 1800 read Decl. 1900.

PRACTICAL SUGGESTIONS.

Persons interested in the topics appropriate to this corner are requested to write briefly and frequently for it.

13. Why do Astronomers think that the white spots about the poles of the planet Mars are snow or ice? G. B. D.

Answer: In connection with this question it was noted by the querist that the telescope shows a change in size of these white patches during the seasons of winter and summer on the planet Mars. This is the main reason why it is thought that the patches consist of ice and snow. It might be added that some good observers have seen indications on the surface of the planet that might be explained by supposing that a fall of snow had covered a considerable area. No astronomer would feel himself justified from his observations, or what he knows of the surface of the planet, in assigning snow or ice as the cause of these white spots. Other plausible reasons could be assigned. Some observers have intimated that clouds in the planet's atmosphere might produce the appearance observed. This explanation does not seem as satisfactory as the former one.

14. From appearance in observation the atmosphere on Mars contains less clouds than that of the Earth. If capacity for heat depends on the vapor in the atmosphere, how is it that the temperature of the planet's surface seems so high compared to that of the Earth, notwithstanding its greater distance from the Sun? G. B. D.

Answer: We are not aware that observers are agreed, or generally think, that clouds are less in the atmosphere of Mars than in our own. That would be an impossible thing to determine by observation at the distance of Mars if we remember that our clouds do not run probably much above two miles in height on the average, except, as it might be inferred, that certain changes in color of surface markings are due to the presence of clouds. It is probable that the density of the atmosphere of Mars is less than that of the Earth, the spectroscope also indicates that there is watery vapor in the atmosphere of Mars. From all that is known, or may be fairly inferred by analogy, we would say the temperature of Mars ought to be much lower than that of Earth. But if, appearances are not misleading, water on its surface does not freeze except in the region of the poles. If Earth were viewed from Mars, it is plain that the polar white caps would be much larger than those of Mars are.

Astronomers do not give any reason for this unexpected difference in surface temperature on the planets. There is no known explanation.

15. I believe Goodsell Observatory of Carleton College is one of the oldest, west of the Mississippi. When was it founded? M. W.

Answer: If memory serves us rightly some other Observatories antedate Goodsell Observatory. This observatory was built in the summer of 1877. It began its public time service in October of the same year. The first electrical time signal was sent out at noon October 23, 1877.

16. As Venus has been approaching the Earth and growing brighter with less and less illuminated disc turned towards us ever since the time of superior conjunction with the Sun last June, why are we not to expect the maximum brilliancy at its inferior conjunction (Feb. 16.) instead of about Jan. 10. W. B. H.

Answer: Because after Jan. 10 the decrease of the illuminated portion of the disc will be more rapid than the apparent increase in area, due to the approach of the planet to the earth. If the reader will refer to the diagram on page 228 (January number) he will see that for the last two months Venus has been approaching the earth rapidly and turning the illuminated half away but slowly. During January the rate of approach to the Earth diminished greatly, while the illuminated half of the disc was turned away more and more rapidly.

17. In the planet notes in the December number of POPULAR ASTRONOMY it is said that the brilliancy of Venus on Jan 10. is 218 as compared with 145 on Dec. 1. What do these numbers mean? A. E. R.

Answer: The unit of light for a planet is the amount of light received by an eye from a circular disc with same albedo, or reflecting power, as the planet, subtending an angular radius of one second of are, situated at the Earth's distance from the Sun, and illuminated by the latter as the disc of the planet is illuminated. The light of the planet on Dec. 1. was equal to that from 145 such discs, and that on Jan. 10 to the light from 218 discs thus illuminated. On March 1 the brilliancy of Venus will be 107, and on March 22 it will be 204 on the same scale.

18. If practical will you kindly describe process, through POPULAR ASTRONOMY for photographing celestial bodies with a kodak and visual telescope? S.

Answer: We fear that the lens of a kodak will be too small to be of use in photographing stars. As to the process of using a camera with a visual telescope we can do no better than refer to the article "Astronomy with the Small Camera," by H. C. Wilson in our first number.

19 How may an observer determine longitude on the Sun? S.

Answer: It would take a long article to answer this query, and we have one in course of preparation. For the present we will say that the period of rotation of the Sun, as adopted at Greenwich is 25.38 days. The heliographic longitude of the center of the Sun's disc therefore changes (diminishes) on an average

13° 12′ each day. According to the reckoning usually adopted the longitude of the Sun's center on Jan. 1, 1894, at noon central time, was 280° 20′. On Feb. 1, at noon it will be 232° 07′, Feb. 5, 179° 27′, Feb. 10, 113° 37′, etc. Spots at the center of the Sun's disk on these dates will have the longitudes noted, those west of the center greater, those east less longitudes.

20. (1). Please give a few tests for dividing and penetrating powers of a four inch glass with power 72. (2). Ought it to show any moons of Uranus? (3). How many of Saturn? (4). How many stars ought it to show in the trapezium of Orion? S.

Answer: (1). See table "Test objects for small Telescopes" elsewhere in this number. (2). No. (3). Five; Japetus, Titan, Rhea, Tethys and Dione. (4). Five; possibly the sixth on best nights.

21. What sized prism having an angle of 90° would be required for a spectroscope with ¾-inch lenses? W. J. T.

Answer: A single prism of glass with a refracting angle of 90° will not transmit light. A compound prism, with 90° prism of flint glass and two crown glass prisms of, say, 20° each, would have to measure about 2 inches on the face of the flint glass, or 2.83 inches on the base. A 60° single prism for the same spectroscope should have a face of about 1½ inch. In either case the height, measured along the refracting edge, need not much exceed ¾ inch. Smaller prisms may be used if the loss of a little light is not of much consequence. J. E. K.

GENERAL NOTES.

Jena Discs.—Mr. J. A. Brashear has secured the beautiful 23-inch discs which were exhibited by the Jena Optical Glass makers at the Columbian Exposition, and will proceed to make an objective from them which will be at the command of astronomers desiring such an objective.

We are pleased to call attention to a brief article by Miss Armitage of New York City on the benefits of a public Observatory. The idea is an excellent one. If the great dailies of America's great city would unitedly take hold of this matter, great things worthy of a good cause would speedily follow.

Venus by Daylight.—Mr. W. Dearden of Trinidad, Colorado, writes that Venus is very easily seen as it crosses the meridian of that place.

No new comets have been discovered since October of last year. Brooks comet *c* 1893 is still visible in our 16-inch telescope but is very faint and probably out of the reach of amateurs.

Holmes' comet 1892 III has just past opposition but so far as we know has not been seen. When last seen nearly a year ago it was very faint and diffuse and unless a new outburst like that in January 1893 should occur there will be no hope of seeing it now. On the night of Jan. 12, 1894 we took a photograph of the region in which the comet should be, giving an exposure of an hour with the new 6-inch camera. There is a slightly oval stain, 20′ in diameter, on the negative, just where the comet ought to be. It has no central condensation and is so suspiciously like a dirty water stain that we hesitate to say anything about it without verification, which last is impossible until the Moon is out of the way.

Face of the Sky.—Inasmuch as the appearance of the sky for February is presented in chart form in the present number, it is unnecessary to publish a descriptive article on that subject as has been done in the earlier numbers.

Changes in Tables of Phenomena.—So many of our foreign subscribers have requested that we change the tables of phenomena so as to include their localities that we have this month tried to give all of those phenomena whose times of occurrence are absolute, that is, independent of the position of the observer.

It would be manifestly impossible to give the Central Standard times or Greenwich times of the rising and setting of the planets for all places, since these depend upon the horizon of the observer. Our tables give the local (not Standard) times of rising and setting for Goodsell Observatory, latitude 44° 27'.7, and will answer practically for all places within 10° of the same latitude. The reader has simply to apply the difference between local and standard time at his own place adding this difference if west, substracting if east of the standard meridian, the time of which is used.

The times of occultations cannot be given except for very small districts, the parallax of the Moon being so great that a change of only a few miles will materially change the times of beginning and ending. The data for computing the times of occultations are given in any of the national nautical almanacs. Those who wish to make a specialty of observing occultations will do well to get one of these almanacs, the *American Ephemeris*, the *Nautical Almanac*, *Connaissance de Temps*, *Berliner Jahrbuch*, *Annuaire de Bruxelles*, etc.

All the other phenomena we will give in Central Standard time of the United States which is just 6 hours less than Greenwich time. In the United States the reader has to add or substract one or two hours, according as he uses Eastern, Mountain or Western time. Foreign readers will add 6 hours to obtain Greenwich time, then subtract their longitude if reckoned west, add if reckoned east from Greenwich.

Gold Medal for Professor Burnham.—Cablegrams from London announce the award of the Gold Medal of the Royal Astronomical Society to Professor S. W. Burnham of the University of Chicago for his discoveries and micrometrical measures of double stars and for his researches on the orbital motions of Binary Systems. This news is especially welcome to American astronomers, and will be favorably received throughout the scientific world, for no observer either living or dead has contributed more to this important branch of modern astronomy than has Professor Burnham, whose discoveries of new and very close pairs have created an epoch in the history of Double Star Astronomy. The discovery of double stars, begun by Sir William Herschel more than a century ago, and since continued by William and Otto Struve, Herschel and Mædler, Dawes and Dembowski, was regarded twenty-five years ago as practically exhausted. But the genius of Burnham working with only a six-inch telescope soon brought to light hundreds of close pairs never before detected, and opened the way to later discoveries of priceless value. Professor Burnham afterwards secured for a time the use of the Dearborn 18-inch refractor, and the Madison 15-inch, and thus extended the list of measures and new discoveries. His work at the Lick Observatory is too recent to need recalling to the readers of this Journal, but it may not be inappropriate to remark that his own stars now number nearly 1300, and include the most rapid and interesting pairs in the heavens.

It is understood that these stars will be made the object of special attention at the Yerkes Observatory, and that they will be carefully followed until their orbits are accurately known. Professor Burnham's catalogue of his new stars and his general catalogue of all the important stars in the northern hemisphere are to be printed among the first volumes issued by the Yerkes Observatory, and will constitute works on Double Star Astronomy which are destined to be "aere perennius."

The high honor conferred upon Professor Burnham is a tribute to pure science which will be fully appreciated by all American astronomers, but it is especially gratifying to the intimate friends of this modest, unselfish and renowned observer.

Other American astronomers who have received this Medal of recent years are:—Professor Simon Newcomb, Professor Asaph Hall, Dr. B. A. Gould, Professor E. C. Pickering, and Dr. G. W. Hill. Last year the Gold Medal was awarded to Dr. H. C. Vogel, and the preceding year to Professor G. H. Darwin.

A Public Observatory for Boston.—The Boston *Transcript*, Jan. 10, gives an account of a meeting of the Boston Scientific Society which has just been discussing the advisability of building a public Observatory. Mr. J. Ritchie favors it. So also P. S. Yendell, E. F. Sawyer, and A. Lawrence Rotch, who briefly noted the present status of "Urania" in Berlin.

Dr. S. C. Chandler presented a paper, the line of argument being that an institution of that nature would have its value as a scientific missionary feature. An important consideration is the encouragement and stimulation of beginners, who have not at the present time the opportunity to enter the domain of astronomy.

In his opinion, if this object could be accomplished, it would be the noblest outcome of such an institution. The astronomer has a distinct duty towards the informed, intelligent citizens, whose sole means of getting proper ideas lie in popular lectures and statements, who should not be misled by information from those institutions or lecturers, where popular reputation is unworthily valued above the esteem of scientific men and real value in work. Dr. Chandler expressed it as his opinion that in competent hands, with a moderate expenditure, not only could the public taste in this department be appeased, but the science of astronomy could be advanced in a way which is very much needed, for the astronomy of this country is peculiar.

Properly organized and administered, it would be a lasting credit to this community. That it could be so organized and economically administered, if it had a moderate endownment, he thought there could be no reasonable doubt, and no more worthy way in which a popular want could be met and science benefited than by a financial provision for its needs, small indeed when compared with the amounts frequently lavished in other directions for the encouragement of science and the arts in our native city.

Remarkable Sun Spots.—Mr. Martin Winger of Brooklyn Village, Ohio, has given us the following list of remarkable sun spots.

Jan. 21st, 1892, Visible with naked eye.
Feb. 5th, 1892, " " " "
Feb. 10th, 1892, " " " "
Jan. 21st, 1893, Visible in opera-glass.
Feb. 5th, 1893, " " "
Feb. 25th, 1893, " " "
Aug. 9th, cluster of spots plainly seen with naked eye.

Also, Aug. 19th and 30th, Sept. 3rd, 4th, 6th and 28th. Oct. 12th to 19th large spots were observed with 4½-inch Clark telescope. Oct. 24th and 25th spots visible with naked eye. Dec. 7th and 8th spots plainly seen with field-glass.

Jupiter's Satellites in 1664.

I have brought to the notice of three astronomers an interesting letter of John Winthrop (the second of that name), written in 1664 to Sir Robert Moray, in which Winthrop declares that, "having looked upon Jupiter with a telescope," August 6, 1663 (old style), he "saw five satellites very distinctly about that planet." He reports the observation with natural distrust, lest it should be "a mistaken novelty." As the letter (which is printed in the Proceedings of the Massachusetts Historical Society for June, 1878, p. 220) had never been noticed by the three astronomers above mentioned, I make the following extract from it for the entertainment of other scientific antiquaries among your readers. If any one knows what has become of Winthrop's astronomical "tube," perhaps he will inform you.—Yours respectfully, D. C. GILMAN.

JOHN HOPKINS UNIVERSITY,
Baltimore, Md, December 22, 1893.

JOHN WINTHROP TO SIR ROBERT MORAY.

HARTFORD, Jan: 27, 1664.

In my former I gave your honor an account of the favor I had of your letter by the Hon. Colonell Richard Nicolls. I then omitted to acquaint your honor what now I will be bold to add: that havinge looked upon Jupiter with a Telescope, upon the 6th of August last, I saw 5 (?) Satellites very distinctly about that Planet: I observed it with the best curiosity I could, taking very distinct notice of the number of them, by severall aspects with some convenient tyme of intermission; & though I was not with out some consideration whether that fifth might not be some fixt starr with which Jupiter might at that tyme be in neare conjunction, yet that consideration made me the more carefully to take notice whether I could discerne any such difference of one of them from the other foure, that might by the more twinckling light of it or any other appearance give ground to believe that it might be a fixed starr, but I could discerne nothing of that nature: and I consider that the tube with which I looked upon them, though so good as to shew very clearely the Satellytes, yet was but of 3 foote and halfe with a concave ey-glasse; and I question whether by a farre better tube a fixt star can be discerned so near the body of that planet when in the ever bright activity of its light, for if so, why are there not often if not alwayes seene with the best tubes the like or more. Is not Jupiter often in neere conjunction with them, especially *in via lactea*?

I have been in much doubt whether I should mention this, which would possibly be taken from a single affirmation but a mistaken novelty; but I thought I would rather beare such sensure than omit the notice of it to such worthy friends as might from the hint of it take occasion to cause more frequent observations to be made upon that planet, & at least this will at length be cleared, whether the light of Jupiter doth not take away the appearance of fixed starrs so neere in conjunction with it, as that they should appear within the periphery of that single *intuitus* by a tube which taketh in the body of Jupiter and that at the same unmoved aspect: and I am bold the rather to mention this as an inquiry whether any such number of Satellites or Moons hath beene seene by your honor or Mr. Rooke or any mathematitians or other gentlemen that have good tubes and often have the curiosity to view the planet, for possibly it may be new to me which hath beene more usually knowne by others, though the notion of such a thinge is not new to my selfe, for I remember I mett with the like narration many years since in a little booke intituled Philosophia Naturalis per Joh. Phociliden, though then I thought that was but a mistake of some fixed starrs."—*Nation*, Jan. 11, 1894.

Yerkes Telescope.—Special attention is called to the plate accompanying Mr. Brashear's article. It is of general interest in that it shows the evolution of a telescope lens, and of special interest as it is the great lens known and talked of the world over.

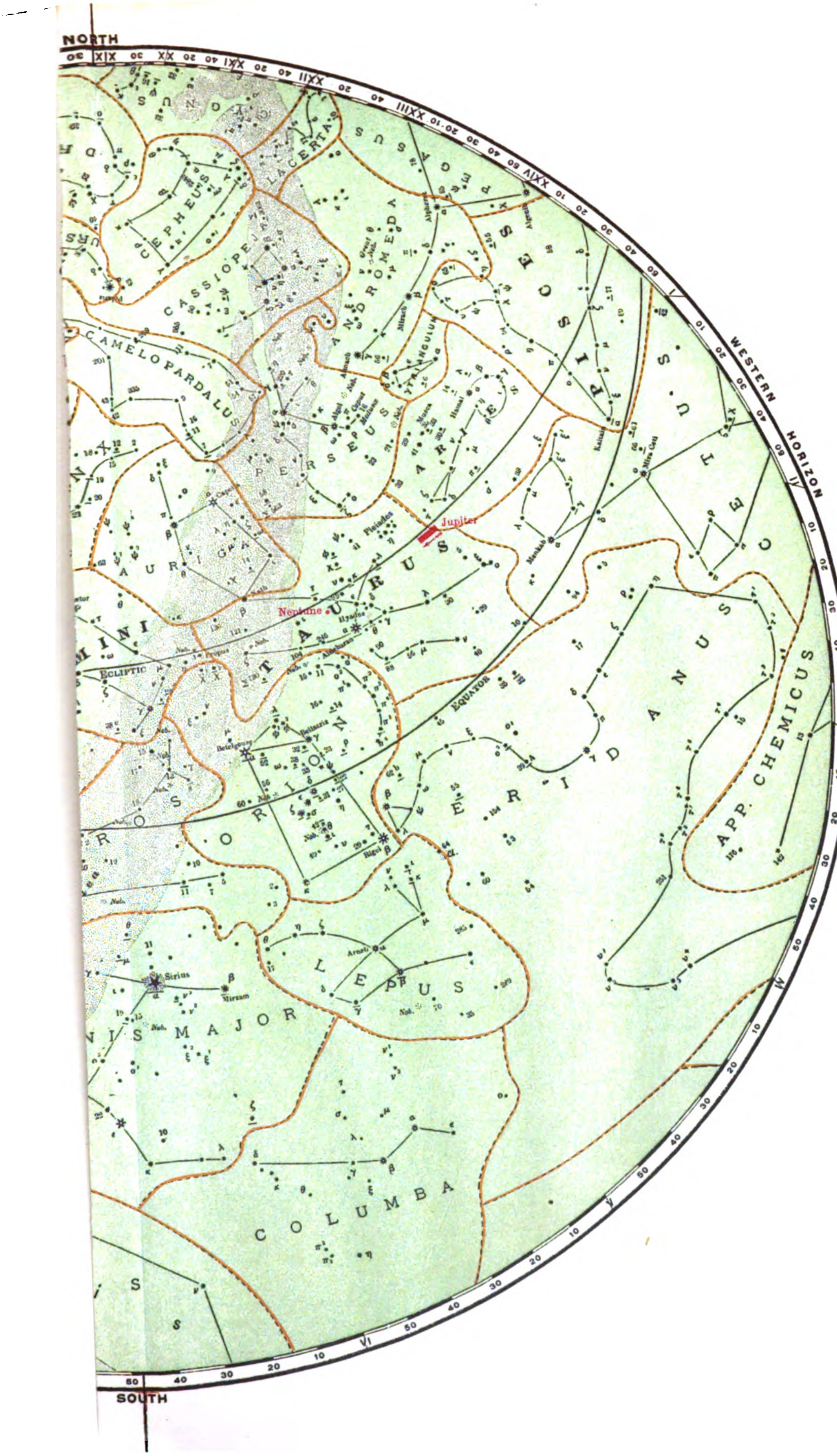
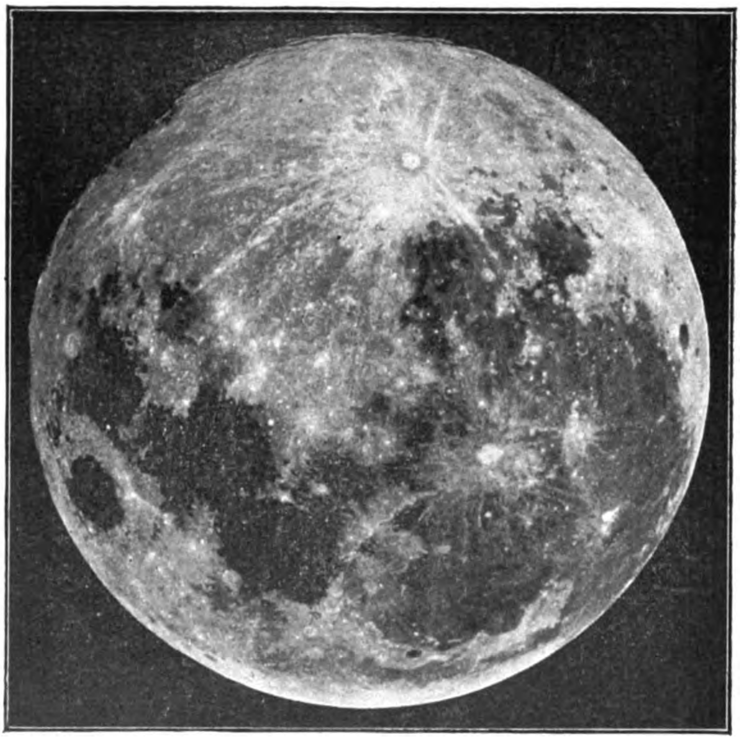

NORTH
WESTERN HORIZON
SOUTH
CEPHEUS
LACERTA
PEGASUS
CASSIOPEIA
ANDROMEDA
CAMELOPARDALUS
TRIANGULUM
PERSEUS
ARIES
PISCES
CETUS
AURIGA
Jupiter
Pleiades
TAURUS
Neptune
Hyades
Aldebaran
Capella
ECLIPTIC
EQUATOR
ERIDANUS
APP. CHEMICUS
ORION
Betelgeuse
Bellatrix
Rigel
LEPUS
Arneb
Sirius
Mirzam
CANIS MAJOR
COLUMBA
Mira Ceti
Menkab
Algol
Hamal
Mirach
Alpheratz

PLATE XVI.



PHOTOGRAPH OF THE FULL MOON,

TAKEN BY A. G. SIVASLIAN, WITH THE 8-INCH EQUATORIAL OF GOODSELL OBSERVATORY, 1893, DEC. 22, 10^h 18^m CENTRAL TIME.

Enlarged in the Telescope about 3¼ Diameters. Exposure, ½ Second.

POPULAR ASTRONOMY, March, 1894.

Popular Astronomy.

Vol. I. MARCH, 1894. No. 7

THE MOON. II.

WM. W. PAYNE.

In the September number of this journal, page 18, reference is made to the advancement of Astronomy during the time of Aristarchus, Hipparchus and Ptolemy. So much interest attaches to the period in which these men lived and worked, that more ought to be said about them before we go on with the later studies of the Moon, although all that we shall notice is matter of history within the reach doubtless of many of our readers.

Aristarchus* of Samos (320–250 B. C.) was a member of the Alexandrian school of Greek philosphy in which ancient astronomy made great advancement. Progress at this time was largely due to the use of superior instruments and to systematic work in observation. He was the first astronomer of marked ability in this school, and his recognition, as such, chiefly grew out of the fact that he first proposed the heliocentric theory (Sun at the center) of the solar system, similar to that taught by Copernicus later, although the new theory was not accepted by astronomers at this time. He also determined the distances of the Sun and Moon from the Earth by very ingenious methods. He found the distance of the Moon to be fifty six times that of the radius of the Earth, and that of the Sun *nineteen* times as great as that of the Moon from the Earth. By his measures the diameter of the Moon was 2°, and the Sun's parallax was 3 minutes of arc in value. We now know that the Moon's distance from us is about 60 times the Earth's radius, that the distance of the Sun is about 390 times that of the Moon, that the Sun's parallax is 8.8 seconds of arc nearly, and that the angular diameter of the Moon is 31′. In first reading we wonder at these great errors of value in almost every instance given above, and ask ourselves if such work was the best that astronomers of this period could do. These instances fairly indicate the degree of precision which astronomy had reached in obtaining fundamental data for the science in these times. It can now be said that Aristarchus, in obtaining the above erroneous results, was right in principle and

* Neison's, *The Moon*, page 82.

method. He was correct in principle and even ingenious in method. He failed to get better results because his appliances were rough and unequal to the delicacy of measure required. Considering the nature of his instruments the values obtained by his observations were the best and the most delicate that could be certainly expected. Although his solar parallax was 20 times as large as it should be, no one could then improve it, and it was adopted by Ptolemy and thought to be the correct value for twenty centuries afterwards.

Erastosthenes (276–196 B. C.) took up the work and tried to obtain the size of the Earth by observing the difference of zenith distance of the Sun at two different places. He made the radius of the Earth 5000 miles, the distance of the Moon 98,000 miles and the distance of the Sun 100,000,000 of miles.

Hipparchus (190–120 B. C.), however, was the ablest observational astronomer of this period. He discovered the elliptical nature of the Moon's orbit, found its inclination to the Earth's path to be 5°, determined the period of the revolution of the Moon's nodes to be 18⅝ years, by parallax found the Moon's distance to be 59 radii of the Earth and the diameter of the Moon as 31′, an exact determination.

For a period of a hundred years the work just mentioned is unexpectedly far in advance of that described earlier in this article, especially when we remember that it was all done with naked-eye instruments. When the study of instruments for observation is taken up later, those in use in these early times will be illustrated and particularly described.

Ptolemy (100–170 A. D.) carried the ancient astronomy of the solar system to its highest perfection in a theory usually now called from his own name, the Ptolemaic system. It was worked out in 140 A.D., at Alexandria and was published in Arabic, under the title, *Almagest*, and was for fourteen centuries a work of supreme authority in Astronomy. In this theory the Moon is represented as revolving around the Earth in a circle, while the latter body is not placed at the center of the circle. The explanation of the motions of the planets and the Sun as determined by this theory will be found in almost any good, modern text-book on Astronomy and need not be repeated here. It need only be added, that scarcely a single thing which this theory claims, is true as we now know, yet cumbersome in detail as it was it completely represented the best observation for a period of 300 years. Who then could successfully dispute the theory of Ptolemy for the long interval following, seeing that the necessary data for such reasoning was wholly wanting, if we except a few observations which Ptolemy was apparently unwilling to set against all others with the weight and real value that belonged to them?

This brief review gives the reader some idea of the progress in lunar and some kindred studies to the time of the invention of the telescope.

We present herewith a picture of the full Moon because the opportunity for taking it, just exactly at the phase wanted came at the date upon the plate. The Moon was then within a few minutes of the full and its declination was 28° 17′, making its zenith distance in this latitude nearly as small as possible, hence its libration in latitude was favorable for viewing surface beyond the south pole. It was also very near the meridian. When we take another picture with libration large in the opposite direction we will have a pair of them that may be used with good effect for stereoscopic pictures. This picture will also be referred to in later descriptions of surface markings visible at this phase and others which may nearly precede or follow it.

OPTICAL GLASS.

With Special Reference to Telescope Objectives.

J. A. BRASHEAR.

Testing for Striæ.

As stated in our last article, warranted discs of optical glass are always polished on the two faces for the purpose of studying the character of the material, as well as the annealing. Plates of best quality are polished on the edges only.

Fortunately we have quite simple methods at our command by which we are able to determine whether it is safe to make an objective of the glass in question, for it would be a rather costly matter if we found, after working for many weeks upon an objective, that it had defects in it of such a serious nature that they would render it worthless for astronomical or other purposes of research.

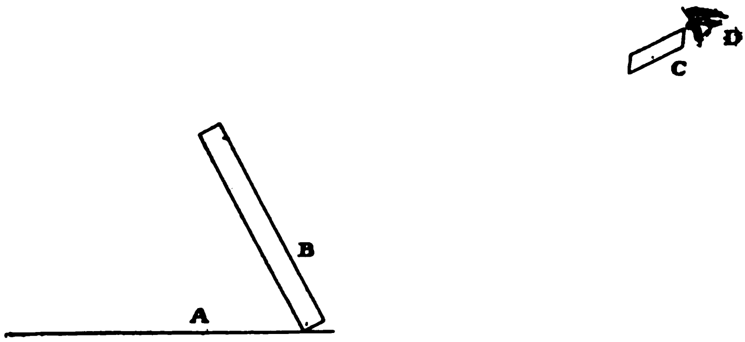
The unaided eye can see stones, bubbles or seeds in the glass, but these things, which disturb the equanimity of the novice, are of the smallest concern to the practical optician. Many of the finest objectives have a large number of bubbles in them, but generally speaking all the harm they do is to stop a little light. The

Washington 26-inch has perhaps a hundred bubbles in the body of the glass, but the 23-inch at Princeton is remarkably free from them. Bubbles are a little unpleasant to the eye, but the practical man, who knows how little harm they do, is glad to pass them by as an insignificant factor if the glass is otherwise all right.

There is no doubt that unequal density of the different parts of a disc of optical glass is the most serious fault it can have, but our glass makers of to-day are very successful in avoiding this difficulty in a large degree, and this is fortunate for there is no satisfactory way to determine this quality until the objective is ground, polished and set up for a preliminary test. But aside from this it is necessary to determine whether the glass is otherwise homogeneous in its nature, *i. e.*, free from "chords" or striæ as the glass makers call what appears as glass or other vitreous substance in the form of light or heavy threads throughout the glass, but slightly different in density or other characteristics from the material of the discs else it could not be detected and would do no harm.

There are two or three methods to detect striæ or chords in glass plates or discs. Perhaps the best method is not readily available to many of our readers, but as it is so excellent and is also valuable for another important investigation I will describe it briefly.

The first requisite is a concave silvered mirror such as is used for a reflecting telescope. The second, a lamp with a cylindrical screen over it with a hole drilled in it about two tenths of an inch in diameter at a place where the maximum light of the lamp flame will pass through it. The disc or plate must be fairly well polished, no attention being paid to scratches, although a novice will at first find some difficulty in deciding between a scratch and some kinds of striæ. The mirror is placed in a vertical position at a convenient height, *i. e.*, so that the center of mirror will be at the same height as the opening in the lamp screen, the lamp being placed on a stand or table. The plate or disc of glass is set upon edge close to the mirror, indeed may lie against it if desired. The lamp is now moved to the approximate center of curvature of the mirror, which will be modified somewhat by the shape of the glass to be tested, but this is of no importance, as all that is necessary is to move the lamp in either direction until the apex of the reflected beam of light comes to a place near the same plane as the lamp, but even this may be varied without detriment to the test, the idea being to concentrate the returning beam upon the pupil of the eye after it has been reflected from the mirror through the glass to be tested. The lamp must be moved a little to one side of the optical axis of the mirror so that the returning beam will be far enough removed from it to allow the eye to intercept it.

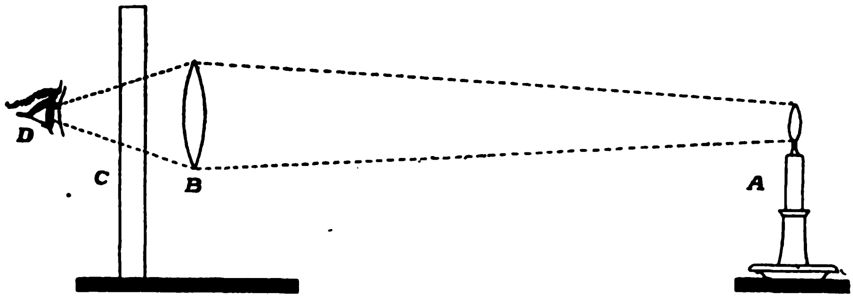


This method of testing brings out striæ, chords or any other imperfections so perfectly that dirt spots, scratches, stains, etc. must be eliminated from chords and striæ. One drawback upon this method is that it is difficult to locate the position of the stria if such be present, with respect to one or other of the surfaces, a matter of great importance, as, when the stria is near one surface the rough grinding may be done so as to cut out the imperfections entirely. The usual method for testing for striæ is as follows:

The same lamp and screen may be used, but the writer finds a candle a first-rate substitute. In this method the candle may be set on a bracket or other support and should be from ten to fifteen feet away from the glass to be tested, according to the focus of the lens to be used for condensing the light. In my own practice I prefer to hold the condensing lens in my hand, so that the conjugate focus of the lens, on the side you are using it to condense the light should not be greater than six or eight inches, otherwise it becomes very tiresome to hold it. A second person can hold and shift the lens, but it is then a very difficult matter for the observer to follow the transmitted beam of light as it traverses the various parts of the disc. Indeed, on first trial, it will be found quite a task to keep the eye in the path of light from the lens, under the best conditions, particularly so when the glass to be tested has one of the surfaces convex or concave.

The disc or plate to be examined may be held vertical in any convenient way, or the lens may be held stationary and the plate moved in front of it if the latter is of small dimensions.

The accompanying sketch shows at a glance the arrangement. *a* is the candle, *b* condensing lens, *c* plate to be tested, *d* the eye placed where it will receive the full beam of light. The room for this work should of course be dark.



It is usual to place the lens between the source of light and the plate or disc of glass, but the writer has just as good success by allowing the light to pass through the plate first, and this method offers advantages in testing large discs, because the lens can be moved over any part of the surface, and if stria is detected, its parallax may be found in a very simple manner, as follows:

Having located the stria, a mark is made in line with it on either of the surfaces, using a small piece of bees-wax or paraffine in making the mark. Condensing the beam of light upon it, the eye is moved to and fro to see if the line of stria shifts with relation to the surface mark. If it does not shift we may conclude that the stria is very close to the surface having the mark upon it. If it does shift then it is best to place a similar mark on the opposite side and observe again, as the stria may be near this side. If, however, the stria shifts in relation to both marks on the glass, we must conclude that it is in the body of the material and a careful study will determine if it is nearer one side than the other. Striæ very frequently cross diagonally through the plate, and then there is but little hope of saving it.

One used to studying glass can readily detect striæ through the polished *edges* of a plate, in which case it may readily be determined whether they are near enough to the surface to be eliminated or not. Striæ and other defects may readily be photographed but eye observations are the most satisfactory.

It is a question with opticians how much striæ may remain in a glass and be harmless. Perhaps there are not many large discs that are perfectly free from small lines of striæ, but the writer will not use a piece of glass that has any striæ that can be detected by ordinary means, and he would recommend to the amateur never to purchase anything but first class plates if he wishes to obtain the highest results. As a proof of the satisfaction in purchasing first quality glass I would say that out of about 500 pieces crown and flint made for me by Mantois of Paris, but one piece 3 inches in diameter has been found with a single stria in it. I have just finished testing the 23-inch discs exhibited at the World's Fair by the Jena manufacturers, and find the crown absolutely free from striæ. A small "bunch" of striæ was located near the edge of the flint; but it was found to be on the surface that will have a convex curve given to it, and not a particle will be left in the disc when finished.

Such discs are of course warranted by the makers, yet it may be seen how important it is that they be critically "diagnosed" before work is commenced upon them.

Perhaps I should give a few directions as to polishing *plates* for preliminary tests.

Grind on plate glass, commencing with rather coarse emery, say No. 90, then with No. 140, then one or two grades of washed emery, prolonging the grinding with the finer emeries until a clean surface is obtained. The crown may be ground on the flint if desired. A felt or cloth surface may be used for the polishing tool, using rouge as a polishing material. A friend of the writer uses the heavy blue cloth made for army clothing and says it answers well. I prefer a pitch polisher for my own use. If cloth is used it is cemented to a flat iron tool using heated coal tar pitch as a cement, and pressing the cloth to a surface with the glass plate which has been previously wetted. A good bright polish is all the better for testing the glass, both for striæ and by polarized light, but the flatness of the surface is of no moment whatever.

It may be of use to our readers to know that rouge and prepared emeries may be purchased of the best quality and at reasonable prices from Mr. Geo. Zucker, 616 West 39th Street, New York.

In our next article we will give methods of testing glass for the character of its annealing.

SHOOTING STARS.

How to Observe Them and What they Teach Us.

W. F. DENNING.

VII.—The Shower of Leonids.

Like the Perseids the Leonids date their observed returns from a remote period several displays having been noticed and historically recorded in the tenth century. Professor H. A. Newton gave a valuable summary of early displays of Leonids, in the *American Journal of Science* for May 1864. The introductory shower appears to have been witnessed in A. D. 902 (nearly 1000 years ago) when meteors are stated to have been too numerous to count and to have fallen as thick as rain. A comparison of the different dates showed that the group developed its maximum intensity at intervals of little more that 33 years, so that approximately there were three brilliant reappearances in 100 years and that, virtually, the same years of each century brought the shower back. Thus the phenomenon was seen in striking grandeur in 902, 1002, 1202 and 1602 and it will recur in 1902 though we may undoubtedly expect the richest displays in 1900 and 1901. In modern times the years 1799, 1833 and 1866 have furnished the most brilliant returns, and the close of the present century and opening of the next will be sure to reward observers with a spectacle which, in its full significance, may be said to come but once in a generation.

The identity of orbit of Tempel's comet of 1866 and these November meteors formed an intensely interesting item in the progress of this branch of astronomy. The comet was computed to have a periodic time of 33.18 years and it is due at perihelion in 1899. There is little doubt that this comet is the same as one observed in China in 1133 and 1366; it is apparently composed of a vast and distended stream of stones with which the Earth comes into collision at the middle of November in several following years near the time of the comet's of perihelion. Thus there were very abundant showers of meteors in 1864, '65, '67, '68 and '69 as well as in 1866, and they prove that the stony fragments forming the comet's material are distributed thickly along a considerable portion of the orbit. During the ensuing few years observers will probably note an increasing activity in the visible returns of this system, and we have evidence of this in Professor

Barnard's statement (Popular Astronomy, Vol. 1, p. 192) relating to the shower of 1893, that the meteors were more abundant than he had ever seen them before.

The radiant point of the stream is placed amid the well known stars forming the sickle of Leo so:—

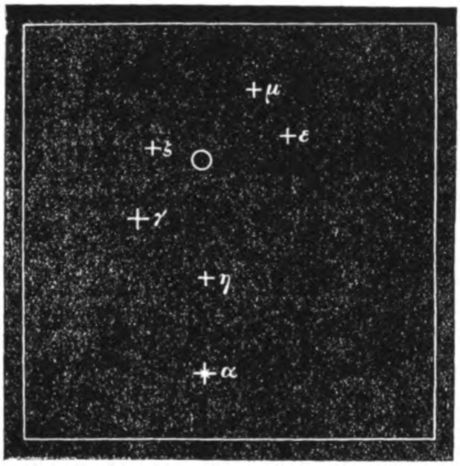


Figure 8. Position of the Radiant in the Sickle of Leo.

From observations at Bristol the exact position of the radiant has been determined at

$$150°.0 + 22°.9.$$

From a mean of 40 good observations by various astronomers in different years the place is

$$148°.9 + 23°.0$$

The radiant is not well clear of the horizon until nearly midnight, so the display is always seen to the best effect in the morning hours.

The system really forms a complete ellipse, for a few meteors belonging to it are recognized every year at the appointed time. No doubt the particles are but sparsely scattered in certain parts far from the parent comet, but the continuity of the stream is manifested by its regular recurrence every November. In 1879 a marked shower of Leonids was observed at Bristol and other places, and in 1880 E. F. Sawyer of Cambridgeport, Mass., redetected it. In the latter year the comet was nearing its aphelion, so the meteors seen must have been placed at the opposite part of the orbit.

Careful observation of the Leonids, especially when the display is not so bright as to engage the whole attention, has proved that a very large number of contemporary showers are in action. The radiant points of many of these are now tolerably well ascertained. We give below a summary of 68 of them; the positions depend mainly upon observations at Bristol between 1876 and 1888:—

Radiants visible with the Leonids November 10–15.

° °	° °	° °	° °
5 + 52	62 + 34	110 + 25	166 + 3
8 + 36	63 + 21	120 + 15	166 + 31
19 + 30	64 + 11	121 ± 0	170 + 47
27 + 71	70 + 66	124 + 55	177 + 10
29 + 37	72 + 4	125 + 40	184 + 29
30 + 16	73 + 42	132 + 21	190 + 21
32 + 51	75 + 15	133 + 31	191 + 58
40 + 10	77 + 32	133 + 48	194 + 67
43 + 6	79 + 51	133 + 70	200 + 57
45 + 60	80 + 24	136 + 8	213 + 35
46 + 21	86 + 75	141 + 27	213 + 75
48 + 43	87 + 20	143 + 50	238 + 49
50 + 30	97 + 27	143 + 69	262 + 64
53 + 71	90 + 44	146 + 8	270 + 70
57 + 18	102 + 73	154 + 41	284 + 43
60 + 28	103 + 48	157 + 49	315 + 60
60 + 49	107 + 11	157 + 74	338 + 59

There are many slow meteors diverging from Perseus and Taurus at this epoch and the region surrounding Leo contains several radiants of bright, streak-leaving meteors. The writer believes the richest of the minor showers lies at the point 154° + 41° a little S. of μ Ursæ Majoris and just outside the N. boundary of Leo Minor. When the Leonids are weakly represented this shower of Ursids takes the foremost place, and some of its meteors are liable to be mistaken for Leonids, as they are very similar in appearance and the radiant is less than 20° distant from that in Leo. The shower near μ Ursæ appears to have first been discovered by F. W. Russell of Natick, Mass., for he gives a radiant at 156° 30′ + 40° 40′ from 11 meteors recorded on November 10, 1861, and the observation is quoted in Professor Eastman's valuable "*Progress of Meteoric Astronomy in America*," p. 328.

There is also a shower at 141° + 27° (close to κ Leonis) which is occasionally well defined, as in 1892, at the period of the Leonids and liable to be confused with the major shower.

Heis found from his observations in November, 1839, to 1847 that of 407 meteors registered, 171 proceeded from Perseus near the star η, and only 83 from Leo. Schmidt in 1851 remarked that Perseus appeared to furnish the greater number of meteors not only in August but throughout the year. In order to test Heis's result the writer examined the paths of 691 meteors observed at Bristol in November 1876-79 and found that there were 50 Perseids and 50 Leonids while there were no less than 99 Taurids. The activity of the autumnal Perseids in former years appears therefore to have been succeeded by an abundance of Taurids and the point is recommended to the attention of future observers.

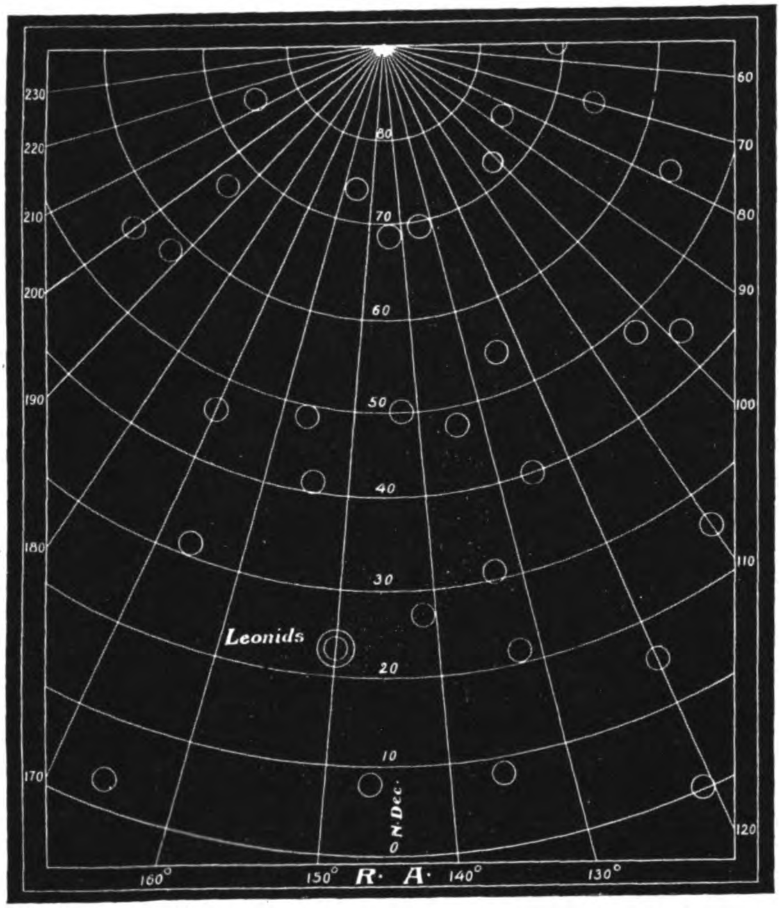


FIGURE 9. RADIANTS VISIBLE IN THE SAME GENERAL REGION AS LEO, NOVEMBER 19 TO 15.

The visible duration of the Leonid shower is much shorter than that of the Perseids and it is apparently confined to the 9 nights from November 9 to 17. It is not yet definitely proved whether the radiant shows a displacement similarly to that of the August shower, but this is highly probable. There are generally very few Leonids to be seen except on one or two nights near the date of maximum, and it has been difficult to determine the place of the radiant at the advent and extinction of the shower. From what the writer has seen he regards the radiant as a shifting one and believes that it is possible to ascertain the rate and direction of its motion by very careful and long sustained observation.

It is a curious circumstance that in November, 1898 (or 1899), two fine meteoric displays may come nearly together. There ought to be a plentiful return of the Leonids on the morning of November 15 while the Andromedes should reappear on the 23d. or only 8 days afterwards. Thirteen years elapsed between the great Andromedec showers of 1872 and 1885, and a similar interval brings us to 1898. If the two systems fulfil expectation meteoric observers will find their hands full of attractive work, and no doubt the general public will take advantage of the opportunity to witness two of the most attractive spectacles which it is possible for the heavens to afford. A meteoric display of the finest character is certainly a most imposing and striking event and presents a peculiarity of aspect which must live long in the memory of those who witness it. Other celestial occurrences have, it is true, their remarkable features, for a large comet, a total solar eclipse and a brilliant display of Aurora Borealis are each magnificent in their way—but a meteoric storm is perhaps the most impressive and animated of all nature's wonders, for the whole firmament becomes, as it were, alive with shooting stars of all magnitudes and gives the idea of a celestial bombardment well calculated to strike terror into the minds of people not acquainted with its real meaning and harmless character.

THE FIXED STARS.

W. H S. MONCK

II.

Every one notices the fact that some stars are brighter than others, and stars have from early times been roughly classed as of the first, second, third magnitudes, etc., accordingly. These classifications were not based on any fixed principle, and different astronomers classed certain stars differently. The defects of such a system were obvious and among other things it often prevented the variations in the light of a star from being recognized, or led to the supposition that there were variations where there were none. It was not until the present century that star-magnitudes were classed upon any scientific basis. It was then noticed that our power of detecting the difference between two lights depended not on the difference between the quantities of light but on the ratio between them (a principle known as Techner's law), and that on an average the stars classed as of one magnitude by astronomers gave about 2½ times as much light as those of the magnitude next below. For convenience of computation the ratio equivalent to one magnitude was fixed at the number whose logarithm is 0.4 and whose value to three decimal places is 2.512. The adoptiou of this scale enabled astronomers to express star-magnitudes much more accurately than before; for example, instead of describing a star as intermediate between the third and fourth magnitudes, we were able to describe it as of magnitude 3.45 or 3.87 as the case might be, provided that we could measure the quantity of light with the requisite degree of accuracy. Photometers for comparing the light of stars with each other were next invented. Those generally in use depend on two different principles. With photometers of the first kind we equalize the light of two stars by means of an instrument which reduces the light of the brighter in a known proportion. We then know the ratio of the light of the two stars or the difference in their magnitudes on the photometric scale, and if we know the magnitude of the one we know the magnitude of the other also. In the second method the light of both stars is extinguished by being passed through a wedge of neutral-tinted glass and the ratio of the lights is inferred from the respective thickness of the glass necessary to extinguish them. Both methods enable us to estimate the difference in magnitude of any given pair of stars and as a rule there seems to be a fair agreement between the results attained by them. We have only then to assume a magnitude for our standard star and we can assign magnitudes to all whose light is capable of being measured by the photometer. The pole star is naturally selected as the standard being always at an altitude (in these latitudes) capable of easy observation. In the well known *Harvard Photometry* its magnitude is assumed to be 2.15 and the magnitudes of all other stars in the catalogue are computed on that basis. The list of magnitudes thus computed is easily converted into a table of the relative quantities of light. Thus if we take Q as the quantity of light given by a star one magnitude brighter than the first, the quantity of light given by a star of the nth magnitude is $Q^{-0.4n}$. The reader may at first be startled at hearing of stars above the first magnitude but every one knows that some stars of the first magnitude are brighter than others. Taking the magnitude of the pole star at 2.15 the star whose magnitude most closely approaches the first is α Aquilæ or Altair. Arcturus, according to the *Harvard Photometry*, is nearly one magnitude brighter than this or very nearly of magnitude 0, while Sirius is more than two magnitudes brighter, which is indicated by giving its magnitude a negative sign, — 1.43. Of course on this scale the lower the magnitude the brighter is the star, and as a star of the first magnitude is brighter than one of the second, a star of magnitude 0 is brighter than a first magnitude star, and a star with a negative magnitude is brighter than one of magnitude 0. The *Harvard Photometry* contains the magnitudes of over 4,000 stars determined in this manner, and there are other valuable collections. Errors will of course creep into any such system of measures but there is reason to think that they are small. Careful observers, moreover, though dependent on the eye only have succeeded in estimating the magnitudes of stars to tenths of a magnitude with an accuracy that photometric measures of the same stars have fully attested.

As light decreases in proportion to the inverse square of the distance the natural assumption to make in the first place was that the differences in the light of stars was mainly, if not solely, due to their distances. Thus a star of the 10th magnitude only gives $\frac{1}{10000}$ of the light of Arcturus (taken as of magnitude 0). Hence it might be assumed to be 100 times as distant, since, if removed to that distance, the light of Arcturus would be diminished in this proportion. But as soon as the spectroscope and the photographic lens were brought into use it was found that any rough conclusions of this kind needed considerable modification. Photography indeed afforded a new kind of photometry—a brighter star producing *ceteris paribus* a larger disc on the photographic plate and *vice versa*. But red stars were found to give smaller discs, and brilliant white or bluish stars larger discs, than were expected. A star which looked fainter to the eye often proved more effective in photography than a brighter one. Feebler in optical rays it was more powerful in photographic rays. The spectroscope gave the same result. The light of different stars differed in kind. The relative intensity of the light at different parts of the spectrum was different and so were the lines which characterized the substances in the stellar atmosphere. Different stars gave different kinds of light and the analogy of terrestrial substances indicated a cause for this difference. When we gradually heat a body it first becomes red hot—it gives red light only. But gradually as the heating proceeds the light becomes whiter and is found on analysis to extend further towards the violet end of the spectrum. Finally it passes beyond the violet end giving in addition to the visible rays others which are invisible to the eye but nevertheless produce well-marked effects on the photographic plate and indeed may be rendered visible by passing the light through a fluorescent substance. The light as the heating proceeds assumes a greenish or bluish tint and the point of maximum intensity on the spectrum moves steadily from the red towards the violet end. It is needless to say that as the heating goes on the quantity of light given out by the body is largely increased. These results are generally applicable to the stars though with some qualifications; for the color of a star undoubtedly often depends to a considerable extent on its atmosphere—an absorptive medium interposed between us and the real source of light. Still it is impossible to doubt that different stars differ widely in temperature and luminosity and that the light which we receive from a star depends not merely on its mass and its distance but also on its temperature or on the intrinsic brilliancy of its surface.

When these results were reached it was natural to infer that there were dark stars in existence or at least stars so feebly luminous as to baffle our best optical instruments though comparatively near us. It was found even before Herschel's discovery of the physical connection between certain double stars that the magnitude of certain stars varied in a manner strongly suggestive of a periodical eclipse. Of these Algol is the best known but the number of variable stars of this type has been considerably increased by recent research. From the motions of Sirius it was inferred that the brilliant star was being attracted by some neighboring object which telescopes failed to detect. More powerful telescopes were used and the disturbing star was discovered: but though from its action on Sirius it is computed to be perhaps half as large as its brilliant companion it does not give $\frac{1}{10000}$ part of the light. A similar result was arrived at in the case of Procyon where even the great Lick telescope has failed to detect the smaller star. The spectroscope has added to this list as will be seen hereafter. Almost simultaneously it was conjectured that some of the outer planets gave a little light of their own besides reflecting the sun-light. We have, however, unmistakeable evidence of dark bodies within the solar system. The inference (subsequently confirmed by other considerations) seemed to be that dark bodies exist outside of the solar system also—that in short stars exist in every possible degree of illumination from one considerably exceeding that of the Sun down to absolute blackness. And the number of black stars (or black bodies in space) may be far greater than we imagine because it is only by some accident that we can detect their existence at all.

The distribution of stars in the sky is evidently not uniform. But when we are dealing with large classes of stars distributed impartially over the sky an approach to uniformity might reasonably be expected. It is therefore worth while to consider what the effect of uniform distribution would be as regards the number and light of the stars of each magnitude. Supposing that no light is lost in transmission we may assume for instance that all the stars up to and including the fifth magnitude are included in a sphere having the Earth as its center and the radius r. All the stars up to the sixth magnitude will then be comprised in another sphere having the same center and the radius $1.585\,r$ — 1.585 being the square root of 2.512 the multiplier which corresponds to a magnitude and the intensity of the light varying inversely as the square of the distance. And if the number of stars comprised in the first sphere be n the number comprised in the second sphere will be $(1.585)^3 n$ or $3.984n$. Of these stars $2.984n$ will be stars between the fifth and sixth magnitudes the total number up to and including the fifth magnitude being n as already stated. Using for brevity 4 instead of 3.984 the stars of any magnitude will thus be three times as numerous as all the brighter stars. Applying the same rule to the stars between the fourth and fifth magnitudes their number will evidently be $\frac{3}{4}n$ and those brighter than the fourth magnitude $\frac{1}{4}n$. The stars of any magnitude will thus be four times as numerous as those of the magnitude next below. This reasoning, it will be seen, is perfectly general. Let us now compare the total light of the stars of two successive magnitudes. The average light of the brighter stars is 2.512 times that of the fainter but the number of the latter is four times as great, and their total light is 1.585 times greater. The total light increases at each magnitude by the number whose logarithm is 0.2. Thus the stars of the tenth magnitude should give collectively ten times as much light as those of the fifth magnitude, the stars of the fifteenth magnitude 100 times as much light and so on. And if this uniform distribution of the light extended to infinity the total amount of light received from the sky would be infinite. But nothing is more evident than that the total light of the sky is of very limited amount. The full Moon bursting through a dense cloud when the rest of the sky is overcast gives more light than we receive from the whole sky on a clear moonless night. What is the explanation of such facts as these? Is the universe finite? Or is there some medium in space which absorbs light and causes it (especially at great distances) to diminish more rapidly than in the ratio of the inverse square of the distance? Or lastly is the region of luminous stars limited, the bodies at greater distances being usually dark? These are among the problems which the astronomy of the future has to solve.

So far as I have compared photometric measures of stars I think the theoretical proportion of 4 to 1 for the numbers of stars of two successive magnitudes is rarely if ever realized. If all stars are of equal intrinsic brightness and light diminishes as the inverse square of the distance, a thinning out commences at (comparatively speaking) no great distance from the Earth or the Sun. But though the proportion seldom if ever reaches 4 to 1 it seems always to exceed 2.512 to 1, and as long as it does so the total light of the stars of each successive magnitude will continue to increase. The limited amount of light which we receive from the entire sky shows that this process cannot go on very long, but where it stops is at present a subject of conjecture only. The stars of the 100th magnitude may collectively give as much light as those of the fifth but I think if the process was carried on as far as the stars of the 1000th magnitude the total light of the sky could not fail to be much greater than it is. That there are dark bodies both within and without the limits of the solar system which intercept some of the light of distant objects must I think be conceded, but this will not account for the observed thinning out of the stars unless we suppose them to be more numerous than is usually supposed. A given quantity of matter will intercept the greatest quantity of light when it is most subdivided. If meteors exist in space to anything like the extent which the Meteoritic Hypothesis supposes, a good deal of the light coming from distant objects must be intercepted by them. But the ether itself may absorb light or convert it into some other form of energy. The entire problem is one of great interest but the solutions hitherto proposed are chiefly speculative. It will be desirable to bear in mind however, that we can only believe in the existence of an infinite Universe of luminous bodies on the hypothesis of a very large absorption of light in the case of the more distant stars—a much larger absorption than in the case of nearer stars and which therefore is not to be explained by the stellar atmospheres or the terrestrial atmosphere but by something which intervenes between us and these stars.

Whether the distribution of stars round the Earth is approximately uniform as regards distance or not, it is undoubtedly not so as regards direction. That the stars are far denser in the Galaxy than elsewhere, and in particular parts of the Galaxy than in other parts, has been long known. And as telescopes with increasing power came to be used it was found that in many parts of the sky remote from the Galaxy there was an evident thinning out of the stars at stages where there was a thickening in most parts of the Galaxy. There are parts of the sky remote from the Galaxy where, if we examine the fainter stars with a more powerful telescope or a photograph taken with longer exposure, instead of the four-fold increase for each magnitude there is sometimes an actual decrease. It seems as if we were looking ***through*** the stars in that direction and that there were no others beyond them. On the other hand the four-fold ratio must at some stages be greatly exceeded in such regions of the sky as that in Cygnus where Mr. Roberts photographed 16,000 stars not one of which was as bright as the sixth magnitude. Observations like these give rise to further problems. Are we *in* the Galaxy or outside it? Do all the stars which we can detect with our present optical means belong to one great galactic system or does that system only include a certain number of them? And what is the shape of this Galaxy? The Galaxy as visible may be described as a very irregular ring whose central line forms a great circle on the celestial sphere. But is it really a ring, the Sun and Earth being somewhere in the vacant space which it encircles, or is it shaped rather like a block-wheel the solar system lying within the block and the stars being thinner in the direction parallel to its axle than at right angles to it for the simple reason that they extend to a shorter distance in the former direction than in the latter? This shape would of course account for our being able to look through the stars near the poles of the Galaxy while failing to do so in the direction of the Galactic circle. All stars would on this latter assumption form part of the same vast system, or at least if there are any stars independent of it we have hitherto failed to detect them. On the other hand if the Galaxy is shaped like a ring—a spoke-wheel instead of a block-wheel though of course the spokes are imaginary—we are outside the galactic system and so are our nearer neighbors, the nearest part of the ring being situated at a great distance from us. Of course both the block-wheel and the spoke-wheel are very rough illustrations but they may serve to distinguish the two systems, one of which makes the Earth and all visible stars part of the galactic system while the other excludes us and our nearer neighbors from it. We are not probably in a position to decide positively between these two theories at present but observations on the proper motions of the stars and to a certain extent observations on their spectra may assist us in making a probable conjecture. But it will be necessary to describe the spectra and the proper motions of the stars before this question can be discussed with advantage. The shape of the Galaxy cannot be determined till we know what stars are to be included in the galactic system, and even then it will be difficult to determine how far its apparent shape is the result of perspective or projection on the celestial sphere.

Attempts have been made to compare the light of some of the brighter stars with that of the Sun but with very unsatisfactory results. The difference is too great and we cannot even observe them simultaneously. The method adopted was comparison with the Moon but various estimates make the light of the Sun greater than that of the Moon in proportions varying from 300,000 to 800,000 to 1. The proportion of incident sunlight which the Moon reflects is also doubtful and the full Moon is too bright for accurate comparison with the light of a star. A comparison of the light of the fixed stars with that of the planets promises better results but there is still an uncertain element—the *albedo* of the planet as it is called, or the proportion of the incident sunlight which is irregularly reflected from its surface. If the entire visible hemisphere were covered at the distance of the planet by a substance which irregularly reflected the whole of the light that fell on it we should receive from this hemisphere as much light as we receive directly from the Sun. We can compute the proportion which the planet's disc (or rather the illuminated portion of it) bears to the entire hemisphere in question and thus compare the planet's light with that of the Sun on the assumption that the whole of the incident light is irregularly reflected from the illuminated portion of the planet; and comparing the light of the planet with that of a star we can obtain the proportion between the light of the Sun and that of a star on this hypothesis. But the planet does not reflect the whole of the incident light and there is a question as to whether some of the planets do not give original as well as reflected light. Our results are consequently uncertain. I may mention, however, that on the lowest estimate of the light of Sirius that has hitherto been made the light of the Sun exceeds it in the proportion of 20,000,000,000 to 1. But the distance of Sirius, as will be explained hereafter, is supposed to be about 500,000 times as great as that of the Sun, and at this distance the Sun's light would be diminished in the proportion of 250,000,000,000 to 1. Sirius thus gives on this computation 12½ times as much light as the Sun. Other computations however make it more than 60 times as bright.

CONSTELLATION STUDY.

WINSLOW UPTON.

V.

Continuing the description of the individual constellations begun in the last article of this series, we will take up those in the first division which are south of north declination 50°. We have already considered Cassiopeia and Camelopardalis, the two circumpolar groups of this division. The three zodiacal constellations, Pisces, Aries and Taurus, will first be described, and then those which lie north and south of them.

Pisces.—This interesting group is composed almost entirely of faint stars, and cannot be traced except on clear, moonless nights. It can be found as follows: The four stars marking the equinoctial colure were α Ursæ Minoris, β Cassiopeiæ, α Andromedæ and γ Pegasi. The line connecting the last two forms the eastern side of the very conspicuous quadrilateral known as the square of Pegasus. Directly south of the Square is a cluster of small stars encircling an area which resembles a polygon of five or six sides. This marks the western fish. Directly east of the Square is a second cluster of faint stars which marks the eastern fish. Two winding lines of stars, running the one eastward from the first fish and the other southward from the second fish, meet at the fourth magnitude star α Piscium, the brightest of the group. The classic figures are drawn with the fishes pointing westward and northward respectively, and with their tails connected by a band.

Aries. The characteristic figure of this group is an elongated triangle which marks the head of the Ram. A line drawn from the Pleiades to γ Pegasi is nearly bisected by the group. A small triangle of rather faint stars five degrees southwest of the Pleiades may also be traced in the eastern part of the area occupied by this constellation, and marking the position of the tail of the animal.

Taurus. The characteristic figures of this constellation are the Pleiades and the Hyades. The former are in the shoulder and the latter in the head of the Bull, only the shoulder and head with the fore legs and horns being represented in the figure. Six stars can be readily distinguished in the Pleiades, and several more have been seen on favorable occasions. The Hyades or V-shaped group, whose vertex is toward the west, contains the bright red star α Tauri or Aldebaran. The middle star in the southern side of the V is a naked-eye double, the components being about 6′ apart. Two prominent stars 5° apart, mark the tips of the horns which may be found by drawing a line from α Tauri northeastward to the twin stars of Gemini, Castor and Pollux. About one-third of the way from α Tauri, this line crosses the line at the extremities of which are the two stars marking the tips of the horns. The northern one, β, is the brighter and is the second in brightness in the whole constellation.

North of the three zodiacal constellations just named lie the constellations Andromeda, Triangulum, Perseus and Auriga, given in the order west to east.

Andromeda. The characteristic figure of this group is three bright stars nearly in line, about 15° apart. The westernmost is lettered α, and has been mentioned already as in the line marking the equinoctial colure and also the northeastern corner of the Square of Pegasus. The line runs northeast, approximately towards the brilliant star Capella in Auriga, and the stars are lettered in order, α, β, and γ. Half way between α and β, a little south of the line is δ, somewhat fainter than the others, and the line may be prolonged to a bright star beyond γ, which is in Perseus and called α Persei. This line is near the southern boundary of the area, and there are a number of fainter stars north of it, which should be associated with the figure. Several of these are near γ, and from β runs a line of faint stars at right angles with the α, β, γ line, which leads to the nebula of Andromeda, just visible to the naked eye. In the figure of the "chained lady" this line of stars is the girdle to which the chain is fastened, and the figure is drawn with the head at α and left foot at γ.

Triangulum. This group, as its name implies, is a triangle of stars which may readily be found as it is half way between the triangle marking the constellation Aries and the star γ Andromedæ.

Perseus. There are two characteristic figures in this area—a curved line of bright stars, and a cluster of stars sometimes given a distinct name:—Caput Medusæ. In order to find the former, continue the line α, β, γ Andromedæ beyond γ about 20° to the bright star α Persei, the brightest of the group. This is in the curved line sought for, two stars lying northwest of it, and one southeast. Several fainter stars are near these. In order to find the head of Medusa, note a triangle formed by α Persei, γ Andromedæ, and a star of nearly equal brightness south of the former and east of the latter. This star is β Persei or Algol, the famous variable star. Close to it are three fainter stars forming with it the group. Between the northernmost star of the curved line and the constellation Cassiopeia is a magnificent cluster of stars, visible to the naked eye, and a gorgeous group in the telescope. This cluster is in the sword of Perseus, and the curved line of stars is in the body of the hero. Another method of tracing the stars, including some other stars in the southern part of the area, is represented on the chart printed in this number of POPULAR ASTRONOMY.

Auriga. This group, east of Perseus, contains the brilliant star α Aurigæ or Capella. From it may be traced the other stars of the constellation;—a third and two fourth magnitude stars south of it, a second magnitude star β east of it, a third magnitude star south of β and two stars, of the third and second magnitude respectively, at the southern boundary of the area, and with those just named forming a large polygon. The second magnitude star last named is now included in the constellation Taurus and called β Tauri. It was referred to above as marking the tip of the northern horn of the Bull. In the ancient figure it also marked the foot of the charioteer and was lettered γ Aurigæ, thus affording an example of a star which was placed in two adjacent constellations.

Immediately south of the zodiacal constellations are the constellations Cetus, Eridanus and Orion, and south of Orion are Lepus and Columba.

Cetus.—This group occupies a very large area south of Pisces and Aries, and contains ten or more bright stars scattered about but forming no special figure. Two groups may be formed, first, two bright stars α and γ, lying east of α Piscium, and which with several fainter stars mark the head of the Whale, and second a quadrilateral of bright stars in the Whale's body adjacent to which on the west are two more bright stars. The famous variable star *o* Ceti, which is usually invisible to the naked eye, but every eleven months attains the brightness of a fourth magnitude star, and sometimes even of a second magnitude star, is in the neck of the figure and forms a triangle nearly equilateral with γ Ceti and α Piscium, lying south of them.

Eridanus.—This winding constellation is only in part visible in northern latitudes. It begins at the eastern part of the area called by its name, close to the brilliant star Rigel in Orion, and winds westward, following the positions of ten rather faint stars. Then the stream turns southward and southeastward, the latter portion containing nine stars of nearly equal brightness all lettered τ, with the numbers 1, 2, 3, etc., added as the right ascensions increase. The stream then turns southward and westward and is lost in the haze about the horizon, as we view it in northern latitudes. Southern observers can trace it to south declination 58° where it terminates in a bright first magnitude star, α Eridani or Achernar.

Orion.—East of Taurus and Eridanus lies this conspicuous constellation, the chief features of which are the three stars of the second magnitude 1½° apart forming the belt, and the two first magnitude stars, one red and the other white, north and south of the belt respectively. The figure may be traced further as follows: The red star, α Orionis or Betelgeuze, makes a triangle with a bright star γ, about 8° west of it, and a fainter star λ north of it. Two fainter stars are close to λ and they mark the hunter's head, the stars α and γ marking his shoulders. South of the belt are three stars close together in north and south line, the northern one quite faint. These are in the sword and the middle star, θ, is the star which is readily resolved in the telescope into the trapezium round which lies the wonderful Great Nebula. The bright star southwest of the sword, one of the most magnificent in the heavens, is β Orionis or Rigel. It marks one foot (the leg drawn up) and a star 8° east of it is in the other leg. On a specially clear evening, a curved line of fainter stars near the boundary of Taurus, west of the shoulder may be readily traced, as shown on the chart.

Lepus.—South of Orion is situated this little group. Its characteristic stars are three of the third magnitude forming a right-angled triangle. They lie south of Rigel about 10°. The line from Rigel passes near two fourth magnitude stars which mark the ears of the Hare, and four other fourth magnitude stars two southeast, and two northeast of the triangle are also easily discerned.

Columba.—South of Lepus is this constellation, the chief stars of which are a second, a third and a fourth magnitude star forming a triangle and marking the body of the Dove.

The Celestial Equator can always be imagined drawn in the sky, without the aid of any stars which are situated near it. For it intersects the horizon at the east and west points exactly, and crosses the meridian at a height above the horizon equal to 90°, less the latitude of the place of observation. Reference to the chart shows how the constellations just described are placed with regard to it and near what stars it is drawn. It will be noticed that it passes through the southern part of Pisces, the northeastern part of Cetus, the extreme southern part of Taurus, the extreme northern part of Eridanus, and nearly centrally through Orion. The brightest star in Pisces, α Piscium, is 2°.7 north of it, and the northern star of the belt of Orion is 0°.4 south of it.

The Ecliptic does not occupy any constant position with regard to the horizon, for the diurnal motion is necessarily along the equator, the stars describing small circles whose planes are parallel with the plane of the equator, and the ecliptic makes an angle of 23° 27′ with the equator. Consequently we can best trace the ecliptic by noting the constellations through which it passes, and then we can note its several positions in the sky from month to month. The ecliptic is wholly in the zodiacal constellations, except that between Scorpio and Sagittarius, in the third division of the heavens, it crosses the area named Ophiuchus. In the first division above described it shows the path followed by the Sun between the vernal equinox and the summer solstice, and hence beginning at its intersection with the equator in Pisces it is to be traced farther and farther north until it reaches its highest northern point as it enters the area Gemini. Its exact position may be readily found from the chart. It will be noted that the two fishes are wholly north of it and that it crosses both lines of stars marking the cord connecting them. The characteristic triangle of Aries, which is 20° north of the celestial equator, lies about 6° north of the ecliptic, which passes nearly half way between the Pleiades and Hyades.

The Solstitial Colure, dividing the first and second divisions of the heavens, may be approximately traced among the constellations above described. It runs only about 2° east of the two conspicuous stars β and θ Aurigæ, and it leaves the leading stars of Orion wholly west of it, the bright red star α Orionis being less than 3° west of it. It passes almost exactly through θ Leporis, an inconspicuous star in that group, east of the leading stars of the figure, which can be found from the guiding lines on the chart.

An explanation may be needed of the words east and west as used in astronomical descriptions. North and south are more readily understood, but even in their use, confusion may arise. North is towards the north pole along any hour circle, and south the opposite direction. Thus the direction from the north pole to the north point of the horizon is south. As we face the north, the direction south is along any of the lines radiating from the north pole in any direction. As we face the south, the direction north if we start at the celestial equator is along converging lines toward the north pole, and the direction south along these lines in the opposite direction; after crossing the equator they converge towards the south pole. The direction *east* is at right angles with the hour circles and in the opposite direction in which the stars move in their diurnal motion. If we face the north and view the circumpolar stars, the direction *east* is along the diurnal paths of the stars, (which are parallel circles smaller and smaller as we approach the pole), in the direction of clock hands or *clock-wise,* and the direction *west* the opposite direction or *counter clock-wise.* If we face the south, the direction *east* is towards the left along the celestial equator or any small circle parallel with it.

The constellations of the first division can best be studied in the autumn, when they are rising in the east. Indeed as a general rule the constellations which rise and set can be most advantageously learned soon after they have risen, and they should be watched carefully for several months that they may still be recognized in their western positions. In March, the division is in the west in the early evening. Pisces and Cetus cannot be seen to advantage if at all, but the others may be traced without difficulty. If this is done it should not be forgotten that the task is only half completed, for it is surprising how different the same groups will appear six months hence when they are in the east. This is especially true of Andromeda and Perseus. For this reason, a careful review of this division of the sky should be made in the autumn evenings.

The following table contains the approximate positions of the leading stars in each constellation.

Approximate Positions of the Leading Stars in the Constellations between 0^h and VI^h Right Ascension, omitting Circumpolar Constellations.

Andromeda.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
α	2.1	0	3	28	33
β	3.4	0	34	30	19
δ	2.2	1	4	35	5
γ	2.2	1	58	41	51

Triangulum.

α	3.6	1	47	29	6
β	3.1	2	4	34	31
γ	4.2	2	11	33	23

Perseus.

γ	3.1	2	58	53	7
β	2.3	3	2	40	35
α	1.9	3	17	49	30
δ	3.2	3	36	47	28
ζ	3.1	3	48	31	36
ε	3.0	3	51	39	44

Auriga.

ι	2.7	4	50	33	0
ε	3.2	4	55	43	41
α	0.2	5	9	45	54
β	2.1	5	52	44	57
θ	2.7	5	53	37	12

Pisces.

α	4.4	1	57	2	17

Aries.

γ	5.0	1	48	18	48
β	2.8	1	49	20	18
α	2.0	2	2	23	0

Taurus.

η (Pleiades)	3.0	3	42	23	48
λ	3.6	3	55	12	13
γ	3.9	4	14	15	23
ε	3.7	4	23	18	58
α	1.0	4	30	16	19
β	1.9	5	20	28	31
ζ	3.0	5	32	21	5

Cetus.

ι	3.6	0	14	− 9	22
β	2.1	0	38	− 18	33
η	3.6	1	4	− 10	43
θ	3.8	1	19	− 8	42
τ	3.6	1	39	− 16	28
ζ	3.8	1	46	− 10	50
ο	var.	2	14	− 3	25
γ	3.6	2	38	+ 2	49
α	2.7	2	57	+ 3	32

ERIDANUS.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
γ	3.0	3	53	−13	47
υ^4	3.3	4	14	−34	2
β	2.9	5	3	−5	13

ORION.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
π^3	3.3	4	44	+6	48
β	0.3	5	10	−8	19
η	3.5	5	19	−2	30
γ	1.9	5	20	+6	15
δ	2.4	5	27	−0	22
λ	3.7	5	30	+9	52
ι	3.0	5	30	−5	58
ϵ	1.8	5	31	−1	16
ζ	2.0	5	36	−1	59
κ	2.2	5	43	−9	42
α	0.9	5	50	+7	24

LEPUS.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
ϵ	3.3	5	1	−22	30
μ	3.3	5	8	−16	10
β	3.0	5	24	−20	50
α	2.7	5	28	−17	54
γ	3.8	5	40	−22	28
δ	4.0	5	47	−20	52

COLUMBA.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
ϵ	3.8	5	28	−35	33
α	2.7	5	36	−34	7
β	2.9	5	47	−35	48

VARIABLE STARS. V.

J. A. PARKHURST.

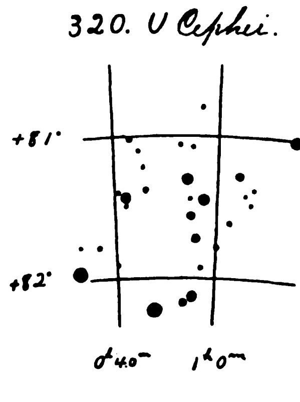
Systematic observations of variable stars began with the noted Argelander, who a generation ago was director of the Observatory at Bonn, Germany. He perfected the method which bears his name and in 1844 published a catalogue of 18 stars. Schönfeld had been observing variables at Mannheim for some years, and when called to Bonn to succeed Argelander, continued the work and brought out two catalogues, the first in 1866 containing 119, the second in 1875 with 143 stars. Schönfeld prepared the ephemerides of variable stars which were printed annually in the *Vierteljahrsschrift der Astronomischen Gesellschaft* till his death in 1891. Since that time they have been prepared by Dr. Ernst Hartwig of Bamberg. Mr. J. E. Gore published in 1884, in the Proceedings of the Royal Irish Academy, a catalogue of 736 suspected variables and in 1887 a revised catalogue of known variables. Dr. S. C. Chandler of Cambridge, Mass., published his first catalogue of variables in the *Astronomical Journal* in 1888. His second catalogue appeared in No. 300 of the same publication in 1893. This is the latest and most complete presentation of the subject extant. It contains 260 known variables, all doubtful stars being excluded, the author adhering strictly to the rule that no star shall be admitted whose variation is not attested by at least two reliable observers.

The observations mentioned so far have been entirely visual, but within a few years the photographic plate has been called upon to furnish data in this department. With a given exposure the brighter the star the larger will be its image on the plate, so that photographic magnitudes are commonly deduced by measuring the diameter of the star images with a micrometer. It would follow from this that if plates of the same region were taken from time to time the diameter of the disk of a variable would change its ratio to the diameters of the adjacent stars, so that by measuring a series of plates the variable's light curve could be drawn.

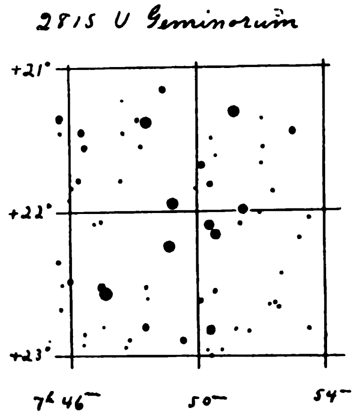
A telescope specially designed for stellar photography is needed for this work and the star disks must be measured by a microscope provided with a micrometer eye-piece in order to attain an accuracy comparable with visual results, so that few amateurs will be able to undertake such investigations. Besides, the time required to expose and develop a plate and make the necessary measurements would suffice to observe a dozen stars visually. The case is different where an extended series of plates, covering a large area may be taken for other purposes. These may also be useful for detecting variables and investigating their actions. The plates taken under the direction of the Harvard College Observatory at Cambridge, Mass., and Arequipa, Peru, are being measured and many new variables have been announced as a result. A very animated discussion has arisen in regard to the weight to which these results are entitled, and the widest differences of opinion are expressed. It is perfectly proper that any new method of astronomical research should be subjected to the severest scrutiny in order that its weak points may be found and strengthened and its proper field assigned. If the visual and photographic results do not agree, all will be interested to learn whether the fault lies in one or the other system, or whether it is due to imperfect work on the part of the observer. Late numbers of *Astronomy and Astro-Physics* and the *Astronomical Journal* contain some of this discussion.

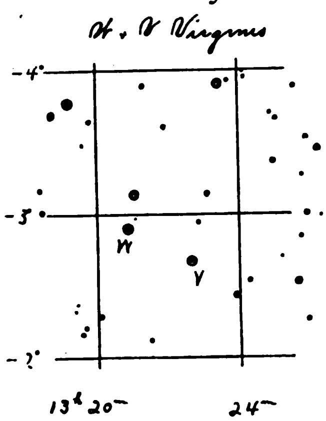
Although good visual work can be done with almost any instrument from an opera glass to the Yerkes Telescope, yet some forms are cheaper and more convenient than others. The main requirement in variable star work is light gathering power, and this can be had at a comparatively low price in a reflecting telescope. The writer is using a 6.2 inch silver-on-glass reflector of 60 inches focal length, made by J. A. Brashear of Allegheny, Pa., which is a model of convenience. It is equatorially mounted with driving clock and divided circles. The R. A. circle is movable and at the beginning of a night's work is set by pointing on any known star. Any telescopic star can then be found by setting the R. A. and Decl. verniers directly, without the trouble of keeping sidereal time and subtracting to find the hour angle, as must be done where the R. A. circle is fixed. The special advantage of a reflector of short focal length is that the eye-piece can always be brought nearly or quite to the level of the eye and to a horizontal position, so that the observer can look straight forward and be spared the fatigue of crooking his neck into an uncomfortable position. The best observations can always be made near the zenith, but zenith work is very trying with a refractor, while with a reflector it is quite convenient. A six-inch reflector is commonly rated as equal in light gathering power to a five-inch refractor, but the loss of light, about four-tenths of a magnitude, between six and five inches is fully made up by the convenience of zenith observations, since fully four-tenths of a magnitude is absorbed by the atmosphere at a zenith distance of 50°. My mirror has been in use nearly two years without resilvering or even repolishing, and yet I can detect no deterioration.

Charts for five more variables are presented this month. These stars will be in convenient position for evening observation in March and April. 320, U Cephei is one of the most interesting of the Algol type variables; as it decreases very rapidly, losing two magnitudes in about two hours. It is then stationary for about two hours and rises to its usual brightness in the same interval of time. The predicted times of minima are given in the latter part of each number of POPULAR ASTRONOMY. The minima will occur in the evening in March, so that observations will be convenient, and they are needed.



2815, U Geminorum is a wonderful star. Usually the 13th magnitude, once in about three months it rises rapidly to the 9th magnitude, then decreases more slowly to the 13th, the whole operation occupying two or three weeks. Its last maximum occurred 1893, Dec. 8, another may be looked for some time in March or April. There are four 11 to 12 magnitude stars within 10′ of the place, but anything as bright as the 10th magnitude will be the variable. Three inches aperture will be needed to deal with it. The place should be examined every clear evening to catch it on the rise, as it sometimes springs to a maximum in less than two days.





4805, W. Virginis is one of the shortest of the "long period" variables. 4816 and 5675 are now faint but will be increasing in the spring and at their maxima in the early summer. They will require 3 or 4 inches aperture in March, and 2 or 3 inches in April and May.

The severe winter weather has restricted the observation of variables, but when spring opens the work will be comfortable and fascinating. For those who wish to begin observing in March I would recommend the selection of three or four stars from the lists given in this and the preceding numbers, observing them at intervals of a few days and adding to the list as practice gives facility. Three inches aperture will suffice in the spring to deal with 793, 814 and 1855 (see January number), four inches will be needed for 5157 (see February number). These with the five charted in this number, give nine variables available for evening work with small telescopes. Mira, from which some have

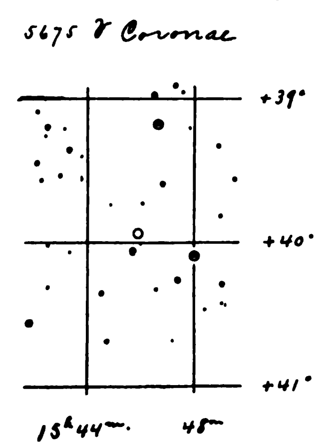


PLATE XVII.

RICHARD ANTHONY PROCTOR.
(1837–1888.)

been expecting so much, is not likely to be visible to the naked eye at its maximum this month (February.)

The following data are taken from Chandlers "Second Catalogue of Variable Stars:"

No.	Star.	1900. R. A.	Decl.	Red-ness	Magnitude Max.	Min.	Period days.
		h m s	° ′				
320	U Cephei	0 53 23	+81 20.2	0	7.1	9.2	2.49
2815	U Geminorum	7 49 10	+22 15.8	0.0	8 9–9.7	13.1	Irreg.
4805	W Virginis	13 20 52	− 2 51.6	0.4	8.7–9.2	9.8–10.4	17.27
4816	V Virginis	13 22 38	− 2 39.2	2.7	8.0–9.0	<13	250.5
5675	V Coronæ	15 45 57	+39 52.3	5.9	7.2–7.7	10.3–12	356.5

MARENGO, ILL.
1894, Feb. 2.

RICHARD A. PROCTOR.

CHARLOTTE R. WILLARD.

At a time when men of affairs as truly as men of science turn with increasing interest to the subject of Astronomy, no small importance attaches to the character and work of the man of whom Professor Young could say, "As an expounder and popularizer of science he stands, I think, unrivaled in English literature."

Richard A. Proctor was born in Chelsea, England, in the year 1837. He was the youngest of four children in a home where learning and refinement greatly influenced the character of later years. Living much in his father's library, at the age of eleven we find him familiar with works of Guizot, Gibbon, Euclid, Shakespeare and Dickens. At the age of nineteen he entered St. John's College, Cambridge. That his attention was not especially turned to mathematics or astronomy during his college career is evident from the following statement from his own pen. "I left Cambridge after taking a respectable degree, with just so much mathematics as I cared to pick up in the time I could spare from literature and from athletic exercises which I thought desirable for my health, then rather delicate. I had read absolutely nothing in astronomy as a science, not imagining then how full of interest that science would one day be to me."

It had been his mother's wish and his own expectation that he should enter the church of England. Finding that this could not be, he considered Law as his possible profession, but at length became an accountant in a London bank. While still in college he had married an Irish lady, and perhaps that fact led him at this time to make his home near Dublin.

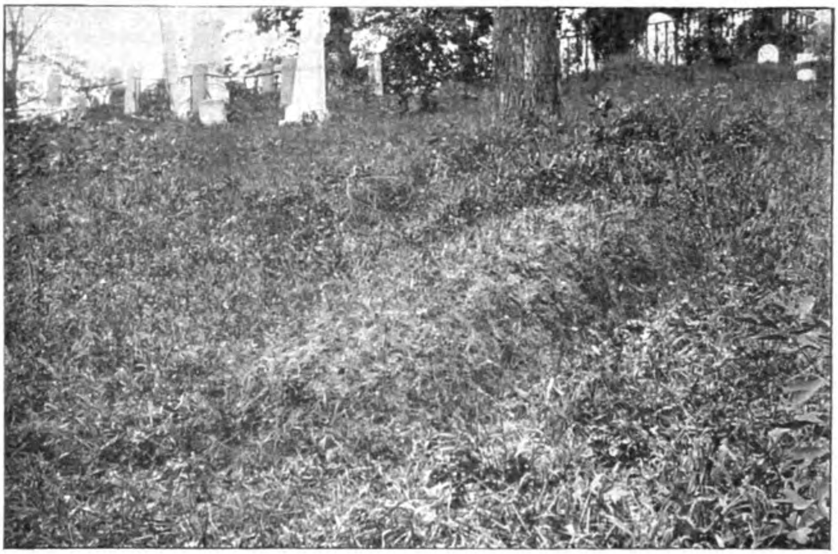
The chance finding of two astronomical books, Nichols' "Architecture of the Heavens" and Mitchell's "Popular Astronomy," at a Glasgow bookstand turned his thoughts in the direction which determined the character of his later work. As his interest in astronomy increased, he tells us that he became possessed of a desire to fit himself to be the teacher of mathematics and astronomy not of schools or popular audiences, but of his eldest son, then two years old.

The first work which Mr. Procter published was a paper on "The Colors of Double Stars," which appeared in the Cornhill Magazine in 1863, and for which the author received fifty dollars. This short paper of nine pages represented six weeks' labor, sometimes not more than four or five lines having been completed in a day. His first book, "Saturn and Its System," was favorably received by scientific men, but proved a financial burden at a time when he especially needed remuneration. The years which followed were full of varied activities. One of his greatest undertakings was the "Charting of 324,000 stars contained in Argelander's Great Catalogue showing the relations of stars down to the 11th magnitude with the Milky Way and its subsidiary branches." He made a careful study of the rotation period of Mars. An idea of the scope of his work may be gained through the following partial list of his writings: Star Distribution, The Construction of the Milky Way, The Distribution of Nebulæ and Star Clusters, The Proper Motion of the Stars, The General Constitution of the Heavens, Geometry of Cycloids, Half-hours with the Telescope and Stars, Light Science for Leisure Hours, Births and Deaths of Worlds, Border Land of Science, The Expanse of Heaven, Myths and Marvels of Astronomy, Our Place Among Infinities, Flowers of the Sky, Poetry of Astronomy; also, Health and Happiness, Watched by the Dead, Mental Phenomena, Luck and Chance, Athletics.

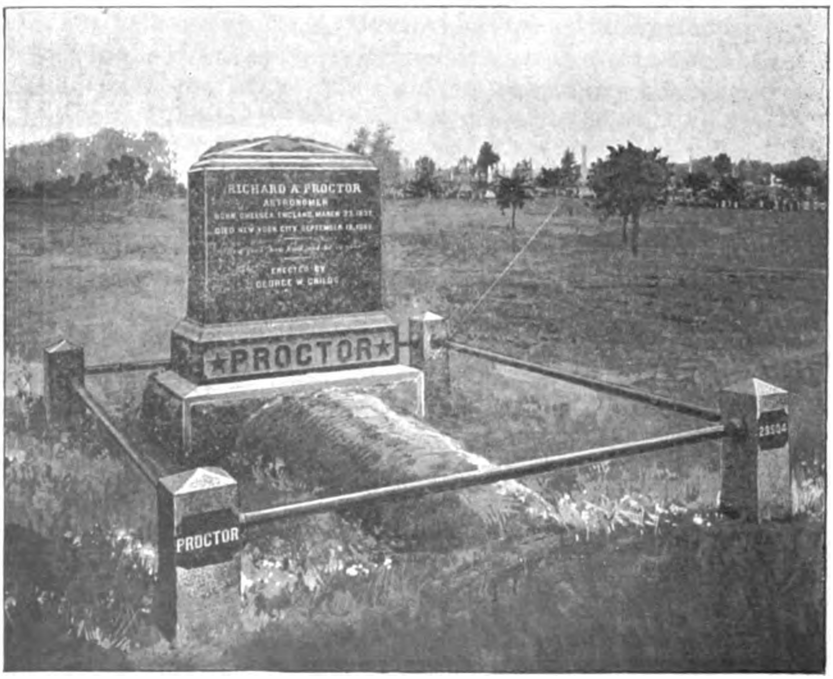
During the last years of his life he was editor of *Knowledge*. Perhaps his most important work was "The Old and New Astronomy" with which he was occupied at the time of his death. It has since been completed by Mr. A. C. Ranyard, the present editor of *Knowledge*.

In 1872 Mr. Procter became secretary of the Royal Astronomical Society of Great Britain, having been previously elected fellow

PLATE XVIII.



VIEW OF FIRST PLACE OF INTERMENT.



MONUMENT ERECTED BY GEORGE W. CHILDS TO THE MEMORY OF RICHARD A. PROCTOR, OCTOBER, 1893.

GREENWOOD CEMETERY, BROOKLYN, N. Y.

POPULAR ASTRONOMY, March, 1894.

From Photographs by Wm. Gray, Brooklyn, N. Y.

of that society. Between the years 1873–1884 he made extensive and successful lecturing tours in the United States, Great Britain and the British Colonies.

In 1884, at the close of a long lecture season in the United States, he purchased a home in St. Joseph, Missouri, and a winter residence at Lake Lawn, Florida. In social life Mr. Proctor was a genial, entertaining companion and a firm friend. As a conversationalist he had exceptional gifts.

On the eighth of September, 1888, Mr. Proctor left his winter home, intending to sail for Europe a week later. In New York he was taken violently ill, and two days after his arrival died of yellow fever in one of the hospitals of that city. As there was no opportunity for friends to choose for him a permanent resting place, a temporary interment was made in the undertaker's lot in Greenwood Cemetery. Here his body remained for five years in a wild, uncared-for spot, unnamed and unhonored. His children earnestly desired to provide a suitable lot and monument to honor their father's memory, but had not the necessary means. Interested friends mentioned the matter to Mr. Geo. W. Childs of Philadelphia, and he with characteristic sympathy and liberality made provision for the work. Through the kindness of William Gray, Photographer, 433 Fulton Street, Brooklyn, N. Y., and the advice of Mr. Childs, we are able to present two Greenwood views, the one showing the spot where Mr. Proctor was first buried, the other, his present resting place and the monument erected by Mr. Childs.

As these lines are being written we receive the sad news of Mr. Childs' death. We would pause to join with many on two continents in a tribute of honor to the memory of this man who was the friend of all science, and a source of power in its progress.

Five of Mr. Proctor's children survive him: Mary Proctor, a writer and lecturer on Astronomy who is now a resident of New York City; Agnes M. Proctor, a student in Baird College; John M. Proctor of Portland, Oregon; Richard J. Proctor of Denver, Colorado; and Henry Proctor of Brighton, England. The material for this sketch was kindly provided by Miss Mary Proctor.

A PHOTOGRAPH OF THE PLEIADES AND TWO ASTEROIDS.

H. C. WILSON.

A photographic plate was exposed to the Pleiades for four hours on the night of Jan. 30, by the writer at Goodsell Observatory. The telescope used has an 8-inch objective with three lenses by the Clarks. It was driven by clock-work and the errors produced by irregular driving and refraction were corrected every minute or two by the observer, who was looking through a 5-inch finder at the star Alcyone, keeping it continually bisected by two cross-wires. As a result a very fine picture was obtained of the nebula involving nearly the whole group of bright stars and exhibiting marvelous details of structure resembling those of the great nebula of Orion. The curious straight lines of nebulosity running in some cases from star to star are shown, but are not quite so narrow and hard-edged as shown in the reproductions of previous photographs. The connection of the nebula with the brighter stars of the Pleiades is so obvious that one could hardly doubt it after inspecting the photograph.

All the star images are round and well defined, the very faintest star visible in our 16-inch telescope being easily seen on the plate, while many more can be made out with a magnifying glass.

Among the stars on the plate were found two straight lines, each about 1.2 mm. long, having, aside from their length, the same structure as the star images. These were at once suspected to be minor planets which, because of their motion during the four hours of exposure, impressed lines instead of round dots upon the plate. When these were examined under the microscope a gap was found in the middle of each trail corresponding to the five minutes in the middle of the exposure, when the plate was covered in order that the driving clock might be wound and the telescope readjusted. This completely verified the supposition that the lines were the trials of minor planets. The same asteroids were photographed again, one of them on Feb. 1 and both on Feb. 3. We have measured their approximate positions from the three photographs obtaining the following results:

Asteroid.	Central Time.			R. A.			Decl.		
		h	m	h	m	s	°	′	″
a.	Jan. 30	9	22	3	38	13.2	+23	27	49
	Feb. 1	7	32	3	39	27.5	+23	28	57
	Feb. 3	8	30	3	40	51.6	+23	30	38
b.	Jan. 30	9	22	3	41	24.6	+24	50	29
	Feb. 3	8	30	3	44	17.0	+24	54	43

The brightness of an asteroid is somewhat difficult to estimate from the trail, since the rate of its motion as well as the duration of exposure enters as a factor into the intensity of the trail. As an approximation we may divide the trail into parts equal in length to the diameter of star images of the same intensity. The ratio of brightness will be the number of parts thus obtained. It remains then to determine the brightness of the stars thus used for comparison.

In the present case the asteroid trail *a* was found to be equal to ten stars whose magnitude was estimated to be 14 on Argelander's scale. This according to the usual formula would give the magnitude of *a* as $14 - 2.5 \log 10 = 11.5$. Asteroid *b* was found to be equal to twelve stars of the fifteenth magnitude, its resulting magnitude being $15 - 2.5 \log 12 = 12.3$.

The identification of an asteroid in the list of nearly four hundred is something of a task unless an accurate ephemeris happens to have been computed for that particular one for the time of the observation. A large number of such ephemerides is published in the *Berliner Jahrbuch*. Each covers, however, only one month near the time when the planet is at opposition, and in the present case the region photographed was not opposite the Sun. Another table in the *Jahrbuch* gives the time of opposition, and the right ascension and declination at that time, of each minor planet. A little study of this table will generally enable the observer to exclude all but five or six of the known asteroids as too far from the given region. For the remaining number is necessary to calculate the latitude and longitude or right ascension and declination of each from the elements of their orbits, in order to compare them with the same coordinates measured from the photograph. Where the elements have been brought up to date, this process is not so very difficult, but when the elements given belong to an epoch several years back it is necessary to calculate the perturbations of the orbits by the large planets, a process involving much labor.

In this instance the asteroids Nos. (33), (184), (196), (203), (207), (235) and (309) were found by inspection to be somewhere in the vicinity of the region of sky photographed. The calculation of the latitudes and longitudes, however, showed that only

(203) was within the region of the photograph, its place falling within 3^m of longitude and 5′ of latitude of that of *a*. The two were therefore assumed to be the same. The asteroid *b* is probably a new one, although it is possible that perturbations which were not allowed for in reducing the elements of (207) and (309) from 1889 and 1890 respectively to 1894 may have sufficiently changed their orbits to bring one or the other of them into the place of *b*.

TWO NEW VARIABLE STARS.*

M. FLEMING.

A recent examination of the photographs of stellar spectra forming part of the Henry Draper Memorial work at the Harvard College Observatory, Cambridge, has led to the discovery that the stars A.G.C. 157 in R.A. 0^h $10^m.4$, Dec. — 32° 36′, Magn. 8, and B.D. + 1° 3417 in R.A. 17^h $14^m.5$, Dec. + 1° 37′, Magn. 9.5 are variable. The first named star is in the constellation Sculptor and its magnitude varies from 6.5 to 10. The second is in the constellation Ophiuchus and it varies from the magnitude 8.5 to 12.5. The approximate positions for 1900 are those given above.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., Feb. 13, 1894.

PLANET NOTES FOR APRIL.

H. C. WILSON.

Mercury will be "morning star" during April, and will be at greatest elongation, west from the Sun 27° 40′, on the tenth of the month. Mercury will be in conjunction with the Moon April 3 at 5^h 37^m P. M. central time.

Venus is also "morning star" and is nearing greatest elongation west from the Sun. The greatest distance from the Sun, 46° 10′, will be reached on the morning of April 27. This will be a favorable month, so far as position is concerned, for the study of the surface markings of Venus, although the fact that she is only visible in the morning will be a drawback to all but the most enthusiastic amateurs. On the morning of April 5 Venus will be near the star α Aquarii, conjunction in right ascension occurring at 2^h 17^m A. M. central time. Venus will then be 19′ south of the star. The illuminated portion of her disc will increase during the month from one third to one half, while her brilliancy will decrease in the ratio of 195 to 139.

* Communicated by Edward C. Pickering, Director of Harvard College Observatory.

Mars improves a little in position during April, but it will not yet pay to spend much time in trying to observe this planet. He will move eastward and northward through the center of the constellation Capricornus. As he is brighter than any of the stars in the constellation it would not be difficult to identify him without the ruddy color which makes him so conspicuous. Mars will be in conjunction with the Moon April 29 at 1 A. M.

Jupiter will be pretty low in the west during the observing hours of April, but some satisfactory views may yet be obtained. He is moving slowly eastward south of the Pleiades. Jupiter will be in conjuction with the Moon, 5° south, April 9 at 5 A. M.

Saturn and *Spica* (α Virginis) make a fine pair in the south in the morning. They are nearly equal in brilliancy but differ a little in color, Saturn having a golden hue while Spica is bluish white. Saturn is retrograding, that is moving westward, and at the end of April will be almost directly north of Spica. He will be at opposition April 11 at noon. The moon will pass by Saturn, 4° to the south, April 10 at 9^h 28^m P. M.

Uranus is toward the southeast from Saturn in the constellation Libra. On the morning of the 27th at 7^h 11^m he will be in conjunction with the second magnitude star α Libræ, being only 4′ north of the brighter component of that star which is a wide double. The motion of Uranus is so slow that he will be in the vicinity of the star for several days, so that this will be an excellent opportunity for the amateur to be sure that he has seen this planet. Note the green color and the visibility of a definite disc.

Neptune may be observed in the early evening but has past the most favorable position. He is about half way between ι and ε in the constellation Taurus.

Planet Tables for April.

[The times given are local time for Northfield. To obtain Standard Times for Place in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Apr. 5	23 21.7	− 5 35	4 47 A. M.	10 25.9 A. M.	4 05 P. M.
15	23 58.8	− 2 52	4 31 "	10 23.5 "	4 16 "
25	0 49.0	+ 2 20	4 22 "	10 34.4 "	4 47 "
			VENUS.		
Apr. 5	22 12.1	− 8 36	3 47 A. M.	9 16.6 A. M.	2 46 P. M.
15	22 44.8	− 6 53	3 34 "	9 09.7 "	2 46 "
25	23 20.6	− 4 22	3 20 "	9 06.1 "	2 52 "
			MARS.		
Apr. 5	20 33.6	− 19 56	2 58 A. M.	7 38.3 A. M.	12 19 P. M.
15	21 02.7	− 18 14	2 40 "	7 28.0 "	12 16 "
25	21 31.1	− 16 18	2 20 "	7 17.1 "	12 14 "
			JUPITER.		
Apr. 5	3 54 5	+ 19 43	7 32 A. M.	2 58.0 P. M.	10 24 P. M.
15	4 02.9	+ 20 09	6 59 "	2 27.0 "	9 55 "
25	4 11.9	+ 20 35	6 26 "	1 56.5 "	9 27 "
			SATURN.		
Apr. 5	13 26.5	− 6 06	6 49 P. M.	12 28.3 A. M.	6 07 A. M.
15	13 23.6	− 5 48	6 05 "	11 46.1 P. M.	5 27 "
25	13 20.8	− 5 32	5 22 "	11 04.0 "	4 46 "

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			URANUS.		
Apr. 5	14 48.4	− 15 47	8 51 P. M.	1 49.9 A. M.	6 49 A. M.
15	14 46.9	− 15 40	8 09 "	1 09.1 "	6 09 "
25	14 45.3	− 15 33	7 28 "	12 28.2 "	5 28 "
			NEPTUNE.		
Apr. 5	4 40.0	+ 20 41	8 12 A. M.	3 43.3 P. M.	11 14 P. M.
15	4 41.0	+ 20 44	7 34 "	3 05.1 "	10 36 "
25	4 42.3	+ 20 46	6 56 "	2 27.0 "	9 58 "
			THE SUN.		
Apr. 5	0 58.7	+ 6 16	5 34 A. M.	12 02.6 P. M.	6 31 P. M.
15	1 35.5	+ 9 57	5 17 "	11 59.9 A. M.	6 43 "
25	2 12.8	+ 13 22	5 00 "	11 57.8 "	6 55 "
			THE MOON.		
Apr. 1	21 26.4	− 19 30	4 03 A. M.	8 46.6 A. M.	1 39 P. M.
3	23 03.0	− 8 40	4 35 "	10 15.2 "	4 08 "
5	0 38.8	+ 4 12	5 21 "	11 42.8 "	6 19 "
7	2 22.6	+ 16 52	6 02 "	1 18.4 P. M.	8 51 "
9	4 22.8	+ 26 06	7 01 "	3 10.5 "	11 33 "
11	6 36.6	+ 28 28	8 43 "	5 16.0 "	1 45 A. M.
13	8 45.5	+ 22 53	11 12 "	7 16.6 "	3 06 "
15	10 37.5	+ 11 51	1 50 P. M.	9 00.5 "	3 54 "
17	12 17.5	− 1 19	4 19 "	10 32.4 "	4 32 "
19	13 55.1	− 13 51	6 42 "	12 01.9 A. M.	5 10 "
21	15 38.2	− 23 27	9 04 "	1 36.8 "	6 02 "
23	17 28.7	− 28 16	11 16 "	3 19.1 "	7 20 "
26	19 20.3	− 27 22	12 57 A. M.	5 02.6 "	9 11 "
28	21 05.0	− 21 18	2 04 "	6 39.2 "	11 23 "
30	22 41.6	− 11 17	2 48 "	8 07.6 "	1 38 P. M.

Phases and Aspects of the Moon.

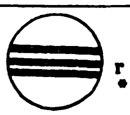
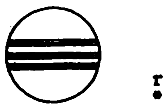
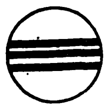
	Central Time. d	h m
New Moon	Apr. 5	10 00 P. M.
Perigee	" 10	9 40 P. M.
First Quarter	" 12	6 32 P. M.
Full Moon	" 19	9 02 P. M.
Apogee	" 26	1 55 A. M.
Last Quarter	" 27	9 21 P. M.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

Date	h m	Date	h m	Date	h m
Apr. 1	7 26 P. M.	Apr. 11	5 40 P. M.	Apr. 21	3 54 P. M.
2	3 17 "	12	11 27 "	22	9 41 "
3	9 04 "	13	7 18 "	23	5 32 "
4	4 55 "	14	3 09 "	24	11 19 "
5	10 42 "	15	8 56 "	25	7 10 "
6	6 33 "	16	4 47 "	26	3 02 "
7	2 24 "	17	10 34 "	27	8 48 "
8	8 11 "	18	6 25 "	28	4 40 "
9	4 02 "	19	2 16 "	29	10 26 "
10	9 49 "	20	8 03 "	30	6 18 "

Jupiter's Satellites for April.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.		III.	
II.		IV.	 No Eclipse.

Configuration at 7h for an Inverting Telescope.

Day.	West.		East.
1	O1· 4· ·3 ·2	O	
2	4·	.O$_3$	·1 ·2
3	·4 1·	O	2· ·3
4	·4 2·	O	·1 3·
5	·4 ·1	O	3· ·2●
6	3· ·4	O	·1 2·
7	3· 2· ·1	O	·4
8	·3 ·2	O	1· ·4
9	·3	O	·2 ·4 ·1●
10	1·	O	2· ·3 ·4
11	2·	O	·1 ·3 4·
12	1·	O	3· 4· ·2●
13	3·	O	1· 2· 4·
14	3· 2· ·1	O	4·
15	·3 ·2 4·	O	1·
16	4· ·3 ·1	O	·2
17	·4 1·	O	2· ·3
18	4· 2·	O	·1 ·3
19	·4 1· ·2	O	3·
20	O3· ·4	O	·1 ·2
21	·4 3· ·1 2·	O	
22	·3 ·4 ·2	O	1·
23	·3 ·1 ·4	O	2·
24	O1·	O	·32· ·4
25	2·	O	·1 ·3 ·4
26	1· ·2	O	3· ·4
27		O	3· ·1 ·2 ·4
28	O2· 3· 1·	O	4·
29	3· ·2	O	1· 4·
30	·3 ·1	O	·2 4·

Phenomena of Jupiter's Satellites.

Central Time.

Date	h	m		Sat.	Phenomenon
Apr. 1	5	54	P. M.	I	Tr. In.
	6	54	"	I	*Sh. In.
	8	08	"	I	*Tr. Eg.
	9	07	"	I	Sh. Eg.
2	2	01	A. M.	II	Oc. Dis.
	6	21	"	II	Ec. Re.
	3	16	P. M.	I	Oc. Dis.
	6	26	"	I	*Ec. Re.
	7	24	"	III	*Oc. Dis.
	9	37	"	III	Oc. Re.
	11	32	"	III	Ec. Dis.
3	1	24	A. M.	III	Ec. Re.
	12	25	P. M.	I	Tr. In.
	1	23	"	I	Sh. In.
	2	38	"	I	Tr. Eg.
	3	36	"	I	Sh. Eg.
	9	14	"	II	Tr. In.
	11	10	"	II	Sh. In.
	11	40	"	II	Tr. Eg.
4	1	34	A. M.	II	Sh. Eg.
	9	46	"	I	Oc. Dis.
	12	54	P. M.	I	Ec. Re.
5	6	55	A. M.	I	Tr. In.
	7	51	"	I	Sh. In.
	9	08	"	I	Tr. Eg.
	10	05	"	I	Sh. Eg.
	3	25	P. M.	II	Oc. Dis.
	7	39	"	II	*Ec. Re.
6	4	16	A. M.	I	Oc. Dis.
	7	23	"	I	Ec. Re.
	9	41	"	III	Tr. In.
	11	54	"	III	Tr. Eg.
	1	31	P. M.	III	Sh. In.
	3	36	"	III	Sh. Eg.
7	1	25	A. M.	I	Tr. In.
	2	20	"	I	Sh. In.
	3	38	"	I	Tr. Eg.
	4	34	"	I	Sh. Eg.
	10	38	"	II	Tr. In.
	12	29	P. M.	II	Sh. In.
	1	04	"	II	Tr. Eg.
	2	53	"	II	Sh. Eg.
	10	46	"	I	Oc. Dis.
8	1	52	A. M.	I	Ec. Re.
	7	55	P. M.	I	*Tr. In.
	8	49	"	I	Sh. In.
	10	09	"	I	Tr. Eg.
	11	03	"	I	Sh. Eg.
9	4	49	A. M.	II	Oc. Dis.
	8	58	"	II	Ec. Re.
	5	16	P. M.	I	Oc. Dis.
	8	21	"	I	*Ec. Re.
	11	48	"	III	Oc. Dis.
10	2	02	A. M.	III	Oc. Re.
	3	33	"	III	Ec. Dis.
	5	26	"	III	Ec. Re.
	2	25	P. M.	I	Tr. In.
	3	18	"	I	Sh. In.
	4	39	"	I	Tr. Eg.
	5	31	"	I	Sh. Eg.
11	12	02	A. M.	II	Tr. In.
Apr. 11	1	47	A. M.	II	Sh. In.
	2	28	"	II	Tr. Eg.
	4	11	"	II	Sh. Eg.
	11	47	"	I	Oc. Dis.
	2	50	P. M.	I	Ec. Re.
12	8	56	A. M.	I	Tr. In.
	9	47	"	I	Sh. In.
	11	09	"	I	Tr. Eg.
	12	00	M.	I	Sh. Eg.
	6	13	P. M.	II	*Oc. Dis.
	10	17	"	II	Ec. Re.
13	6	17	A. M.	I	Oc. Dis.
	9	19	"	I	Ec. Re.
	2	05	P. M.	III	Tr. In.
	4	19	"	III	Tr Eg
	5	31	"	III	Sh. In.
	7	38	"	III	*Sh. Eg
14	3	26	A. M.	I	Tr. In.
	4	16	"	I	Sh. In.
	5	39	"	I	Tr. Eg.
	6	29	"	I	Sh. Eg.
	1	26	P. M.	II	Tr. In.
	3	05	"	II	Sh. In.
	3	52	"	II	Tr. Eg.
	5	30	"	II	Sh. Eg.
15	12	47	A. M.	I	Oc. Dis
	3	47	"	I	Ec. Re.
	9	56	P. M.	I	Tr. In.
	10	44	"	I	Sh. In.
16	12	10	A. M.	I	Tr. Eg.
	12	58	"	I	Sh. Eg.
	7	37	"	II	Oc. Dis.
	11	35	"	II	Ec. Re.
	7	18	P. M.	I	*Oc. Dis.
	10	16	"	I	Ec Re.
17	4	13	A. M.	III	Oc. Dis.
	6	28	"	III	Oc. Re.
	7	34	"	III	Ec Dis.
	9	28	"	III	Ec. Re.
	4	26	P. M.	I	Tr. In.
	5	13	"	I	Sh. In.
	6	40	"	I	*Tr. Eg.
	7	27	"	I	*Sh. Eg.
18	2	50	A. M.	II	Tr. In.
	4	24	"	II	Sh. In.
	5	17	"	II	Tr. Eg.
	6	48	"	II	Sh. Eg.
	1	48	P. M.	I	Oc. Dis.
	4	45	"	I	Ec. Re.
19	10	57	A. M.	I	Tr. In.
	11	42	"	I	Sh. In.
	1	11	P. M.	I	Tr. Eg.
	1	55	"	I	Sh. Eg.
	9	02	"	II	Oc. Dis.
20	12	54	A. M.	II	Ec. Re.
	8	18	"	I	Oc. Dis.
	11	11	"	I	Ec. Re.
	6	32	P. M.	III	*Tr. In.
	8	48	"	III	Tr. Eg.
	9	34	"	III	Sh. In.
	11	41	"	III	Sh. Eg.

Apr. 21	5 27	A. M.	I	Tr. In.
	6 11	"	I	Sh. In.
	7 41	"	I	Tr. Eg.
	8 24	"	I	Sh Eg.
	4 15	P. M.	II	Tr. In.
	5 42	"	II	Sh. In.
	6 41	"	II	*Tr Eg.
	8 07	"	II	Sh. Eg.
22	2 49	A. M.	I	Oc. Dis.
	5 43	"	I	Ec Re.
	11 57	P. M.	I	Tr. In.
23	12 39	A. M.	I	Sh. In.
	2 11	"	I	Tr. Eg.
	2 53	"	I	Sh. Eg.
	10 27	"	II	Oc. Dis.
	2 13	P. M.	II	Ec. Re.
	9 19	"	I	Oc. Dis.
24	12 11	A. M.	I	Ec. Re.
	8 40	"	III	Oc. Dis.
	10 55	"	III	Oc. Re.
	11 34	"	III	Ec. Dis.
	1 30	P. M.	III	Ec. Re.
	6 28	"	I	*Tr. In.
	7 08	"	I	*Sh. In.
	8 42	"	I	Tr. Eg.
	9 22	"	I	Sh. Eg.
25	5 39	A. M.	II	Tr. In.
	7 00	"	II	Sh. In.
	8 06	"	II	Tr. Eg.
	9 25	"	II	Sh. Eg.
	3 49	P. M.	I	Oc. Dis.
Apr. 25	26 40	P. M.	I	*Ec. Re.
26	12 58	"	I	Tr. In.
	1 37	"	I	Sh. In.
	3 12	"	I	Tr. Eg.
	3 50	"	I	Sh. Eg.
	11 51	"	II	Oc. Dis.
27	3 31	A. M.	II	Ec. Re.
	10 20	"	I	Oc. Dis.
	1 09	P. M.	I	Ec. Re.
	11 00	"	III	Tr. In.
28	1 16	A. M.	III	Tr. Eg.
	1 34	"	III	Sh. In.
	3 48	"	III	Sh. Eg.
	7 29	"	I	Tr. In.
	8 06	"	I	Sh. In.
	9 43	"	I	Tr. Eg.
	10 19	"	I	Sh. Eg.
	7 04	P. M.	II	*Tr. In.
	8 18	"	II	Sh. In.
	9 31	"	II	Tr. Eg.
	10 43	"	II	Sh. Eg.
29	4 50	A. M.	I	Oc. Dis.
	7 38	"	I	Ec. Re.
30	1 59	"	I	Tr. In.
	2 34	"	I	Sh. In.
	4 13	"	I	Tr. Eg
	4 48	"	I	Sh. Eg.
	1 17	P. M.	II	Oc. Dis.
	4 50	"	II	Ec. Re.
	11 21	"	I	Oc. Dis.
May 1	2 06	A. M.	I	Ec. Re.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc. denotes occultation; Tr., transit of the satellite; Sh., transit of the shadow; * Visible at Washington.

Annular Eclipse of the Sun, April 5, 1894.—This will not be visible in the United States. The path of the annular eclipse passes from a point in the Persian Gulf, across Hindostan and China, along the east coast of Siberia, ending in Alaska. It will be visible as a partial eclipse throughout Asia, north-eastern Europe and parts of the Indian and Pacific Oceans.

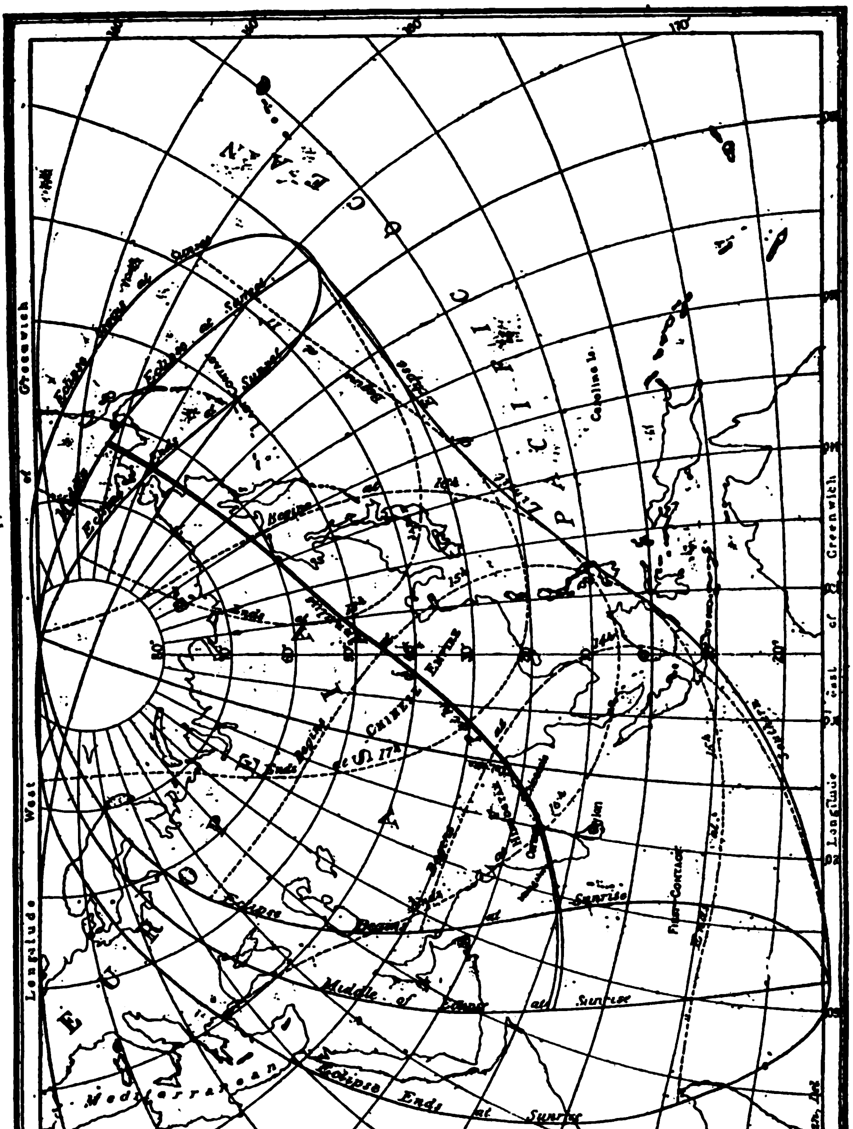
ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension
April 5, 16^h 27^m $39^s.2$

Sun and Moon's R. A.	1^h 00^m $16^s.90$	Hourly motions	$9^s.14$ and 121^s 28
Sun's declination	6° 26′ 11″.6 N.	Hourly motion	0′ 56″ 7 N.
Moon's declination	7 03 48 .5 N.	Hourly motion	15 53 7 N.
Sun's equa. hor. par.	8 .6	Sun's true diameter	15 58 .6
Moon's equa. hor. par.	57 52 .5	Moon's true diameter	15 45 5

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Time	Long. from Greenwich.	Latitude.
Eclipse begins April 5,	13^h $15^m.9$	72° 24′.2 E.	6° 33′.6 S.
Central eclipse begins	14 24 .0	53 51 .8 E.	6 47 .4 N.
Central eclipse at noon	16 27 .7	113 42 .5 E.	47 22 .3 N.
Central eclipse ends	17 23 .3	157 30 .7 W.	62 47 5 N.
Eclipse ends	18 31 .5	179 34 .2 W.	49 44 .5 N.



ANNULAR ECLIPSE OF APRIL 5TH 1894.

Elongations of the Satellites of Saturn.

[In the diagram the points marked 0 are those of eastern elongation of the several satellites. Their positions at intervals of one day after eastern elongation are indicated by the symbols 1*d*, 2*d*, etc.]

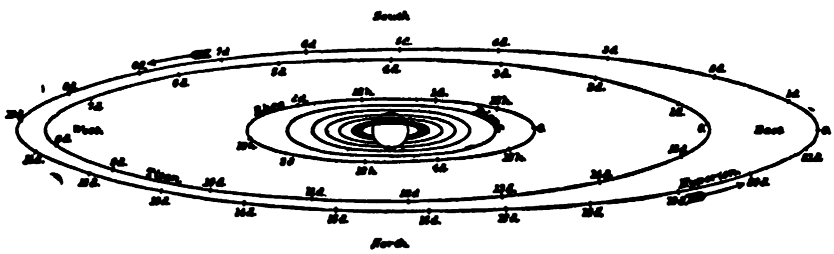


DIAGRAM OF THE APPARENT ORBITS OF SATURN'S SATELLITES.

MIMAS.

		h		
Apr.	4	2.7	A. M.	E
	5	1.3	"	E
	5	11.9	P. M.	E
	6	10.5	"	E
	7	9.1	"	E
	8	7.7	"	E
	9	6.3	"	E
	10	4.9	"	E
	11	3.5	"	E
	12	2.9	A. M.	W
	13	1.5	"	W
	14	12.1	"	W
	14	10.8	P. M.	W
	15	9.4	"	W
	16	8.0	"	W
	17	6.6	"	W
	18	5.2	"	W
	19	3.8	"	W
	20	3.2	A. M.	E
	21	1.8	"	E
	22	12.4	"	E
	22	11.0	P. M.	E
	23	9.6	"	E
	24	8.2	"	E
	25	6.8	"	E
	26	5.4	"	E
	27	4.0	"	E
	28	2.6	"	E
	29	2.0	A. M.	W
	30	12 6	"	W
	30	11.3	P. M.	W

ENCELADUS.

Apr.	2	12.3	P. M.	E
	3	9.1	"	E
	5	6.0	A. M.	E
	6	2.9	P. M.	E
	7	11.8	"	E

ENCELADUS CONT.

		h		
Apr.	9	8.7	A. M.	E
	10	5.5	P. M.	E
	12	2.4	A. M.	E
	13	11.3	"	E
	14	8.2	"	E
	16	5.1	A. M.	E
	17	1.9	P. M.	E
	18	10.8	"	E
	20	7.7	A. M.	E
	21	4.6	P. M.	E
	23	1.5	A. M.	E
	24	10.3	"	E
	25	7.2	P. M.	E
	27	4.1	A. M.	E
	28	1.0	P. M.	E
	29	9.9	"	E

TETHYS.

Apr.	1	4.7	P. M.	E
	3	2.0	"	E
	5	11.3	A M.	E
	7	8.5	"	E
	9	5.8	"	E
	11	3.1	"	E
	13	12.4	"	E
	14	9.7	P. M.	E
	16	7.0	"	E
	18	4.3	"	E
	20	1.6	"	E
	22	10.9	"	E
	24	8.2	"	E
	26	5.5	"	E
	28	2.8	"	E
	30	12.1	"	E

DIONE.

Apr.	2	7.9	P. M.	E
	5	1.6	"	E
	8	7.3	A. M.	E

DIONE CONT.

		h		
Apr.	11	12.9	A. M.	E
	13	6.6	P. M.	E
	16	12.3	"	E
	19	6.0	A. M.	E
	21	11.6	P. M.	E
	24	5.3	"	E
	27	11.0	A. M.	E
	30	4.7	"	E

RHEA.

Apr.	3	12.6	A. M.	E
	7	1.0	P. M.	E
	12	1.4	A. M.	E
	16	1.7	P. M.	E
	21	2.1	A. M.	E
	25	2.5	P. M.	E
	30	2.9	A. M.	E

TITAN.

Apr.	1	5.4	A. M.	I
	5	8.4	"	W
	9	10.3	"	S
	13	5 0	"	E
	17	2.5	"	I
	21	5.5	"	W
	25	7.8	"	S
	29	2.5	"	E

HYPERION.

Apr.	1	4.0	A. M.	E
	7	11.2	"	I
	12	6.2	P. M.	W
	17	3.9	A. M.	S
	22	8.3	"	E
	28	3.9	P. M.	I

IAPETUS.

Apr.	9	9.0	A. M.	E
	27	9.2	"	I

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

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

Apr. 2	5 A. M.
4	4 P. M.
7	4 A. M.
9	4 P. M.
12	4 A. M.
14	4 P. M.
17	3 A. M.
19	3 P. M.
22	3 A. M.
24	3 P. M.
27	3 A. M.
29	3 P. M.

ALGOL.

R. A. .... $3^h\ 1^m\ 1^s$
Decl. .... $+40°\ 32'$
Period .... $2d\ 20^h\ 49^m$

Apr. 3	8 P. M.
6	5 "
9	2 "
12	11 A. M.
15	8 "
18	4 "
21	1 "
23	10 P. M.
26	7 "

R CANIS MAJORIS.

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

Apr. 1	2 P. M.
2	5 "
3	9 "
4	12 midn.
6	3 A. M.
7	6 "
8	10 "
9	1 P. M.
10	4 "
11	8 "
12	11 "
14	2 A. M.
15	5 "
16	8 "
17	12 noon.
18	3 P. M.
19	6 "
20	10 "
22	1 A. M.
23	4 "
24	7 "
25	11 "
26	2 P. M.
27	5 "
28	8 "
29	12 midn.

S CANCRI.

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

Apr. 3	12 midn.
13	12 noon.
23	12 midn.

S ANTLIÆ.

(Every third minimum.)

R. A. .... $9^h\ 27^m\ 30^s$
Decl. .... $-28°\ 09'$
Period .... $0d\ 7^h\ 47^m$

Apr. 1	8 P. M.
2	7 "
3	7 "
4	6 "
5	5 "
6	4 "
7	4 "
8	3 "
9	2 "
10	2 "
11	1 "
12	12 noon.
13	12 noon.
14	10 A. M.
15	4 "
16	10 "
17	9 "
18	9 "
19	8 "
20	7 "
21	7 "
22	6 "
23	5 "
24	5 "
25	4 "
26	3 "
27	3 "
28	2 "
29	1 "
30	1 "

δ LIBRÆ.

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

Apr. 2	7 P. M.
5	3 A. M.
7	11 "
9	7 P. M.
12	3 A. M.
14	10 "
16	6 P. M.
19	2 A. M.
21	10 "
23	6 P. M.
26	2 A. M.
28	10 "
30	6 P. M.

U CORONÆ.

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

Apr. 4	3 A. M.
7	2 P. M.
11	1 A. M.
14	12 noon
17	10 P. M.
21	9 A. M.
24	8 P. M.
28	7 A. M.

U OPHIUCHI.

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

Apr. 1	6 A. M.
2	2 "
2	10 P. M.
3	6 "
4	1 "
5	11 A. M.
6	7 "
7	3 "
7	11 P. M.
8	8 "
9	4 "
10	12 noon
11	8 A. M.
12	4 "
12	12 midn.
13	8 P. M.
14	4 "
15	1 "
16	9 A. M.
17	5 "
18	1 "
18	9 P. M.
19	5 "
20	1 "
21	9 A. M.
21	6 "
23	2 "
23	10 P. M.
24	6 "
25	2 "
26	10 A. M.
27	6 "
28	2 "
28	11 P. M.
29	7 "
30	3 "

Y CYGNI.

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

Apr. 1	1 P. M.
3	1 A. M.
4	1 P. M.

Y CYGNI CONT.		Y CYGNI CONT.		Y CYGNI CONT.	
Apr. 6	1 A. M.	Apr. 15	1 A. M.	Apr. 24	1 A. M.
7	1 P. M.	16	1 P. M.	25	1 P. M.
9	1 A. M.	18	1 A. M.	27	1 A. M.
10	1 P. M.	19	1 P. M.	28	1 P. M.
12	1 A. M.	21	1 A. M.	30	1 A. M.
13	1 P. M.	22	1 P. M.		

Occultations Visible at Washington.

Date 1894.		Star's Name.	Magnitude.	IMMERSION Washington M. T.		IMMERSION Angle f'm N pt.	EMERSION Washington M. T.		EMERSION Angle f'm N pt.	Duration.	
				h	m	°	h	m	°	h	m
Apr.	8	9 Tauri	7	8	17	74	9	12	266	0	55
	10	136 Tauri	5	12	35	160	12	55	209	0	20
	12	ω^2 Cancri	6	12	57	65	13	22	333	0	25

Maxima and Minima of Variable Stars.

MAXIMA			MINIMA		
April	1	R Herculis	April	5	X Bootis
	2	U Virginis		5	W Scorpii
	10	R Arietis		6	S Cygni
	11	V Leonis		13	R Canum Ven.
	12	X Scorpii		15	U Monocerotis
	14	V Capricorni		15	U Bootis
	16	L^2 Puppis		18	S Ursæ Maj.
	18	V Capricorni		19	R Lyræ
	20	U Capricorni		23	R Ursæ Maj.
				23	S Vulpeculæ
				25	S Piscium
				28	T Arietis

New Asteroids 1894 AQ, AR and AS.—These were discovered photographically by Charlois at Nice on the nights of Jan. 8 and 10. Their positions were as follows:

			G. M. T.	R. A.	Decl.	Daily motion	Mag.
			h m	h m s	° ′	′ ′	
1894	AQ	Jan. 8	9 25	7 21 48	+20 01	−48 +1	13
	AR	8	9 25	7 36 12	+24 10	−60 +4	13
	AS	10	10 45	8 33 16	+17 48	−44 +6	12.5

Numeration of the Asteroids of 1893.—Dr. A. Berberich who prepares the tables of Minor Planets for the *Berliner Jahrbuch* sends us the following note:

"You gave recently the numeration of the Minor Planets from *Astronomische Nachrichten* 3194. You will have seen, by *Bulletin Astronomique* Nov. and *Astr. Nach.* 3201, that No. 359 must be omitted, as 1893 L proves to be identical with (89) Julia. I took every precaution in order to avoid similar errors in computing the dates of oppositions for 1894, but it is impossible to vouch for the exactness of all of 240 ephemerides, only 60 of which are computed in duplicate.

"The later planets of 1893 receive the following numbers.

		Discovered by	
1893	AJ = 373	Charlois	Sept. 15
	AK = 374	"	Sept. 18
	AL = 375	"	Sept. 18
	AM = 376	"	Sept. 18
	AN = 377	"	Sept. 20
	AP = 378	"	Dec. 6

"The name 'Chicago,' chosen at the astronomical Congress for a minor planet, has been conferred by Professor M. Wolf upon the planet (334). This planet presents a good means of determining the mass of Jupiter. It undergoes very remarkable perturbations by that great planet. The planets (153) Hilda, (190) Ismene, (279) Thule and (361) are also exposed to considerable perturbations, but only in future times. A conjunction of Hilda and Jupiter some years ago coincided with the perihelion passage of Hilda so that the distance of the two bodies has been at a maximum.

"I find that the Watson planet (175) Andromache, rediscovered in 1893 by Charlois and photographed in 1892 by Wolf, was in proximity to Jupiter in 1886-87, being near aphelion and moving very slowly. As the period of (175) is nearly one-half of that of Jupiter that conjunction will be repeated every 11-12 years, in about the same position. The effect will be a retardation of the mean motion, probably of large amount. I think the moderately distant planets are of greater value for the determination of Jupiter's mass than those very remote, like Hilda, since the conjunctions with Jupiter are much more frequent. Thus in one century we may observe 8 conjunctions of Andromache but only 4 of Hilda and scarcely 3 of Thule, with Jupiter."

PRACTICAL SUGGESTIONS.

22. Why do astronomers use high magnifying power in looking at the fixed stars, since it is held that they are mere points of light without any sensible disc?

Answer.—It is true that all stars (except our Sun) are so far distant that the largest telescope has not power to show any real disc. What is seen is an intensely lighted spot, not a point of light, which astronomers call a spurious or diffraction disc. This false disc is probably due both to irradiation and the wave nature of light. Bright bodies on a dark background always appear larger than they really are however carefully measured; this effect is called irradiation.

In studying the stars by the aid of the telescope, the observer may wish to learn their colors, magnitudes, spectra, motions, binary nature or some other characteristic, and this spurious disc and its light are the given quantities in the problem. The disc consists of a bright center rapidly fading out to darkness at its edges, which is surrounded by a series of colored rings, the smallest of whic only is seen easily by those accustomed to observe the stars, yet any one may see it when attention is called to it under favorable circumstances. The diameter of this false disk varies inversely as the aperture or size of the object-glass, a fact which is somewhat troublesome to those who have not studied the wave theory of light. It may be here sufficient to say that astronomers can calculate the size of this ring-and-disc system from the known lengths of the waves of light and the diameter of the object-glass of the telescope, and that their computed and observed sizes agree very precisely. Now, if an observer wishes to examine the colors of bright stars even in good "seeing," he will ordinarily use low powers or none at all, because he has light enough at command. But when he wishes to try the fainter stars the case is different and magnifying power is needed. To understand how the telescope works in this regard, point it to the sky illuminated by daylight and notice the small circle of light on the lens of the eye-piece. That is the image of the object-glass. The ratio of the diameter of the object-glass to that of the small circle is the magnifying power of that particular eye-piece. The same eye-piece on telescopes of different sizes will cause this light circle to vary in size and brightness. Let s be the diameter of the circle, o the diameter of the object-glass and e the diameter of the pupil of the eye; then $\frac{o}{s}$ is the magnifying power. If $s = e$ the eye can use all the light from the celestial body if not too bright, which passes through the object-glass except small losses by reflection and absorption. The amount of light so received is $\left(\frac{o}{e}\right)^2$ times that which would be received by the naked eye. Also the apparent area of the circle is magnified $\left(\frac{o}{e}\right)^2$ which, since $s = e$, is the same as the increase of light. Hence brightness of the circle is the same as the naked illumination of the sky. If s is greater than e it can be shown that the same conclusion will follow. But the most common case in practice is when s is less than e; then no light is wasted and the pupil of the eye is filled. The light received is $\left(\frac{o}{e}\right)^2$ times that the naked eye would receive, and the magnification of the apparent area is $\left(\frac{o}{s}\right)^2$. The brightness of image then is to brightness of object seen by the naked eye as

$$\left(\frac{o}{e}\right)^2 : \left(\frac{o}{s}\right)^2, \text{ or as } s^2 : e^2;$$

that is, as the area of the circle to the area of the pupil of the eye. So that for real or extended surfaces of light under view, it is impossible by any optical arrangement to obtain an image whose brightness shall exceed that of the object itself. But this rule will not hold in regard to the brightness of stars in all particulars. They are really points of light and their images are due to the intensity of the light source as a point. If we call the light which a star sends to the naked eye unity, the light seen in its image will be $\left(\frac{o}{s}\right)^2$, if we neglect reflection and absorption in the path of the ray through the lenses, and it is the square of linear magnification if the false disc equals the pupil of the eye in diameter. But if the power is increased by change of eye-piece the disc will be diminished in size and thereafter the quantity of light remains unchanged being $\left(\frac{o}{e}\right)^2$. This expression is the measure of the space-penetrating power of the telescope, shown in revealing faint stars. Large apertures furnish great advantage in this respect. The visibility of faint stars in the telescope is also promoted by darkening the background of the sky surrounding the star which varies directly as s^2 and inversely as the magnifying power if s is less than e. Hence use high power for faint stars. But in the case of a faint comet or a faint nebula the low power is obviously needed for best results.

23. Is the illumination of the image of a star in the telescope altogether a function of the object-glass? W. B. H.

Answer.—No; see answer to number 22.

24. Capt. Wm. Noble in his book entitled *Hours with the three-inch Telescope*, recommends the use of power 160 in viewing stars like the companion of Polaris. Why not use a lower power? Your querist can not see that star with a 3½-inch glass with power as high as 160. W. B. H.

Answer.—The companion to Polaris should be easy in a three-inch telescope. Dawes proposed it as a general standard finding that a power of 80 on a two-inch glass would show it, if the eye and telescope are good. Other astronomers have seen it with less aperture. Amateurs must not be discouraged by what the keen-eyed, experienced professionals can do. Knowledge of the star's place and how it looks help much in such tests.

25. Professor Swift says (November number) that the great nebula of Andromeda is spectroscopically a star cluster. The Celestial Handbook by Poole Brothers says that spectrum analysis indicates that this nebula is entirely gaseous.

Answer.—The nebula of Andromeda is classed with the white nebulæ and the spectrum of it is continuous, and according to Young "perfectly expressionless," meaning by that, it is unmarked by any lines or bands, either bright or dark. Although the spectrum looks like that of a stellar cluster, a gaseous mass under pressure would appear in the same way. So also do masses of solid or liquid when heated to incandescence. Neither the spectroscope nor the telescope decide anything conclusively about the white nebulæ especially the brightest one of them all, the Andromeda nebula. While there are observations that support the two views given above, it seems to us that they have not been sufficient to decied the question.

GENERAL NOTES.

It is suggested to subscribers that remittances should be made in advance unless arrangements with the publisher provide for a later pay day.

H. H. Turner Honored.—On the 14th of February a complimentary dinner was given to Professor H. H. Turner, by the staff of Royal Observatory, Greenwich, and other astronomical friends. Professor Turner has recently been appointed to succeed the late Professor Pritchard at Oxford.

The Arago Gold Medal.—On Feb. 6, Professor E. E. Barnard of Lick Observatory, Mt. Hamilton, received the Arago Gold Medal from the Academy of Sciences of France given on account of the discovery of the fifth satellite of Jupiter. A fuller note concerning this medal will be found in the January number of *Astronomy and Astro-Physics*, page 81.

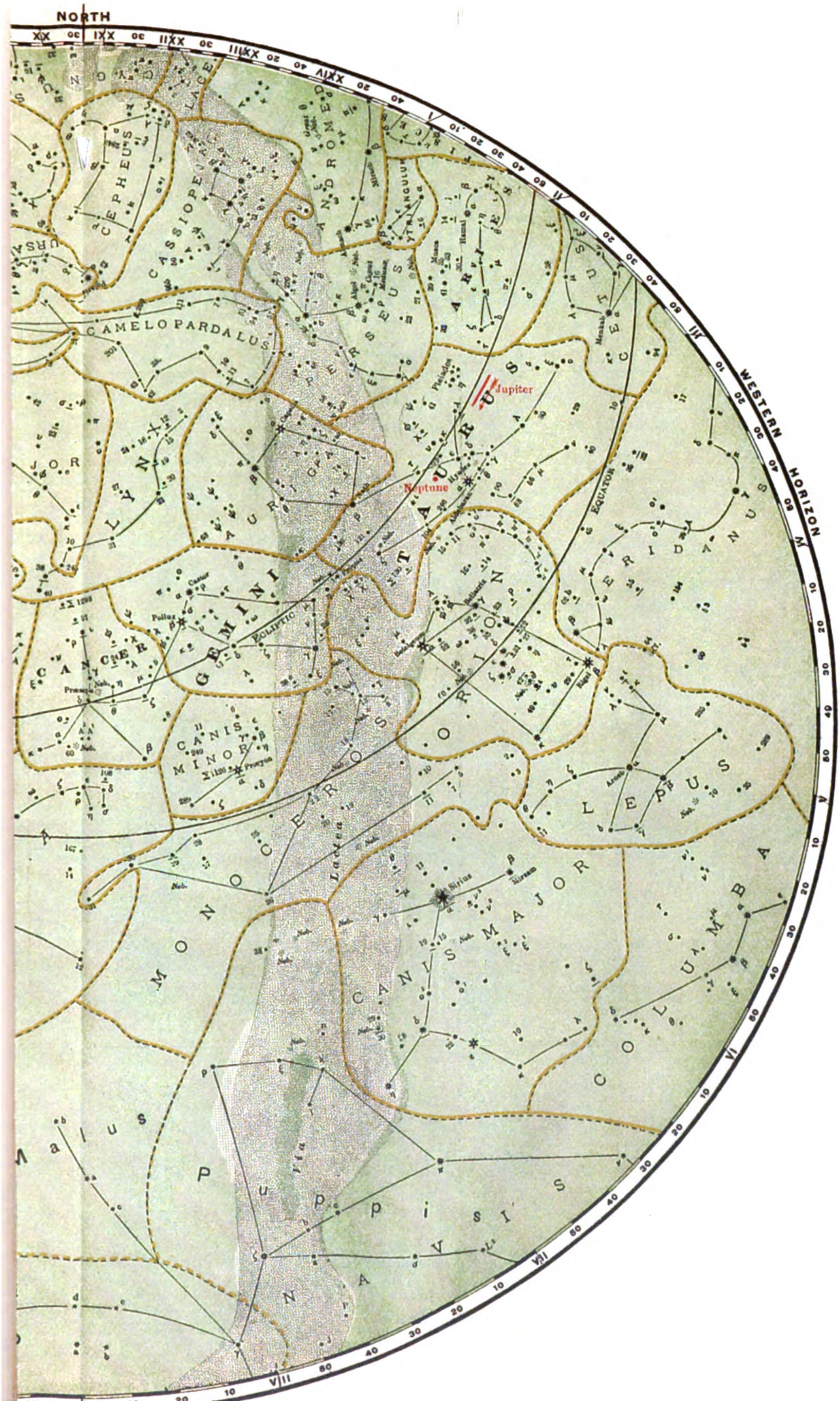
Miss Dorothea Klumpke now at the Bureau of Measurements, Paris Observatory, received the degree of Doctor of Sciences on the 14th of December, 1893. She was formerly from California and is recently spoken of in the French papers as the young American woman. She was given equatorial work in the Paris Observatory under the late Admiral Mouchez, who spoke freely of her aptitude and skill in work requiring patience and precision. The theses which she presented to the Faculty of Sciences of Paris for the doctor's degree in mathematical science are papers worthy of extended notice which will soon be given in *Astronomy and Astro-Physics*. But the amusing thing for western Americans to read from French papers is the suggestion that scholars should not be surprised at the success of young women in mathematics, for physiologists now claim that the female brain is peculiarly adapted to the study of the exact sciences, and that the few cases known, comparatively, are due to custom rather than natural aptitude. What a discovery for a physiologist to make! The western schoolmaster knew that a half century ago.

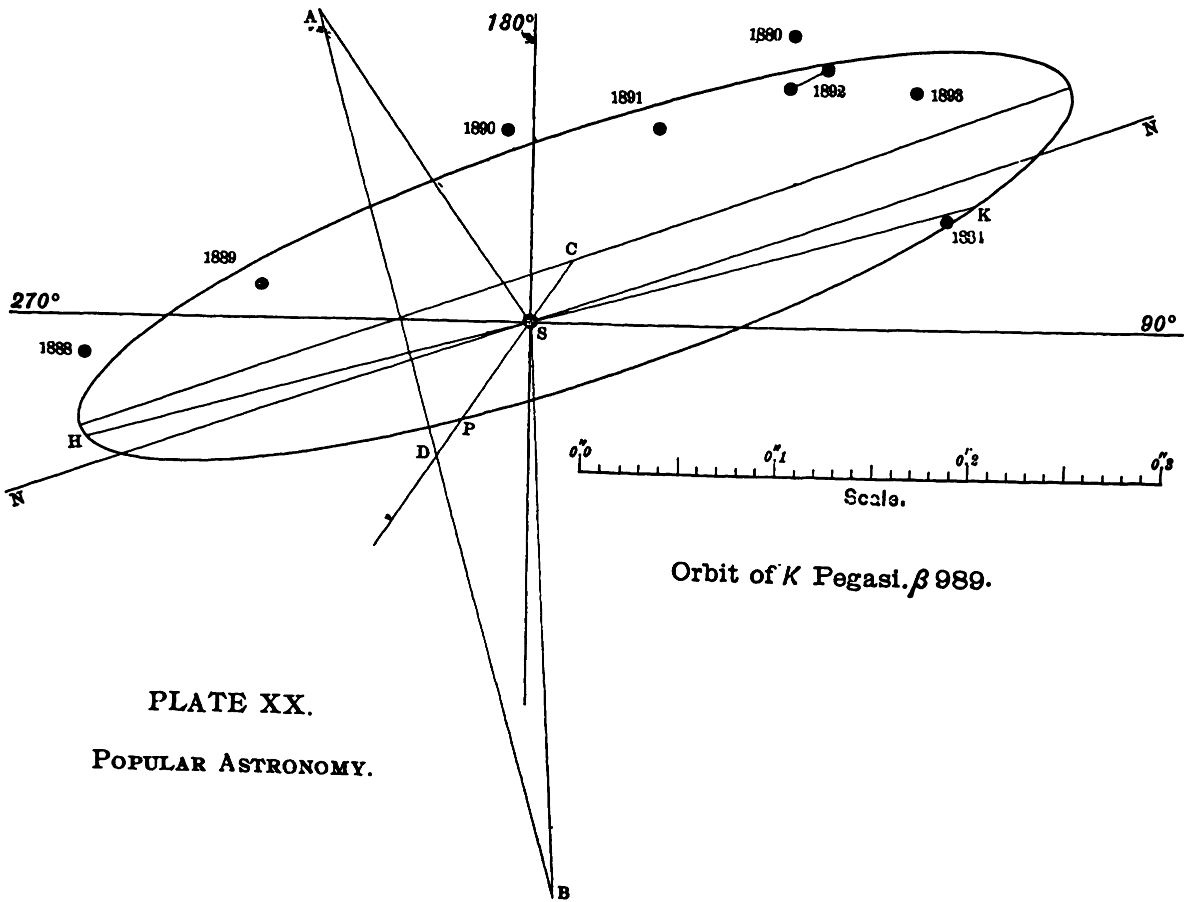
Errata.—In December number, 1893, p. 148. The Perseid radiant given as 49° + 67° in the table should be 49° + 57°.

February, 1894, p. 272. The correct figures showing the close agreement in independent determinations of the Perseid radiant, should be as follows:—

	1879. Aug. °	1879. Radiant. °	1880. Aug. °	1880. Radiant. °
G. L. Tupman............	45	+ 56	44	+ 56
H. Corder..................	45	+ 57	45	+ 58
E. F. Sawyer.............	44½	+ 57	44¾	+ 56¼
W. F. Denning...........	46	+ 58	44	+ 56

February, 1894, page 254, line 7, "west" should be inserted before the first word "point;" line 9, "to" should read "of."


NORTH
WESTERN HORIZON
CEPHEUS
CASSIOPEIA
ANDROMEDA
TRIANGULUM
PERSEUS
ARIES
CAMELOPARDALUS
LYNX
AURIGA
TAURUS
CETUS
ERIDANUS
GEMINI
CANCER
CANIS MINOR
ORION
LEPUS
MONOCEROS
CANIS MAJOR
COLUMBA
Malus
Puppis
NAVIS
Via Lactea
ECLIPTIC
EQUATOR
Jupiter
Neptune
Pleiades
Hyades
Aldebaran
Castor
Pollux
Praesepe
Procyon
Sirius
Mirzam
Rigel
Hamal
Algol



Orbit of κ Pegasi. β 989.

PLATE XX.

POPULAR ASTRONOMY.

Popular Astronomy.

Vol. I. APRIL, 1894. No. 8

THE GEGENSCHEIN OR ZODIACAL COUNTER GLOW.

E. E. BARNARD.

Many people not over familiar with the work of an astronomer think that his occupation in the main is to sit at the telescope night after night and gaze on the mysterious and wonderful landscape of the Moon. These same people will sigh for the astronomer when the Moon finally withdraws its wonders from the sky for a few days near new Moon, and will doubtless wonder what he can find to do and to study until it again returns.

No one questions the wonderful charm contained in a view of the lunar world, and its mountains and craters and vast silent plains where the husbandman's voice can never be heard.

But the Moon is a very small consideration indeed to a large majority of observers. Of course when it is around they look at it once in a while and wish they knew more about its mysteries. Many of these observers, however, wish it were away and that it never would return again, and if they were put to it they would declare that they could not see any use in the Moon anyway outside of helping to run the tides and to sometimes guide the occasional sailor along his watery way, and to suppyly light for silly lovers to coo by, and certainly all these things could get along easily enough by themselves, especially the last, if there were no Moon at all.

For these beautiful moonlight nights, that are so successful in producing love and poetry, are the bane of a certain class of observers, for the silvery beams which so beautifully and softly illuminate the landscape also illuminate the atmosphere, and by whitening the sky blot out from view a host of the most important and interesting of the "citizens of the sky." The glories of the Milky Way—the most superb of all the wonders of the sky—are lost in all this glare of lunar light. They require the untouched blackness of space to set off the richness of their beauty. The mysterious and beautiful nebulæ—the original matter from which all things come according to the Nebular Theory—are lost; their filmy light requires a clear moonless night to present them in all their beauty. The mighty comet also loses its grandeur in a moonlit sky, and that one which would otherwise have made a record passes away scarcely noticed, if its display be coincident with a bright moon.

It is true the planets do not suffer from the presence of the Moon, and the whitening of the sky on which they shine is rather an improvement than otherwise. This may be said also of the individual fixed stars.

There is one thing in the sky, however, that the least glimpse of moonlight most totally anihilates, and there is perhaps more mystery connected with this object than with any other in the entire heavens. Very few people have seen it—indeed I don't think there are many scores of people on the face of the Earth who have seen it. And there are comparatively few who have ever heard of it. The lack of familiarity with this mysterious object is in no wise due to a lack of powerful instruments, for it is wholly invisible in any telescope—nor is it due to the smallness of the object, for it is certainly the biggest thing in the sky so far as appearance goes.

This object which defies the power of the telescope, has been known for about half a century, yet in all that time we have found out very little about it and have so far come to no satisfactory conclusion as to its nature.

In the first half of the century a German astronomer, Brorsen by name, in watching the face of the sky on moonless nights, noticed a large feeble glow of very diffused light in the midnight sky. This feeble light was from 10° to 15° in diameter. He soon found after a few observations that the object was moving nightly towards the east among the stars. A series of naked-eye observations soon showed him also that it was not only moving easterly among the stars, but that it was exactly opposite the Sun and always remained so, and that its center lay exactly in the ecliptic. So exactly did it move with and in opposition to the Sun, that if an imaginary line were passed from the Sun through the center of the Earth and prolonged to the sky it would always pass through the center of this queer object. This fact being established, suggested to the Germans a name for it—they accordingly called it the Gegenschein—a combination of two words *gegen*, opposite, and *schein*, light, meaning a light in opposition.

It seems after this, for a time to have been neglected, if not almost forgotten.

In 1871, however, it was again independently discovered by Mr. T. W. Backhouse at Sunderland, England, who secured observations, that confirmed its opposition to the Sun. But even this second discovery did not attract attention to it as it should have done, and many people still doubted its existence.

In 1883 about October 1st the writer in seeking comets at Nashville, Tennessee, one night happening to look up to rest his eyes, saw a faint hazy glow near the constellation of Pegasus. This was thought to be a bit of local haze, though it seemed abnormally permanent. The next night it was seen again and was therefore no ordinary haze. A few nights' location of its position showed that it was moving along the ecliptic eastward about one degree a day. Could it be an immense comet? It was certainly no ordinary meteorological phenomenon.

The positions obtained were sent to an eminent astronomer with the suggestion that it might be some extraordinary kind of comet. He wrote back that I had discovered the Gegenschein.

Since then I have been very much interested in the object and have made numerous observations of its position. From these observations some new facts have been developed concerning this remarkable phenomenon.

I have said that this object defies the power of the telescope; this is true. From its great size and diffuse nature no telescope can grapple with it, its feeble light being destroyed by the power of the instrument and the want of contrast—the largest field being vastly smaller than the Gegenschein. Though it can not be seen with any telescope, it is nevertheless a decidedly noticeable object with the naked eye when you know where to look for it.

Just what this mysterious light is no one has yet been able to satisfactorily explain.

Professor Arthur Searle of the Harvard College observatory has made an extensive study of the Gegenschein and is inclined to believe it due to an infinite number of small asteroids.

Between the orbits of Mars and Jupiter are known to be no less than four hundred small planetary bodies. It is probable there are thousands and possibly millions more of these dust worlds. The smaller ones found in recent years are pehaps not over 10 or 15 miles in diameter. As they decrease in size doubtless they multiply in number until finally they exist in untold multitudes of a size comparable with small stones and particles of dust, which no telescope will show individually. Each one of these small bodies is a miniature planet and must shine as a planet by reflecting the light of the Sun. It therefore must present to us phases just as Mars does, but from the smallness of the objects we cannot see these phases—but none the less they must have an effect on the brightness of each little asteroid, and must diminish its light accordingly.

Let us assume there are a sufficient number of these tiny planets —though they may be too small to be seen individually in a telescope yet their combined light may be so great as to affect the eye and thus we might expect to see a feeble zone of light extending across the sky and corresponding to the asteroidal zone. Such we actually have in the zodiacal band. What would be the effect of phase of these individually small bodies upon the appearance of this zone of light? When opposite the Sun each of the objects would shine with full enlightened disc, and this vast collection of fully illuminated particles would augment the light of the zone and give a greater luminosity immediately opposite the Sun. Away from opposition and the phase would begin to diminish the quantity of illumination. To this must also be added the fact that at opposition each asteroid would be nearer us and brighter from this cause also. Both causes tending to give a maximum of light opposite the Sun—a gegenschein.

This theory certainly appears very plausible, but there are objections to it.

There is one thing certain, if the gegenschein is not really an atmospheric phenomenon—and everything except the fact of its existence seems to go against this supposition—it is at a considerable distance from us. Careful observations have shown no evidence of parallax. Of course observations of such an indefinite object cannot be made with anything approaching to accuracy, but if it were at no greater distance than 100,000 miles, its parallax would have shown in the observations.

That a satisfactory explanation of this most singular phenomenon will be arrived at when it has been sufficiently observed there is no doubt. Therefore it is very desirable that as many careful observations of its position and descriptions of its appearance as possible should be obtained.

Here is a field which offers a splendid opportunity for amateurs to do new and valuable work where no instrument whatever is needed—nor indeed can be used. All that is required is a star chart and an approximate knowledge of the time—to within an hour or so. The observer will find much to interest him in watching this—one might almost say—uncanny thing as it circles the sky with its slow and measured pace.

The gegenschein is best seen in September and October when it is passing from Sagittarius to Pisces. It is then a large and roundish glow, some 15° or 20° in diameter. After passing the vernal equinox it becomes elongated and is connected with a zodiacal band. The position of its center should be carefully located with reference to neighboring stars, and a description of its appearance given. A knowledge of the point in the sky opposite the Sun should be avoided, as it might bias the observer in his location of the gegenschein.

In the fall of 1893 systematic observations were carried over the two months of September and October to decide certain questions concerning it. One of these points was to show whether there was any observable parallax to the object.

Professor Bailey at the Arequipa (Peru) station of the Harvard College Observatory was to make observations in the southern hemisphere, while observations north of the equator were to be carried on by Professor Searle of Harvard College Observatory and by the writer at the Lick Observatory. These observations will be discussed by Professor Searle as soon as the southern reports are in. Thus we have for the first time simultaneous observations of the gegenschein made from opposite hemispheres of the Earth.

These will definitely settle the existence of any parallax as large as 1° or 2°. However there is no question but this will be settled in the negative—that is, the object, if it is not an atmospheric phenomenon, must be farther away from us than half the distance of the Moon.

That the object is intimately connected with the zodiacal light there is no doubt, and the explanation of the one doubtless rests upon that of the other.

MT. HAMILTON, 1894, Feb. 1.

LIFE AND WORK OF E. E. BARNARD.*

S. W. BURNHAM.

In 1881 Barnard began to search for new comets with his five-inch telescope, and very soon discovered the comet known in astronomical works as Comet VI. This was quickly followed by Comet 1882 III, and in the succeeding year by Comet 1884 II (a comet of short period, 5.4 years, due again in 1895). The next year, 1885, yielded two new comets, 1886 one, and three more were discovered in 1887. Nearly every year since beginning this work he had found one or more of these strange celestial visitors. In

* Continued from January number. This is the second of a series of articles portions of which have already appeared in *Harper's Magazine*, August, 1893.

the seven months from October, 1886, to May, 1887, he discovered four new comets. He discovered every comet of the year 1891. Many of these have proved to be of more than common interest, in consequence of their periodic returns and peculiarities of motion in the approach to and recession from the Sun.

In 1883 he left the photographic business, having received a fellowship in Astronomy at the Vanderbilt University. During these preceding years he had given all his spare time to study, working in the day time, and studying alone at night, and had acquired a good education in the ordinary branches of knowledge. He was promptly placed in charge of the Observatory attached to the Vanderbilt University, and continued his researches with the 6-inch equatorial. This instrument was superior in power to that previously used, and having a fixed equatorial mounting, with driving clock and micrometer, it was much better adapted to the work of determining the absolute positions of unknown objects. While connected with the Observatory, he took in the University a thorough course in English, French, German, Mathematics and Physics; and graduated from the School of Mathematics in 1887. Work with the telescope was constantly going on, and in addition to many other discoveries and observations he found eight comets during the time of his connection with the University, one of them completing its circuit about the Sun in less than five and a half years and having next to the shortest period known. By this time he had become known throughout the world as the leading observer of comets, and an authority upon the subject generally. Since that time he has found not less than ten new comets, and now stands at the head of all living astronomers in the number of comet discoveries.

While he was still at Nashville, and working his way through the University, he had an opportunity of turning his astronomical discoveries to a very practical account. Mr. H. H. Warner of Rochester, N. Y., in connection with the Warner Observatory, offered a prize of $200 for the discovery of each new comet. The zeal and industry of the young astronomer in this field were duly rewarded; and the amounts thus received were turned to good account in supplying him with books and other necessary accessories and enabled him to make the most of his opportunities. In this way Mr. Warner's liberality in rewarding these discoveries was a more permanent and valuable contribution to astronomical science than he could have imagined at that time.

The work at Nashville was by no means confined to comets. The astronomical journals of that time, show a great variety of observations. One of these discoveries may be mentioned because it is unique, and illustrates his remarkable skill as an observer and his ability to detect and interpret unsuspected phenomena. In 1883 he was observing an occultation of the well known star β Capricorni, by the Moon. It is probably well known to most readers that when the Moon passes between the observer and a fixed star, the disappearance of the latter is absolutely instantaneous. This is because the star at the distance from which we look at it, is a point only, and, as the Moon has no surrounding atmosphere, the instant the edge of the lunar surface touches the line joining the eye of the observer and the star, the star vanishes from sight. When the Moon passed in front of the star referred to, the observer noticed that instead of disappearing instantly, the process was gradual. The interval between the diminution, and complete extinction of the light occupied only a few tenths of a second, but it was long enough to put the expert observer upon inquiry, and was evidently a matter requiring explanation. Mr. Barnard called attention to this curious phenomenon in one of the astronomical journals, and suggested that the most probable explanation was that this star, always heretofore known as one of the ordinary type, was really composed of two stars, so extremely close together that to the ordinary telescope they appeared as one star. It was also inferred that one of these stars must be considerably brighter than the other from the fact that at the beginning of this fraction of a second, the change in brightness was less than at the end. Subsequent examination of this star with the 6-inch telescope with which the occultation was observed, failed to show any peculiarity in it under the highest powers, and therefore the attention of astronomers with more powerful telescopes was called to the matter. The 18½-inch equatorial of the Dearborn Observatory at Chicago was subsequently turned on this object by the writer, and it was seen to be a close and unequal double star, and one which taxed the powers of that splendid instrument to show it even to a trained eye. A set of micrometrical measures of the two stars was made at this time, and it was subsequently measured with the still more powerful telescope at Mt. Hamilton, and these observations make it highly probable, if not certain, that this double star is an interesting binary system, the two stars revolving about their common center of gravity in perhaps several hundred years.

His discoveries of Nashville include many new nebulæ. There is very little, if any, difference in appearance between a faint telescopic comet, and a correspondingly faint nebula, as seen in the telescope; but the class to which the unknown object belongs is soon determined by measuring its position with reference to some adjacent star. If it be a comet it will soon change its place in the sky, and occasionally the unknown object will turn out to be a nebula which had escaped the vigilant search of the Herschels, and other distinguished observers in this field.

He independently discovered in 1883 that singular phenomenon called the "Gegenschein," which is an extremely faint diffused light seen at times in the sky at night, at points exactly opposite the Sun. It is always difficult to see, and even now but few of the astronomers of the world have seen it, although it was first discovered many years ago by a German astronomer. The cause of this appearance is still a mystery.

In 1888 he was offered a position in the Lick Observatory then about to be opened with the largest equatorial and the best equipment of astronomical instruments in the world. The temptation of superior facilities for astronomical work and discovery, and the opportunity to devote his whole time and strength under these circumstances to the work of his life, left no hesitation in regard to his future course; and much to the regret of the University, and the citizens of Nashville generally he left for Mt. Hamilton, and commenced with increased enthusiasm a series of brilliant observations and discoveries which are familiar to the astronomical world, and to the readers of scientific literature.

It is impossible within the limits of this article to do more than briefly refer to a few of these achievements. They are recorded in the standard astronomical periodicals and publications of the world. In the volumes of the publications of the *Royal Astronomical Society*, *the Astronomische Nachrichten*, the *Astronomical Journal*, the *Sidereal Messenger*, and many others, will be found scores of papers, not of a speculative or descriptive character, but founded upon original observations, and forming valuable contributions to our knowledge of the universe beyond.

Reference has already been made to the new comets discovered by Barnard on Mt. Hamilton from 1888 to 1892. These were systematically measured from night to night, with the micrometer and the same line of observations followed with regard to the comets discovered by other observers, as well as the returns of the various periodic comets. Many of these bodies were observed long after they had passed beyond the reach of other astronomers. Comet V of 1889 was followed for nearly a year after it had become so faint as to be invisible at all other observatories.

In the course of his observation of these bodies for the determination of their places and motions around the Sun, many curious things were found out concerning these mysterious visitors. In August, 1889, he discovered that Brook's comet of that year was passing through space with four minute comet satellites, moving generally with the parent body, but with some relative motion of their own. Nothing of this kind had ever been observed before, and it naturally attracted a great deal of attention from the scientific world. Some of these objects were very faint and could only be seen by experienced observers with large instruments. They were fully measured by Barnard at every available opportunity as long as they were visible, and a valuable paper embodying these observations was published by him in the *Astronomische Nachrichten*. His observations of new and periodic comets have always had a special value from the fact that in consequence of his keenness of vision and experience in observing faint and difficult objects of this class, aided by superior instruments for the work, he has carried his measures far beyond the time when these objects had ceased to be visible to other observers. With the large telescope at Mt. Hamilton he followed one of his comets (I 1889) more than one hundred millions of miles beyond the orbit of Jupiter. The extreme distance at which any previous comet had been seen was much less than the distance of Jupiter.

SHOOTING STARS.

How to Observe Them and What They Teach Us.

W. F. DENNING.

VIII. THE ANDROMEDES OF BIELA'S COMET.

Though we do not appear to possess any ancient records of this shower, its modern history is so interesting and its cometary correlation so remarkable that it undoubtedly takes a prominent place in this department of astronomy. It has furnished no less than three brilliant displays during the last quarter of a century, namely, on November 27 in 1872 and 1885, and on November 23 in 1892. Similar exhibitions will probably occur in 1898, 1905 etc. There are visible features connected with this system which render it especially worthy of attentive study. The Perseids, Leonids and Orionids have rendered us familiar with the swift, streak-leaving meteors, but the Andromedes present us with another and a more interesting type, for they move very slowly and leave trains of yellowish sparks. From the relative positions of the orbits of the Earth and meteor stream at the time of the rencontre, the meteors have virtually to overtake the Earth, and thus their apparent velocity is near the absolute minimum of these phenomena. In fact the apparent motion of the Andromedes is only about ten miles per second, whereas that of the Leonids is about forty-four miles per second, for the latter represent the very swiftest class of these bodies.

The radiant of the Andromedes is a very singular one, for it comprises an area several degrees in diameter on the N. W. side of γ Andromedæ, and only three or four degrees distant from that star. For the great shower of Nov. 27, 1872, Professor Herschel found the mean place at $24°.54 + 44°.74$ from 90 observations by different observers. For the similar display in 1885 I derived the mean place at $23°.7 + 44°.3$ from thirty-three independent observations.

As to the diffuseness of the radiation Professor Herschel found from his observations in 1872 that 60 per cent of the meteors he recorded indicated a circular area about 5° in diameter. In 1885 Mr. Cowper Ranyard thought the area to be elliptical with its major axis N. and S., some 12° or 15° long, and a minor axis of of 6° or 8°. Professor Young also found it oval, and stated it to be 4° long, N. and S., and 2° wide. At Bristol the writer estimated it at about 7° diameter, but recognized no peculiarity of shape. In 1892 Professor Young alluded to the shower of Nov. 23 in that year as giving a "radiant not well defined, its area being at least 4° in diameter."

Another singularity in connection with the radiant is that its position undergoes considerable variation during the day of 24 hours. This has not been fully demonstrated from observation, but the late Joseph Kleiber's theoretical investigations prove that the attraction of the Earth must occasion a large displacement of the radiant as observed at different hours. His computed positions for it at intervals of three hours from noon on Nov. 26 to noon on Nov. 29 are given as follows in *Monthly Notices*, Vol. III, p. 352–3:

POSITIONS OF THE ANDROMEDÆ RADIANT.

Hour.	Nov. 26.		Nov. 27.		Nov. 28.	
	°	°	°	°	°	°
0	16.96	+ 51.08	18.04	+ 51.60	19.12	+ 52.18
3	15.14	+ 47.40	16.22	+ 47.98	17.30	+ 48.56
6	17.09	+ 44.62	18.07	+ 45.20	19.25	+ 45.78
9	20.60	+ 43.33	21.68	+ 43.91	22.76	+ 44.49
12	24.92	+ 43.78	26.00	+ 44.32	27.08	+ 44.90
15	28.98	+ 46.25	30.06	+ 46.83	31.14	+ 47.41
18	29.21	+ 50.23	30.29	+ 50.81	31.37	+ 51.39
21	24.04	+ 53.56	25.12	+ 54.14	26.20	+ 54.72

The following diagram, taken from one by Mr. Kleiber, exhibits in a graphic manner the curious, roughly circular motion of this radiant.

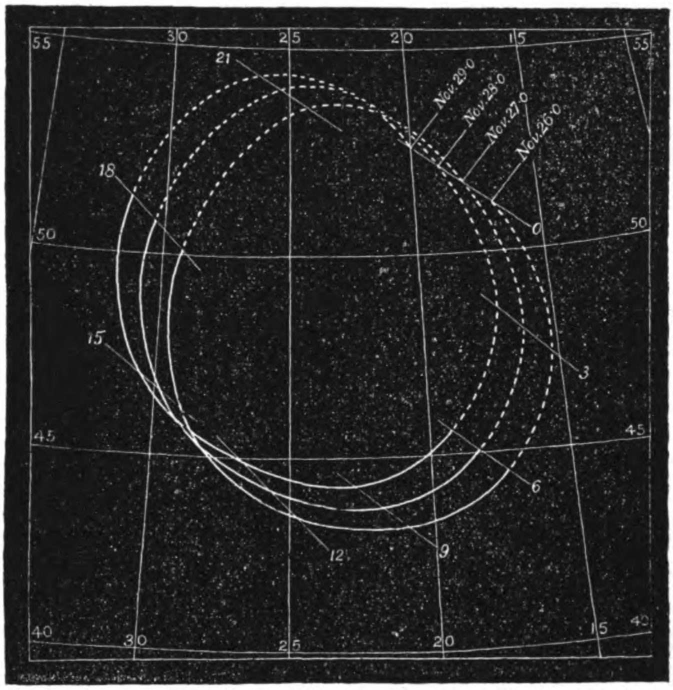


FIG. 10. MOTION OF THE RADIANT OF ANDROMEDES.

The table and diagram given above will scarcely, however, apply correctly to future returns of the shower as, from the observations in 1892, they will probably occur on Nov. 23 instead of on Nov. 27 as formerly. This is confirmed by M. Bredichin in a paper published in the *Astronomische Nachrichten*, No. 1219, in which he states "the descending node of the stream has receded almost 4° to the west between 1885 and 1892. The cause of this is due to Jupiter, the perturbations set up by this planet accounting for the mean daily motion which is nearly equal to that possessed by Biela's comet. An approximate computation of the special perturbations for the whole period during which Jupiter had any influence, gave for the recession of the node a little over 4°, the inclination decreasing about 0°.6." From this it will be seen that the alteration of date in the shower's return is distinctly attributable to the disturbing action of Jupiter and that observation and theory are in excellent accordance as to the extent of the disturbance.

A great number of minor showers manifest themselves simultaneously with the Andromedes, but they appear to be similar in many cases to those accompanying the Leonids a fortnight earlier in the same month. It will therefore be unnecessary to enumerate them in anything like a complete manner, but a short list is appended of 15 radiants comprising some of the best visible at this epoch:

METEORIC RADIANTS VISIBLE NOV. 25–30.

° °	° °	° °
27 + 71	61 + 37	155 + 40
31 + 37	63 + 21	162 + 58
44 + 56	70 + 66	190 + 58
48 + 42	74 + 41	194 + 43
60 + 49	79 + 23	332 + 58

The majority of these may be expected to prominently attest their existence in future years.

More observations of the Andromedes will doutless elicit some further interesting developments. Among the features requiring attention may be mentioned the following:—

1. Are some of the meteors visible every year? Existing observations are insufficient to settle the point. If the stream recurs annually it must form a complete ellipse like the Leonids, Perseids and many other showers.

2. What is the diameter of the radiant area? Is it oval or circular? Very accurate mapping of a number of paths near the radiant will be necessary to define this.

3. What are the horary positions of the radiant centre during the night? It is very desirable to ascertain this in order to practically test Mr. Kleiber's deductions. It may easily be done during a really active return of the shower; indeed the radiant might then be deduced every half or quarter of an hour and the resulting series of positions would offer an excellent means of comparison with those derived from theory.

—

4. What is the duration of the shower? In 1872 the display appears to have been limited to the 27th, whereas in 1885 it continued from November 25th to 30th. The Earth undoubtedly traverses the very rich portion of the stream in a few hours, but it is desirable to note how long the radiant is in evidence even in a feeble state. Observations should be conducted from the middle to the end of November and special efforts should be made in 1898 or any other year promising an abundant display.

Some other points might be referred to but for the present the above short summary will suffice. The questions propounded will doubtless be answered at some future time, for observers will never neglect a system possessing such significant relations. We have already determined its radiant accurately, but it must be confessed that our knowledge is very inadequate as regards certain other details of its visible behavior. The story of its physical identity with Biela's lost comet is an old one and need not be told again here, but the circumstance referred to gives a special interest to the stream apart from the great attraction it possesses in itself from the brilliant character of its periodical displays.

HOW TO FIND THE ORBIT OF A DOUBLE STAR BY A GRAPHICAL METHOD.*

S. W. BURNHAM.

With this arrangement we can change the eccentricity of the ellipse very quickly and conveniently, and without making any knot or loop in the other end of the wire, as it is easily held in place by the hand. After experimenting with the foci, axis, etc., until the proposed ellipse is apparently satisfactory for a first attempt, the outline is made in pencil lightly, and the foci marked so that when a second trial ellipse is made, the variation in these points and the length of the Major axis can be quickly made. The next step is to measure the areas of the several portions of the ellipse represented by measures, and ascertain whether they are proportional to the respective times. At first they will probably be only roughly so, but it will be apparent how to improve it in a second trial. This must be done by successive attempts until after a most careful comparison of the apparent orbit with

* Continued from February number, p. 248.

the observations, considered each upon its own merits, the result is considered as satisfactory as can be found.

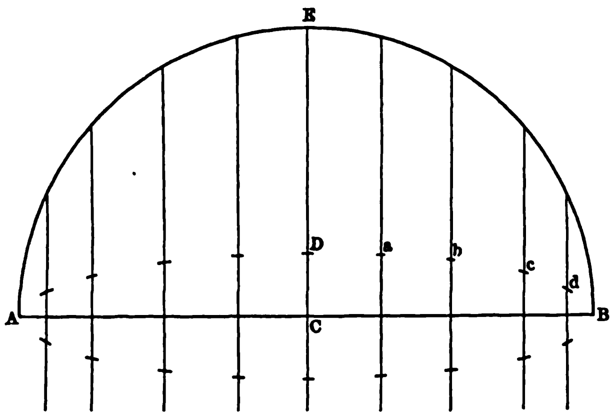
This cannot be done too thoroughly and carefully, since everything depends, in this as in all other methods, upon the accuracy with which the apparent orbit represents the measures. When this is properly done, the elements of the real orbit are readily found. Whatever methods are used, the results should be the same.

It must be borne in mind that the ellipse must represent the distances well. The distances of binary stars when measured by observers of experience with the micrometer, are always better than the angles; and therefore the apparent ellipse should be such that the measured distances fall very near the curve, so that with a reasonable change in the angles they will conform almost exactly. With close pairs, such as we have in nearly all rapid binaries, an expert observer can estimate the distances, which in most instances are considerably less that 0″.5, and down to 0″.1, more accurately than any one can measure the position angles. The reason for this is obvious when we consider how short the base line is for measuring the angle, and how insignificant to the eye a change of even ten degrees from parallelism would be. Some of the old computers attempted to dispense with the distances altogether, and get orbits based on angles alone. However, satisfactory these results may have appeared at that time, it is certain now that the plan was as unreliable in practice as it was in theory. Dr. See has pointed out (ASTRONOMY AND ASTRO-PHYSICS, December, 1893,) that some of the best known orbits at the present time are founded upon the measured distances alone. Such a course was necessary in these instances because the plane of the orbit was almost exactly in the line of sight, and consequently the position angle was practically constant. Of course the logical and scientific way is to use all of the measures, angles and distances, whenever it is possible to do so. It is only in this way we can expect to get the best possible result from the observations.

It is sometimes desirable, especially when the original diagram is to be reduced in the camera for reproduction, that the final ellipse should be put, as the other lines and positions have been, in india ink. This is easily done if a very small hole is drilled in one side of the drawing pen, about one-sixteenth of an inch from the lower end, and a piece of a small wire firmly fastened in the hole, and projecting outwardly sufficient to catch and hold up the string or wire as the pen moves around in describing the ellipse. In this way ink can be used as readily as a pencil.

It will occasionally happen that it is necessary to draw an ellipse so elongated that the string should not be depended on to make a figure which is sufficiently exact. In such a case points should be laid down at various portions of the curve to fix its boundaries. The general form of the ellipse, and the dimensions of the axes can be found in the manner previously described. The following is an easy and accurate method of finding the boundary of such an ellipse.

Lay down the major axis AB and the semi-major axis CD. On AB as a diameter, describe the semi-circle AEB, and then find the ratio of EC to DC. At equal distances from the center of the circle, draw any convenient number of parallel lines at right angles to AB, and on them from the intersection of the respective lines with the diameter, lay down the points *a*, *b*, *c*, etc., having the same ratio to the lines as EC : DC. These points will lie in an ellipse which will be a projection of the circle described on AB, and the ratio of EC to DC will be the cosine of the inclination.



Of course it will only be necessary to find the points *a*, *b*, *c*, etc., for one-fourth of the ellipse, as they will be the same for each quadrant. The most rapid and convenient method of finding these points is by the use of the proportional dividers. By trial the sliding center is set so that when one pair of the points is made to include EC, the opposite pair will give DC. Then all the points can be taken directly by opening the dividers to the distances of the other semi-chords. The points thus found may be transferred to the original diagram; or the last ellipse may be cut out and if on thick paper the drawing pen can be passed around its edge on the original sheet.

Elements of the Orbit.

The final ellipse having been drawn it only remains to find the elements of the real orbit. These elements are:

P = Period.
e = Eccentricity.
a = Semi-major axis.
i = Inclination.
Ω = Node.
λ = Angle of node to periastron.
T = Periastron passage.

Various geometrical methods have been suggested for finding some of the elements from the apparent ellipse, but by far the best is that given by Ball in his valuable *Atlas of Atronomy*, and a considerable part of that is used here, but for the reasons already given, I have preferred to deal directly with the measures themselves, and to deduce the period from direct measurements of the ellipse.

To best illustrate the application of the graphical method as I have used it heretofore, I propose to take the observations of a binary and show how the several elements can be found. For this purpose I have selected κ Pegasi (β 989), one of the most interesting and rapidly moving systems known. In fact it has, as we shall see, a shorter period than any other known pair in the heavens. I have thought it best in this instance to rely entirely on my own measures, and those made at my request by Professor Barnard with the 36-inch at Mt. Hamilton when it was no longer possible for me to continue the series:

Measures of κ Pegasi.

1880.68	137°.9	0″.20	4*n*	Burnham
84.87	104 .7	0 .22	1*n*	Burnham
88.78	274 .7	0 .23	3*n*	Burnham
89.51	262 .3	0 .14	4*n*	Burnham
90.57	187 .1	0 .10	4*n*	Burnham
91.71	147 .3	0 .12	7*n*	Burnham
92.39	132 .8	0 .18	4*n*	Burnham
92.88	131 .0	0 .20	1*n*	Barnard
93.71	121 .7	0 .23	1*n*	Barnard

These positions were laid down on a scale of 0″.1 = 2 inches in the manner already described; and after repeated trials, and a careful measurement of the relative areas, the ellipse shown on the diagram was finally adopted as satisfactorily representing the apparent orbit. Each trial ellipse was measured with sufficient care to show how far it was in harmony with the law of equal areas in equal times. When the last ellipse was laid down, the areas described by the radius vector between the successive observations was measured with all possible precision. The areas corresponding to the respective measures are as follows:

	Time	Area	*t* (0.186)
1880 — 84	4.19	7.41	7.79
1884 — 88	3.91	7.15	7.27
1888 — 89	0.73	1.41	1.37
1889 — 90	1.06	2.85	1.98
1890 — 91	1.14	1.61	2.12
1891 — 92	0.68	1.39	1.28
	11.71 =	21.82	
	1 yr. =	0.186	
1880 — 92		0 63	
1892 — 93	1.32	2.08	2.45

We see from the last column, giving the respective areas as de duced from the mean motion, that on the average the angles are represented as well as could be expected in so close a pair. With a single exception, a very small change in the position angles will be sufficient to make the areas strictly proportional to the times. This amount is far within the probable errors in so close and difficult a pair, and as the errors of distance are exceedingly small, and wholly insensible quantities even in the largest telescope, we may fairly conclude that this ellipse must very nearly represent the apparent path of the companion. According to this orbit, the position angle found in 1890 requires a correction of a little more than 10°. The distance at this time was less than at any other observation, and in fact less than 0″.1; and when we remember that most of the old and frequently observed pairs, with distances between the components more than twenty times that of κ Pegasi, have errors in some of the position-angles greater than that in question, we are justified in treating this single variation as not a very serious objection to the acceptance of this ellipse as a satisfactory representation of the apparent orbit.

It will not be difficult from the measures of the areas, to distribute the errors, and find the changes required in the various position-angles to make the corresponding quantities in the last two columns equal, but it is hardly worth while doing this after the comparison already given, and the graphical presentation of the whole subject in the diagram.

The distance errors, measured directly with the scale, are as follows:

1880.68	— 0″.03
84.87	0 .00
88.78	— 0 .02
89.51	+ 0 .02
90.57	— 0 .01
91.71	+ 0 .02
92.39	+ 0 .02
92.88	0 .00
93.71	+ 0 .04

Nothing could be more satisfactory since the variations are all practically zero.

In this example we have more than one revolution. As the last measure is from a single night, I have derived the mean motion from the intervals ending with 1892. To find the period, therefore, we have:

$$11.71 - \frac{.063}{.186} = 11.37 \text{ years.}$$

In this connection it may be well to give a few suggestions in regard to the best way of measuring parts of an ellipse. It may be done in two ways. The first requires only the dividers and the scale previously used. The portion of the ellipse to be measured is separated into a convenient number of triangles by lines drawn from S to the circumference, and the area of each found by multiplying this line as a base by the altitude of the triangle. As the smaller side is a curve, allowance must be made in measuring the altitude. This is easily done, and with great accuracy by drawing a straight line with india ink on any transparent medium like celluloid or mica, and laying this down so that it shall pass through the outer end of the base, and revolving it about that point so that it shall intersect the other line of the triangle produced, and make the areas equal on each side of the curved side. This is done in an instant, and with an accuracy which would be surprising to one who had not tried it. At the end of the work it is easily tested, since the sum of the areas of all these triangles should be equal to the semi-major axis × semi-minor axis × 3.1416.

The second method is by the use of the planimeter. This of course is a very accurate way, and very much quicker than any other, as it is only necssary to pass the pointer arm over the lines of the figure to be measured, and read the area directly from the index. The areas previously given of this ellipse were measured with this instrument. The results given are in square inches. The sum of the areas of all the parts of the ellipse, in seven different sections, is 21.19, while a direct measurement of the ellipse as a whole gave 21.13 for the area.

To obtain the other elements of the orbit, draw a line from the center, C, of the ellipse through the principal star, S, to meet the ellipse in P. This will be the projection of the major axis of the real ellipse. Draw a chord H S K through S in such a position that HS = SK. The position of this chord may be determined geometrically, but finding it by trial with most ellipses is sufficiently accurate. This is quickly done by driving a fine needle through S, and revolving the scale at some even division about it until the readings both ways are equal. To find it geometrically, draw any chord parallel to CSP. From the middle point of this chord, draw a line through C, and parallel to this line, draw a line HK through S which will be the chord required.

Take a point D on the line CSP continued so that

$$SD = \frac{CP^2 - CS^2}{CP}$$

In this case we have

$$SD = \frac{.101^2 - .040^2}{.101} = 0''.085.$$

Through the point D draw a line perpendicular to the chord HK, and find points A and B on this line so that DA = DB = SH.

Eccentricity. The eccentricity is unchanged by projection and

$$e = \frac{CS}{CP} = \frac{.040}{.011} = 0.396.$$

Inclination. The inclination of the real orbit to the plane of projection is

$$\cos i = \frac{SB - SA}{SB + SA} = \frac{.106}{.490} = 0.216326.$$

From a table of natural cosines we find this corresponds to 77°.5, which is the inclination of the real to the apparent orbit.

Node. Draw a line from S bisecting the angle ASB and the position angle of this line will be the line of nodes. When expressed numerically this should be always given in the first or second quadrant, and not 180° from that point. It may be found by measuring with protractor the position-angle of A and B and taking a mean of the two for the angle of the node. In this case,

$$SB = 363°.0, \text{ and } SA = 214°.4.$$

Therefore, the line of nodes will be

$$214°.4 + 78°.3 = 288°.7 = 108°.7.$$

This is shown on the diagram by the line NSN.

Semi-major axis. For the semi-major axis of the real orbit we have:

$$a = \frac{SB + SA}{2(1-e^2)} = \frac{.490}{1.686} = 0''.29.$$

ANGLE OF LINE OF NODES AND PERIASTRON.

The element λ is the angular distance between the line of nodes and the major axis, CSP, measured on the real ellipse. We find by the protractor that the position-angle of the periastron or line of the projected major axis is 325°.8, and therefore the angle between this line and the node on the apparent ellipse is 37°.1. To reduce this to the plane of the real orbit take

$$\tan \lambda = \sec. i \times \tan 37°.1$$

$$\begin{aligned} \sec. i\,(77°.5) &= 10.664663 \\ \tan\ 37\ .1 &= \ \ 9.878691 \\ \hline & 10.543354 = 74°.0 \end{aligned}$$

There has been much confusion heretofore in giving the value of λ. Sometimes the value of ☊ has been taken on one side and sometimes the other (± 180°); and the distance from N to P has been reckoned in both directions, retrograde and direct. It is usually impossible to tell how the computer has done this without laying down the apparent orbit from the elements. Dr. See has proposed (*Astronomy and Astro-Physics*, August, 1893) to avoid this uncertainty in the future by always counting from ☊, taken in the first or second quadrant, to periastron *in the direction of the motion*. This will make all results uniform, and prevent confusion hereafter. He has adopted this plan in all his investigation of binaries, as I have done, and I trust it will be followed by all others in the future, Attention is specially called to the two important papers on this subject by Dr. See printed in *Astronomy and Astro-Physics* for August and December, 1893.

In accordance with this, we find that this element should be,

$$108°.7 - (288°.7 + 74°.0) = 106°.0$$

Periastron Passage. It only remains to find the time of the passage of the companion though P, the point of nearest approach in the real orbit. This is easily done by comparing the areas on either side of SP with the observed positions. In this way we find T = 1886.0.

In addition to the elements of the real orbit of a binary, the data for platting the apparent ellipse should always be given. This enables any one to lay down in a few minutes the orbit found by the computer, and compare it with the observations used. In no other way can the real value of the work be seen. The usual tabular comparisons of observed and computed positions are entirely insufficient. A good many orbits have been computed by the old methods, and passed without criticism which probably would have been rejected at once by the authors if the ellipse and the measures had been laid down on paper. It would have appeared then that the result reached was without foundation, and that the lack of sufficient data could not be cured by mathematical formulæ, however, scientifically administered.

Dr. See has devised an an elegant geometrical method of finding the apparent ellipse from the elements of the real orbit (*Astronomy and Astro-Physics*, August, 1893). This will be found to be very useful for laying down orbits to ascertain in what way the measures are represented. Hereafter I hope all investigators of the orbits of binary systems, whatever method may be used, will make their work complete by giving in all cases diagrams showing the apparent orbit, and the observed positions upon which such orbit is based.

ELEMENTS OF κ PEGASI.

We have the following elements of this binary:

$P = 11.37$ years.
$T = 1886.0$
$e = 0.40$
$a = 0''.29$
$i = 77°.5$
$\Omega = 109\ .2$
$\lambda = 106\ .1$

APPARENT ORBIT.

Length of major axis =	0''.54
Length of minor axis =	0 .13
Angle of major axis =	110°.0
Angle of periastron =	326 .0
Star from center =	0''.04

The period of this pair was first determined by the writer graphically (*Monthly Notices*, March, 1891), using the measures down to and including 1890, and the time of one revolution found to be 11.13 years. Subsequently Glasenapp (*Monthly Notices*, June, 1892) investigated it, using the measures of 1891, and a single measure in 1892, and made the period 11.54 years. Since that time other measures have been made, and more than one revolution described by the companion since my first measures in 1880.

This orbit differs very materially in most of the elements from those previously referred to. The eccentricity is double that of Glasenapp's, and the inclination much larger. It certainly has a shorter period than any binary of which we have any knowledge. The next in order of time is δ Equulei (OΣ535) for which Wrublewsky (A. N., 2771) in 1887 found a period of 11.54 years. Dr. See has recently investigated it, using the last measures made, and finds the periodic time to be 11.50 years. As this is based upon four complete revolutions, it is not likely that it will be sensibly reduced hereafter.

I have endeavored to make this plan of investigating the motion of a binary clear and practical, and to avoid befogging it with unnecessary formulæ and complications. I am satisfied that when the purely graphical method comes to be better understood and used, its value will be generally accepted.

VARIABLE STARS. VI.

J. A. PARKHURST.

It will doubtless be of interest to readers of POPULAR ASTRONOMY to learn something of what is being done in the observation of variable stars at the present time, and where the results of the work are published.

In Germany, the land of Argelander and Schönfeld, a number of industrious observers are working at variables. Among them may be mentioned Dr. Ernst Hartwig, Director of the Municipal Observatory at Bamberg, who is observing with a 6-inch refractor of the "comet-seeker" form, mounted in the very convenient way designed by the Repsolds. Dr. Hartwig's observations are published in the *Astronomische Nachrichten*. He also prepares annually an ephemeris of variables for the *Vierteljahrsschrift der Astronomischen Gessellschaft*.

Dr. Otto Knopf, of Jena, observes with an 8-inch Bamberg refractor. In 1892 he made 464 observations of 40 variables. He is a frequent contributor to the *Astronomische Nachrichten*.

Mr. Friedrich Krüger of Kiel has made indirectly an important contribution to the literature of variable stars by publishing in 1893 a "Catalogue of Colored Stars," giving the magnitude, color and spectral type of 2297 such objects including many of the known variables.

Professor A. Safarik of Prague, Austria, has been an industrious variable star observer, though he announces in the last *Vierteljahrsschrift* that he intends soon to bring his observing work to a close in order to devote his time to the reduction and publication of his observations, of which he has about 20,000. In 1892 he made 1727 observations of 140 stars. Professor Safarik has used a 4½-inch refractor, a 6½-inch reflector, and also a refractor whose exact size I cannot find, though it is probably above

6-inches, since he reports observations of minima of S Cassiopeiæ and R. Lyncis, which at that stage are difficult objects for a 6-inch.

Professor N. C. Dunér of Upsala, Sweden, has been observing variables with a 6½-inch refractor. In 1892 he reported 1325 observations. His work is of great value, notably his researches on the peculiar variations of the remarkable Algol type variable, Y Cygni. Professor Dunér is a contributor to the *Astronomical Journal.*

In Russia Professor S. Glasenapp has been observing variables with a 9-inch refractor at Abastuman. He writes frequently for *Astronomy and Astro-Physics.* In Italy, Professor J. Porro observes at Turin with a 4.8 inch refractor.

Among the few variable star observers in the southern hemisphere may be mentioned Mr. Alex. W. Roberts of Lovedale, South Africa, who has communicated some of his results to the *Astronomical Journal.*

A large number of workers in this field are found in Great Britan. Prominent among them is Rev. T. E. Espin of Wolsingham Observatory, Tow Law, near Darlington, who observes with a 17¼-inch reflector, and an 8-inch photographic refractor. The latter gives plates on almost the same scale as the Durchmusterung charts, so that stars can be at once identified by laying the plate on the chart. Any marked change in the brightness of the stars since the epoch of the chart is at once made evident by this operation. Espin also observes stellar spectra with the reflector, and as nearly all variables have the same type of spectrum (Secchi's Type III) a number of new ones have been discovered in this way. Chandler's Second Catalogue contains ten variables discovered by Espin. He is a frequent contributor to the *Astronomische Nachrichten.*

Mr. Geo. Knott of Cuckfield, Sussex, observes with a 7⅓-inch Clark refractor. Mr. Joseph Baxendall, Jr., of Birkdale, Southport, uses a 6-inch Cooke refractor. As an indication of the industry of the Baxendall's, Sr. and Jr., may be mentioned the fact that Chandler's Second Catalogue contains 12 variables discovered at Southport. Mr. Cuthbert E. Peek of Rousdon Observatory, Devon, observes with a 6.4-inch refractor. He makes monthly reports to the *English Mechanic.*

In Edinburg, Thos. D. Anderson is observing. He is renowned for his discovery of the new star in Auriga in Jan., 1892, aided only by a small spy glass and Klein's Atlas. Mr. Anderson has lately discovered a new variable in Cassiopeia, B. D. + 58°, 2560, which was bright enough in Dec., 1893, to be seen with a field glass, but 1894, Feb. 21, was about the 12th magnitude. Mr. Anderson thinks that this should be classed as a "temporary star" and not as an ordinary variable, but further observations will be needed to decide as to its classification.

Mr. J. Ellard Gore of Ballysodare, Ireland, is one of the best known British authorities on variable stars. He is the Director of the Variable Star Section of the British Astronomical Association. His two catalogues of variables were mentioned in the March number.

America is by no means behind in this respect, either in the number of observers or the quality of their work. We have with us the greatest living authority on variable stars, Dr. S. C. Chandler, of Cambridge, Mass. The excellence of Dr. Chandler's work lies not only in his own observations, which are made with a 6¼-inch refractor, but in his sifting, comparing and reducing a mass of observations made all over the world, and deducing therefrom the true elements of the variables. This work has been done so well for his "Second Catalogue" that Dr. Hartwig of Bamberg accepts its elements as the basis of his ephemeris for 1894, published in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, Vol. XXVIII. By common consent of astronomers the lettering and numbering of newly discovered variables is left to Dr. Chandler, as the like work for newly discovered asteroids is done by Professor Tietjen of the Recheninstitut of the Berlin Observatory. Dr. Chandler is an associate editor of the *Astronomical Journal* and a frequent contributor to its columns.

Mr. Henry M. Parkhurst of Brooklyn, N. Y., is a veteran observer. His work is done with a 9-inch Fitz refractor and special photometric appliances devised by himself. His observations are published in the *Astronomical Journal* and in the Annals of the Harvard College Observatory. Vol. XXIX of the Annals contains a very important paper giving about 3600 of Mr. Parkhurst's observations of known and suspected variables made between 1883 and 1893, a table of light curves and magnitudes of comparison stars. Dr. Gould calls this "one of the most valuable contributions to the subject which we possess." Continuations of the same series of observations are published in Nos. 308 and 311 of the *Astronomical Journal*.

Mr. Edwin F. Sawyer of Brighton, Mass., is a very careful and accurate observer. He contributes to the *Astronomical Journal*.

Mr. Paul S. Yendell of Dorchester, Mass., is one of the most assiduous variable star observers in the world. His work formed the basis of a considerable part of Chandler's Second Catalogue. He observes with a 4¼-inch Clacey refractor and contributes regularly to the *Astronomical Journal.* Nos. 309 and 310 contain confirmations by Mr. Yendell of the variation of eight suspected variables.

Rev. J. G. Hagen of Georgetown College, D. C., has observed variables for a number of years with 3 and 5 inch refractors. He takes as his special field the southern variables which are within reach at his latitude.

Mr. S. D. Townley while at Washburn Observatory, Madison, Wis., made a valuable series of observations of faint variables with the 15½-inch Clark refractor. These observations extend from Nov., 1889, to July, 1892, and were printed in Vol. VI, of the Publications of Washburn Observatory.

Frequent notices appear in *Astronomy and Astro-Physics* and the *Astronomische Nachrichten* of the discovery of new variables on the photographic plates taken at the Harvard College Observatory and its southern station at Arequipa, Peru. The discussion which has arisen in regard to these was mentioned in the March number.

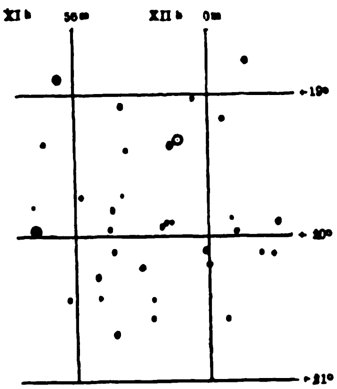
The foregoing account is necessarily incomplete but will give some idea of the work in progress in this department.

Charts of four more variables are presented this month. The following are the principal data concerning them:

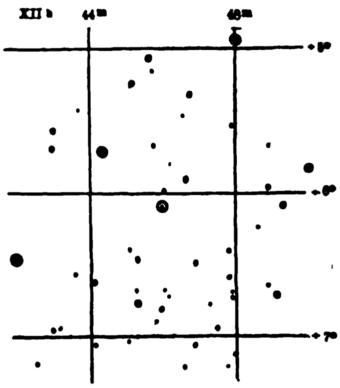
No.	Star. Name.	Place for 1900. R. A.			Decl.		Redness	Magnitude. Max.	Min.	Period days.
		h	m	s	°	′				
4315	R Comæ	11	59	7	+ 19	20.3	4.0	7.4 — 8.0	< 13.5	361
4596	U Virginis	12	46	1	+ 6	5.8	1.1	7.7 — 8.1	12.2 — 12.8	207.0
4847	S Virginis	13	27	47	− 6	40.8	2.6	5.7 — 7.8	12.5	376.4
5194	V Boötis	14	25	42	+ 39	18.5	3.6	6.9 — 7.3	9.2 — 10.5	256

These stars are selected since they become bright enough so that good determinations of their maxima can be made with a two-inch telescope. They will reach their maxima during the coming spring and summer (for reasons before mentioned it is best not to state the times more definitely); and at that time they will be in convenient position for evening observation. V Boötis can be followed through its whole period with a 3-inch telescope. It is easily found, being in the field with the third magnitude star γ Boötis.

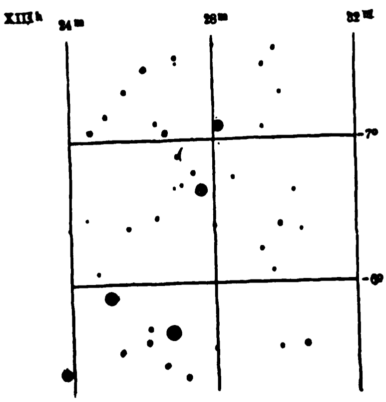
Since writing the note in regard to Mira in the March number that star has increased so as to be visible to the naked eye. Feb. 21st, it was a little brighter than the 5th magnitude.



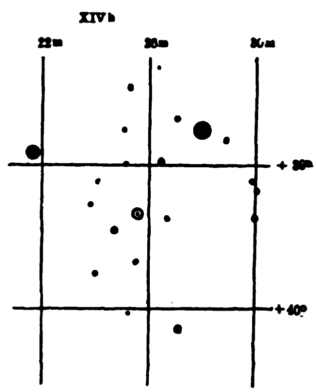
4315 R Comæ.



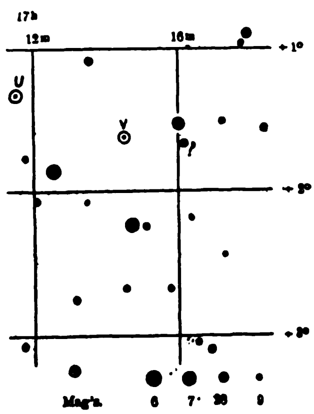
4596 U Virginis.



4847 S Virginis.



5194 V Boötis.



B. D. + 1°, 3417.

Mr. Edward N. Botsford of New Haven, Conn., has ordered a 4½-inch refractor and expects to take part in variable star work.

I have just received the March POPULAR ASTRONOMY containing the announcement of the discovery by Mrs. Fleming of two new variables on the Harvard plates. One of them is

B. D. + 1°, 3417, R. A. 17^h $14^m.5$, Dec. + 1° 37′, 1900.

Mrs. Fleming says—"it varies from the magnitude 8.5 to 12.5." I therefore give a chart of the vicinity, the new variable being marked V. The same chart contains the Algol-type variable U Ophiuchi, marked U, and a star marked ? whose magnitude has been variously estimated from magnitudes 7.8 to 9.0, which will bear watching. It is B. D. + 1°, 3422.

MARENGO, Ill., 1894, Feb. 26.

CONSTELLATION STUDY.

WINSLOW UPTON.

VI.

We now take up the constellations in the second division of the heavens—that included between the hour circles of 6 and 12 hours right ascension. We have already considered the circumpolar constellation of this group, the enormous area designated Ursa Major. The constellation Lynx might also have been regarded as circumpolar, but its leading stars are south of 50° declination, and it will be described below.

The zodiacal constellations of this division are Gemini, Cancer and Leo.

Gemini. The two leading stars of this group are Castor and Pollux, or α and β Geminorum. The latter is the southern of the two and though lettered β is appreciably the brighter. They are about 5° apart and are the only especially conspicuous stars between Taurus and Leo. They can also be readily found from Orion, by extending the line from Rigel to Betelgeuse, one and a half times the distance between these brilliant stars. These stars are in the heads of the twins, and the figures are drawn southwesterly with their feet near the boundary of Orion. Two lines of stars may be readily traced, as indicated on the chart, following the respective figures. The northern one follows the body of Castor and the latter that of Pollux. The feet are also marked by stars; ξ and γ are the feet of Pollux and ν and μ those of

Castor. This line of stars, ξ, γ, ν, μ is easily traced, and is near the western boundary of the area. Just west of μ is a star of nearly equal brightness lettered y. This is very near the place occupied by the Sun at the summer solstice. The solstitial colure may therefore be traced by following the line connecting this star with the Pole Star.

Cancer. The space allotted to this group is rather small and there are no conspicuous stars. The characteristic figure is the cluster called Præsepe which may be found by passing from β Geminorum to α Leonis, the bright red star in that constellation. The cluster is a little south of this line. Two fourth magnitude stars flank this cluster on the east, and two more of similar brightness are readily found, the one north and the other southeast, the four making a curved line, convex towards Præsepe.

Leo. This fine constellation is easily traced. It has two characteristic figures,—the "Sickle" at the western and a right angled triangle at the eastern boundary of the area. The Sickle contains six bright stars, the group closely representing the shape of the article named. The bright red star at the end of the handle is α Leonis or Regulus. The Sickle is east of Cancer. East of the Sickle is the right-angled triangle, the easternmost star, β Leonis, having also the name Denebola. The figure of the lion is drawn with the Sickle for the forepart, the curve of the Sickle terminating in the head, and the triangle forms the hinderpart and tail of the animal. A number of faint stars south of the triangle represent the hind legs, the area, as shown on the chart, having a large southern extension.

North of the three zodiacal constellations are the two inconspicuous groups Lynx and Leo Minor. The eastern portion of Auriga is also north of Gemini and Ursa Major touches Leo on the northeast corner.

Lynx. This area is almost wholly destitute of stars visible to the naked eye, and is the name of the space between Auriga and Ursa Major. The head of the animal contains a number of stars near the limit of vision, north of the head of the Charioteer. The tail in the southeast of the area contains two stars easily noted, the southern of which, 40 Lyncis, is the brightest of the constellation. One of the fore paws of the Great Bear overlies the tail of the Lynx, and the two stars just named might with advantage have been included in Ursa Major, as mentioned in describing that constellation, and this overlapping thereby prevented.

Leo Minor. This group lies north of the Sickle and south of the hind paws of the Great Bear, which were each marked, it will be remembered, by a pair of stars. An elongated triangle of fourth magnitude stars, numbered 21, 31 and 46 with a line of somewhat fainter stars south of them, numbered 30, 37 and 42 designates the characteristic figure. Or they may be traced by the guiding lines drawn on the chart.

Six constellations may be traced south of the zodiac by northern observers and a seventh is partly visible in the extreme south.

Monoceros. This is the name given to the space east of Orion north of the conspicuous group Canis Major and south of Gemini, Canis Minor and Hydra. The outlines of the area may be roughly determined by noting the positions of the five brightest stars, 11, 15, 22, 26 and 30, or the guide lines of the chart may be followed for a more minute study. The constellation was one of those added by Hevelius to name a space not already appropriated. All such constellations would necessarily be inconspicuous. The Unicorn is drawn with his head towards the northwest, at the star numbered 15.

Canis Minor. This group consists of two leading stars south of Castor and Pollux. They are quite like the latter pair in distance and might be confounded with them but for their marked difference in brightness, while Castor and Pollux are of nearly equal brilliancy. The brighter is α Canis Minoris or Procyon, one of the most brilliant stars in the sky, slightly preceding Sirius, the Dog Star, in its time of rising (as seen by northern observers), which is immortalized in the etymology of its name, the star preceding the Dog Star.

Hydra. This winding constellation is an interesting one to trace. The head is a group of stars south of Cancer and east of Leo Minor. From this several faint stars curve southward to the brighest star of the constellation, α Hydræ. Then a line of faint stars may be followed southward and eastward. The line runs south of Crater, into the third division of the heavens, south of Corvus and Virgo to the western boundary of Scorpio. On the chart this part of the heavens is drawn very much larger in proportion than the more northern constellations, which is a necessary but misleading feature of the planisphere projection. The constellation extends over about 100° in right ascension, which is about the distance between the Pleiades and the Sickle.

Sextans. This small area, the name of which was also assigned by Hevelius, lies between Hydra and Leo, and contains no conspicuous stars. The brightest star is of the fourth magnitude and is 12° directly south of Regulus.

Crater. This group lies south of the southern extension of Leo and north of Hydra. It is not difficult to trace a resemblance to a cup by following the guide lines of the chart. But the group must not be confounded with the much more conspicuous quadrilateral adjacent on the east, which is Corvus. The line of stars marking Hydra should also be traced first, when the relation of this group to the adjacent groups will be recognized.

Canis Major. This group, southeast of Orion is noteworthy because containing the brightest of the fixed stars, Sirius or α Canis Majoris. The characteristic figure is an elongated quadrilateral, formed by α and β, the latter of which is 5° west of the former, and δ and ϵ, southeast of this pair. The side α, δ, has an additional star o; beyond the quadrilateral, another bright star 10° west of ϵ, lettered ζ, marks the southwestern part of the area, while another star, η, forming an equilateral triangle with δ and ϵ marks the southeastern part.

Argo Navis. This constellation belongs to those southern groups, which are almost wholly below the horizon of observers in northern latitudes. The mast and stern of the ship, however, are in the region south of Hydra and east of Canis Major. As the constellation occupies an enormous area in the heavens, it is customary to subdivide it into smaller areas, like the counties of a state, which are named from the parts of the vessel. *Malus* and Puppis are the subdivisions in the region under discussion. The only stars easily visible however to observers in the United States are those in Puppis which are immediately adjacent to the southeastern part of Canis Major. A little group of inconspicuous stars is east of η Canis Majoris while 10° northeast is the only conspicuous star of the group, named ι Navis or φ Puppis. The latter designation is that given on the chart. Two conspicuous stars in this constellation may be seen to better advantage by observers in the southern part of the United States, than by those farther north. They are of the second magnitude and lettered ζ and γ respectively. The former is in the prolongation of the line from α Orionis to α Canis Majoris, and the latter 7° south of the former. Almost due south of Sirius is Canopus or α Argus, one of the most brilliant stars of the heavens, but as its declination is nearly 53° south, it cannot be seen by observers north of latitude 37°.

There are several points connected with the stars in this second division of the heavens which are worth noting:

It contains the brightest and the faintest of the stars which are called first magnitude stars. The division of the stars into "magnitudes" is as old as the classical period of astronomy, and has come down to us from the Greeks, who used six classes into which the stars were graded according to their brightness. The word "magnitude" is evidently a misnomer, for the apparent brightness of a star depends upon its distance and its intrinsic brightness as well as upon its size, but the word is still retained as a synonym of apparent brightness. The classification was good for the second to the sixth magnitudes, but in the first grade all stars were included which are brighter than the limit between the first and second grade, and there is a wide range among the nineteen stars thus grouped. The photometric classification of stars follows the old one of magnitudes as far as is possible, but subdivides the first magnitude class into 1st magnitude, 0 magnitude, and as the scale runs out is obliged to call Canopus and Sirius of the — 1 magnitude. There is a disagreement as yet as to the lower limit of the first magnitude group, some writers placing *α* Cygni or *α* Crucis in the list, and giving the number as 20 or 21. But *α* Leonis or Regulus is the one next brighter than the two named and may therefore be taken as the lower limit of brightness at present allowed without dispute for a first magnitude star. Any star in the sky which is between Sirius and Regulus in brilliancy is a first magnitude star. Fourteen of the nineteen are visible to northern observers. In the first division are Capella, Aldebaran, Betelgeuse and Rigel, or *α* Aurigæ, *α* Tauri, *α* Orionis and *β* Orionis respectively, and in the second division are Pollux, Regulus, Procyon and Sirius or *β* Geminorum, *α* Leonis, *α* Canis Minoris, and *α* Canis Majoris respectively.

The six first magnitude stars, Sirius, Procyon, Betelgeuse, Rigel, Aldebaran and Pollux are near enough in the sky to be grouped together. The first three named form a nearly equilateral triangle, to which Rigel may be added to form a quadrilateral, nearly square; or Pollux may be added to the three to form a diamond-shaped quadrilateral.

The zodiacal constellations of this division are those through which the Sun moves in summer, and hence are north of the equator. The leading stars of the groups are situated as follows regarding the ecliptic. *Gemini*: *η* is nearly at the solstitial point as above mentioned and Castor and Pollux are 7° and 12° respectively north of the ecliptic. The ancients adopted 8° as the width of the zodiac north and south of the ecliptic. The northern boundary of the zodiac therefore passes between these stars. *Cancer*: Præsepe is 2° north of the ecliptic. *Leo*: Regulus is a little north of the ecliptic.

The celestial equator, which passes very close to the westernmost star of the belt of Orion, is 5° south of Procyon, and 7° south of the head of Hydra.

The constellations of the second division are best studied in the winter months, but can be well seen in the early spring also. At the first of April the meridian in the evening passes through Leo, and the constellations are for the most part in the west. If learned in this position they should be reviewed in the autumn when in the east in the evening sky.

The following table gives the approximate positions of the leading stars in each constellation.

Approximate Positions of the Leading Stars in the Constellations between VI^h and XII^h Right Ascension, Omitting Circumpolar Constellations.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
		Lynx.			
38	3.8	9	13	37	14
40	3.4	9	15	34	49
		Leo Minor.			
		No bright stars.			
		Gemini.			
η	3.5	6	9	22	32
μ	3.2	6	17	22	34
γ	2.0	6	32	16	29
ε	3.2	6	38	25	14
ξ	3.4	6	40	13	0
δ	3.6	7	14	22	10
α	2.0	7	28	32	7
β	1.1	7	39	28	16
		Cancer.			
ε (cluster).	—	8	34	19	58
		Leo.			
ε	3.1	9	40	24	15
μ	4.1	9	47	26	29
η	3.6	10	2	17	15
α	1.4	10	3	12	27
ζ	3.6	10	11	23	55
γ	2.2	10	14	20	21
δ	2.8	11	9	21	5
θ	3.5	11	9	15	55
β	2.2	11	44	15	8
		Monoceros.			
		No bright stars.			
		Canis Minor.			
β	3.1	7	22	8	30
α	0.5	7	34	5	29

SEXTANS.

No bright stars.

HYDRA.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
ε	3.6	8 41	+ 6 47
ζ	3.3	8 50	+ 6 20
α	2.0	9 23	− 8 13
ν	3.3	10 45	− 15 40
γ	3.5	13 13	− 22 38

CRATER.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
α	4.1	10 55	− 17 46
β	4.4	11 7	− 22 16
δ	3.9	11 14	− 14 14
γ	4.2	11 20	− 17 8
ζ	4.9	11 40	− 17 48

CANIS MAJOR.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
ζ	3.0	6 16	− 30 1
β	2.0	6 18	− 17 54
α	− 1.4	6 41	− 16 34
ε	1.5	6 55	− 28 50
o^2	3.0	6 59	− 23 41
δ	1.8	7 4	− 26 12
η	2.4	7 20	− 29 6

ARGO NAVIS.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
ξ	3.4	7 45	− 24 37
ζ	2.5	8 0	− 39 43
ν	2.9	8 3	− 24 1
γ	3.0	8 6	− 47 2

SUGGESTIONS TO AMATEURS.

Nebulæ and Clusters.

LEWIS SWIFT.

There are many varieties of nebulæ, as bright and faint, large and small, round, elliptical and irregular, etc., but they may be divided into two general classes, resolvable and irresolvable, or, what is still better, into stellar and gaseous nebulæ. But for the decisive revelations of the spectroscope, it would now, as in former times, be reasonable to infer that, inasmuch as many have been resolved into stars, all would be found thus resolvable if sufficient optical power were at our command. We find clusters of nebulæ as well as clusters of stars, the most wonderful series being the Magellanic Clouds of the southern hemisphere, not far distant from the pole. The most extensive group visible from our latitude is found in Virgo, where it often happens that several are visible in a single field of the telescope. No one has ventured to suggest the reason for such a profusion in areas so small as these we have cited. It would seem that at some time, if not now, they were physically connected. This can scarcely be doubted of those so near together as to be in the same field of the telescope, but the most powerful telescopes fail to deal intelligently with them.

Leo, also, contains many nebulæ. With a field of 32′ on my 16-inch telescope, I have seen at one view nine conspicuous nebulæ, and Professor Burnham once saw, in another part of the sky, eighteen in a much smaller space. If eighteen stars of equal magnitude were found in such close proximity, they would certainly be pronounced a physically connected cluster.

In R. A. $16^h\ 1^m$, Dec. + 18°, there are twelve in one field of 32′ with one or two suspected ones, while just outside the field are eight others.

In a single field near Algol, I once counted twelve at one view.

There appears to be no relation whatever between the nebulæ and neighboring stars, and yet Sir William Herschel is reported as having bidden his sister when he encountered a vacancy or a region sparse in stars, to "Prepare to write, nebulæ are coming." The sky is filled with such vacancies, but it is contrary to my own experience to find that nebulæ are more numerous near these deserts, and the statement is so far from the truth that I must doubt his having uttered it.

Like many of the stars, some of the nebulæ are double and triple. One of my own, New General Catalogue, No. 6679, is a close double, suspected with a power of 132, confirmed with 200, and well separated with 250. I also found one of Sir William Herschel's to be an equally close double. It would be a great satisfaction to be fully assured that they are binaries.

Of clusters resolvable with such telescopes as amateurs possess, the sky affords numerous examples as the following list for A. D. 1900 will show:

No. 1. The Pleiades. On an exquisite night several years ago, I counted with my 4½-inch refractor three hundred stars in the cluster. On that occasion I first saw the Merope nebula which I strongly suspected to be a comet. Six hundred are visible with my 16-inch glass, but the celestial camera plainly depicts on the negative plate 2,326 stars.

No. 2. $2^h\ 15^m + 56°\ 39'$. This is the magnificent double cluster in Perseus, visible to the naked eye as a small, hazy spot between Cassiopeia and Alpha Persei.

No. 3. $8^h\ 34^m + 20°\ 20'$. This is the well known cluster visible to the naked eye as a small, round, hazy spot. It was first discovered or, at least, recorded by Hipparchus. It is number 44 of Messier's Catalogue, 1681 of Herschel's G. C., and 2652 of N. G. C. It is called Præsepe or the Beehive. It shows many little triangles, and is a very pretty object for small telescopes.

No. 4. $13^h\ 37^m + 28°\ 53'$. In the Hunting Dogs on a line with and nearly midway between Arcturus and Cor Caroli, a little nearer the former star. A grand cluster of one thousand stars of the eleventh magnitude. It is not visible to the naked eye. Sir William Herschel is made to say that it exhibited a mottled appearance to him which must certainly apply to some other object.

No. 5. $16^h\ 38^m + 36°\ 39'$. A gorgeous cluster through larger telescopes; one of the six visible to the unassisted eye. It is on a line between Eta and Zeta Herculis but nearer to Eta. It was discovered by Halley in 1714, and is number thirteen of Messier's Catalogue. Herschel, it is said, asserted that it contained 14,000 stars, a misprint no doubt for 4,000.

No. 6. $17^h\ 14^m + 43°\ 15'$. Also in Hercules, but the stars are fainter than in Messier 13. It is 92 of M. Cat. Its stars are from the eleventh to the eighteenth magnitudes.

No. 7. $18^h\ 12^m - 18°\ 29'$. A glorious field of stars in the Milky Way. This, with the 16-inch, is the most attractive object to visitors at the Observatory. The contrast between it and a black opening (coal sack) near by is very striking and elicits much comment. In this vacancy I see but three stars.

In $13^h\ 26^m + 47°\ 43'$ is the famous double nebula, 51 M., or the great spiral of Lord Rosse.

$17^h\ 59^m + 66°\ 38'$ = Gen. Cat. 4373; $19^h\ 42^m + 50°\ 17'$ = Gen. Cat. 4514; and $23^h\ 21^m + 42°$ = Gen. Cat., 4964, are the places of three bright planetary nebulæ. The second, one of the most interesting of nebulæ, has a very faint star exactly in its center, a severe test of vision. According to Professor Mitchell, "now you see it, and now you don't see it."

Mine differ from other eyes, if a blue color can be seen in any planetary nebula.

ROCHESTER, N. Y., Jan. 29, 1894.

To ask or search, I blame thee not, for heaven
Is as the book of God before thee set,
Wherein to read His wondrous works, and learn
His seasons, hours or days, or months, or years.

—Milton.

WHAT A FIVE-INCH TELESCOPE WILL SHOW.

GARRETT P. SERVISS.

In one of the early numbers of the *Sidereal Messenger*, Professor H. L. Smith, then of Hobart College, described the beautiful work done by a short focus telescope made for him by John Byrne of New York. The glass was of 4¼-inch aperture and 38-inch focal length. I had the pleasure of looking through that glass just after it had been finished by Mr. Byrne and before he had shipped it to its purchaser. It seemed to me then that I had never beheld such clean-cut star disks, and such admirable views of Saturn as it afforded.

Recently I have procured through Messrs. Gall and Lembke of New York, with whom Mr. Byrne is now associated, a short-focus 5-inch telescope of Byrne's making, and I think some account of its performances will be of interest to the readers of POPULAR ASTRONOMY. This telescope, of 5-inch clear aperture, has a focal length of 52½ inches. If made according to the ordinary formula it would have been about 75 inches in length. Two distinct advantages are gained through cutting down the focal length; first greater ease in handling, and second, increased light in proportion to length.

One of the first objects upon which I chanced to turn the glass last summer, after receiving it from the hands of the maker, was Antares. Everybody knows the story of the discovery by Professor Mitchell of the seventh magnitude green companion of this great fiery star. He saw it emerging before its brilliant comrade from occultation behind the Moon. It is not an easy star to see with telescopes of moderate size. Herschel missed it with his great instruments, and until 1844 nobody in Europe had ever seen it. I was gratified at the exceeding ease with which the 5-inch showed it. The disks of both stars were beautifully defined, and the diffraction rings playing around Antares added splendor to the contrast of color between it and its little companion. It was a most charming sight.

Wishing to try a closer test object, I turned to the star Σ 2173 in Ophiuchus. The components are each of sixth magnitude and their distance apart is $0''.91$. This is just at the limit of separating power for a 5-inch according to Dawes' rule, and I might therefore have anticipated some difficulty. But I found none. The stars were split at once. The double ξ Scorpii, distance $1''.23$, was so easily divided that I was able to show it to a person who had had no experience in using telescopes.

This winter I have tried the glass in Orion with equally gratifying success. In the presence of the Moon at first quarter I have seen both the fifth and the sixth stars in the trapezium almost without effort. The 1″ double, η Orionis, which Webb says was sometimes split by his 5½-inch, I can see completely separated at all times. The flocculent appearance of the great nebula as shown with this glass is a most interesting reminder of its appearance when viewed with the large telescopes of the observatories.

I have mentioned these particulars because I believe that it is a matter of interest, as well as of importance, to every amateur in astronomy to know what a really good glass of any given aperture should be able to do, and to know, moreover, who is competent to make good glasses. There are not so many men who can do it that there is any danger of their elbowing one another out of the field. Then, too, I wish to say a word in behalf of short-focus telescopes, especially for portable use. Nobody who has used a good short telescope will ever consent to be bothered with a long one of the same aperture.

BROOKLYN, N. Y., Jan. 17.

THE APEX OF THE EARTH'S WAY.

T. J. J. SEE.

The annual motion of the Earth westward round the Sun gives rise to the apparent eastward motion of the Sun among the stars, which is easily observed by noting the changing position of the Sun among the constellations lying near the ecliptic. In this way the path of the Sun among the stars was investigated by the ancients, who called the great circle which the Sun annually traces out in the sky, the *ecliptic*, because the eclipses, which depend upon the positions of the Sun and Moon with respect to the Earth (as was fully understood by the ancients) occur near this apparent path of the Sun, which is the intersection of the plane of the Earth's orbit with the celestial sphere.

Now, if we look at the Sun at noon, we know that it is apparently moving eastward, and that the Earth is really moving westward, in the plane of the ecliptic in a direction perpendicular to the line drawn from the observer to the Sun. The apex of the Earth's way at noon will, therefore, generally be near the western horizon, at a point in the ecliptic 90° from the Sun. The direction from which the Earth is moving will be situated at a point in the ecliptic 90° ahead of the Sun, and at noon will therefore be near the eastern horizon. Now when the Sun is setting the point from which the Earth is receding will be near the meridian, and the apex of the Earth's way will be under the Earth, the two points being 180° apart, on exactly opposite sides of the celestial sphere. At midnight, when the Sun is at its lower culmination, the apex of the Earth's way will be rising, while the point of the heavens from which the Earth is receding will be setting. If, therefore, we know the path of the ecliptic by the positions of naked-eye stars, we shall be able to locate the apex of the Earth's way at any given time of the year. Owing to the motion of the Earth, the position of this apex will move eastward along the ecliptic at the rate of about a degree per day, the same rate as the Sun moves. The point from which the Earth is moving advances at the same rate, and if we can locate the apex of the Earth's way, it will be easy to locate the point of the heavens from which the Earth is moving. In observing shooting stars it is often important to be able to locate the apex of the Earth's way by means of naked-eye stars, as it is the point from which most meteors will generally appear to come, owing to the motion of the Earth being here added to the independent motion of the meteorites in space. By the use of star charts, or a celestial globe, this is easily effected. If we begin with January the apex of the Earth's way, for the twelve months of the year, is situated successively in the following constellations:

Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces, Aries, Taurus, Gemini, Cancer, Léo.

Any amateur who is familiar with the constellations along the ecliptic can therefore easily locate the apex of the Earth's way at any time, and it is thus easy in contemplating the heavens to look back on the path we have traversed in our journey round the Sun, and to locate the apex of the Earth's way towards which we are moving at the rate of about 19 miles per second.

THE UNIVERSITY OF CHICAGO, 1894, Jan. 25.

Brilliant Meteor.—At about 8:30 last evening, March 2, a bright meteor swept across the southern sky, meeting the meridian at about an angle of 80°, moving westward and a little southward. It passed about 1° south of Sirius, and its path seemed to be about 15° long. The first half or two-thirds of the track showed many sparks, while the last of it was very distinctly blue and was very bright and without sparks. Moreover, this portion seemed to be of an extremely elongated spindle shape, tapering slightly towards the ends, and there being cut off cleanly. The track disappeared instantly, and did not extend farther west than the star in the nose of Canis Major. W. S. A.

PLANET NOTES FOR MAY.

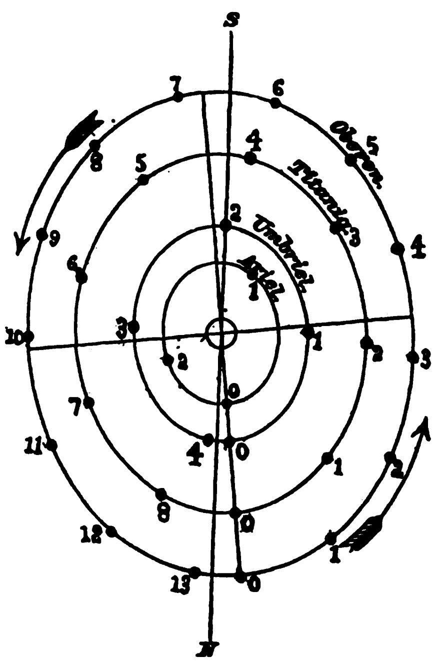
H. C. WILSON.

Mercury will be at superior conjunction, *i. e.*, behind the Sun, May 20 at 9^h 44^m central time. During May this planet will be wholly hidden to the eye by the glare of the Sun, although it is calculated to reach its greatest brilliancy on the 23d.

Venus will be in good position for observation about 4 o'clock in the morning during May. Her phase will increase from about half to two-thirds during the month, while her brilliancy will diminish in the ratio of 137 to 97 in the same time, because of her recession from the Earth. Venus and the waning Moon will be in conjunction May 1st at 5^h 07^m P. M. central time and again May 31 at 3^h P. M.

Mars is also to be observed in the morning. He is about 30° west and 14° south from Venus, in the constellation Capricorn and will move northeast into Aquarius during May. At the end of the month he will be found about half way between the first magnitude stars Fomalhaut (*α Piscis Austrini*) and Markab (*α Pegasi*). Mars will be in conjunction with the Moon March 28 at 2^h 18^m central time. Observers in Central and South America may see the planet occulted at this time.

Jupiter and *Neptune* will be too low in the west during the early evening hours for any satisfactory observations during this month. The tables of the satellites are therefore omitted. On Poole Bros. map for this month, however, the courses of Jupiter and Neptune among the stars are indicated for the six months from April 1 to Sept. 1.



APPARENT ORBITS OF THE SATELLITES OF URANUS IN 1894.

Saturn will be in best position for observation during May, crossing the meridian about 10 o'clock in the first half and 9 o'clock P. M. in the latter half of the month. The rings of Saturn are now pretty well widened out, so that the three parts can be distinguished readily and the Cassini division can be followed all the way around. The elevation of the Earth above the plane of the rings is about 12°. Saturn is in the constellation Virgo about 5° north of the first magnitude star Spica, with which he is almost equal in brightness. A conjunction of the Moon and Saturn occurs May 16 at 10^h 55^m A.M.

Uranus is also in good position for observation, being at opposition May 3. We give this time a diagram showing the apparent courses of the four satellites about the planet. In the tables we give the times when each satellite will be at greatest elongation, that is, at the point 0 on the diagram. The black dots with the numerals beside them indicate the positions of the satellites on the successive dates after the northern elongation. For example, Umbriel will be at northern elongation, *i. e*, at the point marked 0 on its orbit, May 3 at $8^h.6$ P. M. On May 4 at the same hour it will be at the point marked 1, May 5 at the same hour it will be at 2, etc.

The four oldest of the minor planets, *Ceres*, *Pallas*, *Juno* and *Vesta*, all happen to be in the region of sky covered this month by Poole Bros'. map, and their apparent courses for the next six months are shown in red upon the map. Ceres, Pallas and Vesta have passed the best time for their observation but will all be bright enough to be found without much difficulty during the next three months. Ceres was at opposition March 13. Its brightness will be equal to that of a star of the 7.2 magnitude April 1, 7.5^m May 1, 7.9^m June 1, 8.2^m July 1, 8.5^m August 1, and 8.8^m September 1. Pallas was at opposition Feb. 7. Its brightness will be 7.0^m April 1, 7.6^m May 1, 8.1^m June 1, 8.5^m July 1, 8.8^m Aug. 1, and 9.1^m Sept. 1. Vesta was at opposition March 10. Its brightness will be 6.5^m April 1, 6.8^m May 1, 7.2^m June 1, 7.5^m July 1, 7.8^m Aug. 1 and 7.9^m Sept. 1. Juno is not so favorably situated. Although she comes to opposition May 7 she is so far from her perihelion, or point of nearest approach to the Sun, that she will at brightest be only of the tenth magnitude and will therefore probably not be seen by the amateur.

Planet Tables for May.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1894.	R. A. h m	Decl. ° ′	Rises h m	Transits h m	Sets. h m
			MERCURY.		
May 5	1 50.6	+ 9 16	4 15 A. M.	10 56.5 A. M.	5 38 P. M.
15	3 06.3	+16 58	4 18 "	11 32.7 "	6 47 "
25	4 35 7	+23 14	4 27 "	12 22.5 P. M.	8 08 "
			VENUS.		
May 5	23 58.4	− 1 15	3 05 A. M.	9 04.5 A. M.	3 04 P. M.
15	0 37.7	+ 2 17	2 51 "	9 04.4 "	3 18 "
25	1 18.2	+ 6 03	2 37 "	9 05.4 "	3 34 "
			MARS.		
May 5	21 58.9	− 14 11	1 58 A. M.	7 05.3 A. M.	12 12 P. M.
15	22 26.0	− 11 55	1 36 "	6 53.1 "	12 10 "
25	22 52.4	− 9 32	1 14 "	6 40.2 "	12 07 "
			JUPITER.		
May 5	4 21.2	+20 59	5 53 A. M.	1 26.5 P. M.	9 00 P. M.
15	4 30.8	+21 22	5 22 "	12 56.8 "	8 32 "
25	4 40.6	+21 43	4 50 "	12 27.2 "	8 04 "
			SATURN.		
May 5	13 18.2	− 5 18	4 39 P. M.	10 22.1 P. M.	4 06 A. M.
15	13 15.9	− 5 05	3 56 "	9 40.5 "	3 25 "
25	13 14.1	− 4 56	3 14 "	8 59.4 "	2 44 "
			URANUS.		
May 5	14 43.6	− 15 25	6 45 P. M.	11 47.2 P. M.	4 49 A. M.
15	14 41.9	− 15 18	6 04 "	11 06.3 "	4 09 "
25	14 40.4	− 15 11	5 22 "	10 25.4 "	3 28 "

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			NEPTUNE.		
May 5......	4 43.6	+20 50	6 16 A. M.	1 49.1 P. M.	9 22 P. M.
15......	4 45.2	+20 52	5 38 "	1 11.2 "	8 44 "
25......	4 46.7	+20 55	5 00 "	12 33.4 "	8 07 "
			THE SUN.		
May 5......	2 51.0	+16 24	4 44 A. M.	11 56.5 A. M.	7 08 P. M.
15.....	3 30.0	+18 59	4 32 "	11 56.2 "	7 20 "
25......	4 10.0	+21 03	4 23 "	11 56.7 "	7 31 "
			THE MOON.		
May 2......	0 16.4	+ 1 02	3 24 A. M.	9 34.2 A. M.	3 56 P. M.
4......	1 58.0	+14 11	3 59 "	11 07.7 "	6 34 "
6......	3 56.9	+24 38	4 58 "	12 58.5 P. M.	9 12 "
8......	6 13.3	+28 33	6 30 "	3 06.6 "	11 36 "
10......	8 27.0	+24 03	9 01 "	5 12.0 "	1 08 A. M.
12......	10 21.9	+13 34	11 41 "	6 58.8 "	2 01 "
14......	12 02.0	+ 0 43	2 09 P. M.	8 30.7 "	2 38 "
16......	13 37.8	−11 49	4 30 "	9 58.4 "	3 15 "
18......	15 18.4	−21 56	6 50 "	11 30.9 "	4 03 "
20......	17 07.4	−27 42	9 05 "	1 11.6 A. M.	5 15 "
22......	18 59.6	−27 51	10 53 "	2 55.8 "	7 01 "
25......	20 45.6	−22 38	12 05 A. M.	4 33.6 "	9 10 "
27......	22 22.0	−13 24	12 52 "	6 02.1 "	11 23 "
29......	23 54.3	− 1 36	1 28 "	7 26.2 "	1 38 P. M.
31......	1 31 8	+11 11	2 04 "	8 55.4 "	4 03 "

Phases and Aspects of the Moon.

	Central Time. d	h m
New Moon..	May 5	8 42 A. M.
Perigee..	" 7	10 24 P. M.
First Quarter..	" 12	12 21 A. M.
Full Moon..	" 19	10 43 A. M.
Apogee..	" 23	6 20 P. M.
Last Quarter..	" 27	2 04 P. M.

Elongations of the Satellites of Uranus.

[The diagram shows the apparent form of the satellites of Uranus during the summer of 1894. The black dots with the numerals indicate the positions of the satellites at intervals of 1 day after each northern elongation. The points marked 0 are those of northern elongation.]

ARIEL.

	h	
May 3	11.2 A. M.	N
5	11.7 P. M.	N
8	12.2 P. M.	N
11	12 7 A. M.	N
13	1.2 P. M.	N
16	1.7 A. M.	N
18	2.1 P. M.	N
21	2.6 A. M.	N
23	3.1 P. M.	N
26	3.5 A. M.	N
28	4.0 P. M.	N
31	4.5 A. M.	N

UMBRIEL.

	h	
May 3	8.6 P. M.	N
8	12.1 A. M.	N
12	3.5 "	N
16	7.0 "	N
20	10.5 "	N
24	2.0 P. M.	N
28	5 4 "	N

TITANIA.

	h	
May 2	7.8 P. M.	S
7	4.3 A. M.	N

TITANIA CONT.

	h	
May 11	12.8 P. M.	S
15	9.3 "	N
20	5.8 A. M.	S
24	2.3 P. M.	N
28	10.8 "	S

OBBERON.

	h	
May 7	9.8 A. M.	S
14	3.4 "	N
20	9.0 P. M.	S
27	2.7 "	N

Elongations of the Satellites of Saturn.

MIMAS.

		h		
May	1	9.9	P. M.	W
	2	8.5	"	W
	3	7.1	"	W
	4	5.7	"	W
	5	4.3	"	W
	6	2 9	"	W
	8	12.9	A. M.	E
	8	11.5	P. M.	E
	9	10.1	"	E
	10	8.8	"	E
	11	7.4	"	E
	12	6.0	"	E
	13	4.6	"	E
	14	3.2	"	E
	16	1.2	A. M.	W
	16	11.8	P. M.	W
	17	10.4	"	W
	18	9.0	"	W
	19	7.6	"	W
	20	6.2	"	W
	21	4.8	"	W
	22	3.4	"	W
	24	1.4	A. M.	E
	24	12.0	midn.	E
	25	10.6	P. M.	E
	26	9.3	"	E
	27	7.9	"	E
	28	6.5	"	E
	29	5.1	"	E
	30	3.7	"	E

ENCELADUS.

May	2	3.6	P. M.	E
	4	12.5	A. M.	E
	5	9.4	"	E
	6	6.3	P. M.	E
	8	3.1	A. M.	E
	9	12.0	M.	E

ENCELADUS Cont.

		h		
May	10	8.9	P. M.	E
	12	5.8	A. M.	E
	13	2.7	P. M.	E
	14	11.5	"	E
	16	8.4	A. M.	E
	17	5.3	P. M.	E
	19	2.2	A. M.	E
	20	11.1	"	E
	21	7.9	P. M.	E
	23	4.8	A. M.	E
	24	1.7	P. M.	E
	25	10.6	"	E
	27	7.5	A. M.	E
	28	4.3	P. M.	E
	30	1.2	A. M.	E
	31	10.1	A. M.	E

TETHYS.

May	1	9.4	P. M.	E
	3	6.7	"	E
	5	4.0	"	E
	7	1.3	"	E
	9	10.6	A. M.	E
	11	7.9	"	E
	13	5.2	"	E
	15	2.5	"	E
	16	11.8	P. M.	E
	18	9.1	"	E
	20	6.4	"	E
	22	3.7	"	E
	24	1.0	"	E
	26	10.3	A. M.	E
	28	7.6	"	E
	30	4.9	"	E

DIONE.

May	2	10.3	P. M.	E
	5	4.0	"	E
	8	9.7	A. M.	E

DIONE Cont.

		h		
May	11	3.4	A. M.	E
	13	9.0	P. M.	E
	16	2.7	"	E
	19	8.4	A. M.	E
	22	2.0	"	E
	24	7.7	P. M.	E
	27	1.4	"	E
	30	7.1	A. M.	E

RHEA.

May	4	3.3	P. M.	E
	9	3.6	A. M.	E
	13	4.0	P. M.	E
	18	4.4	A. M.	E
	22	4.8	P. M.	E
	27	5.2	A. M.	E
	31	5.5	P. M.	E

TITAN.

May	2	11.9	P. M.	I
	7	3.0	A. M.	W
	11	5.2	"	S
	14	11.8	P. M.	E
	18	9.4	"	I
	23	12.3	A. M.	W
	27	2.7	"	S
	30	9.3	P. M.	E

HYPERION.

May	3	10.8	P. M.	W
	8	8.3	A. M.	S
	13	1.0	P. M.	E
	19	8.7	"	I
	25	3.4	A. M.	W
	29	12.8	P. M.	S

IAPETUS.

Apr.	27	9.2	A. M.	I
May	17	4.3	"	W
June	6	3.7	"	S

Maxima and Minima of Variable Stars.

MAXIMA

May	2	R Trianguli
	3	S Carini
	3	U Monocerotis
	4	R Lyræ
	6	U Aurigæ
	7	V Ophiuchi
	10	V Virginis
	11	S Virginis
	13	R Tauri
	17	U Geminorum
	18	S Serpentis
	19	T Pegasi
	91	S Vulpeculæ
	20	S Aquilæ
	21	T Herculis
	24	T Cassiopeiæ
	27	R Aurigæ
	29	W Tauri
	31	S Hydræ
	31	S Piscis Austrini

MINIMA

May	1	T Ursæ Maj.
	1	T Libræ
	1	R Scuti
	3	Y Virginis
	10	η Geminorum
	16	S Orionis
	18	S Leonis
	18	R Camelopardi
	21	W Cygni
	22	V Tauri
	22	R Serpentis
	22	R Sagittæ
	29	R Ceti
	30	U Monocerotis

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

May	2	2 A. M.
	4	2 P. M.
	7	2 A. M.
	9	2 P. M.
	12	2 A. M.
	14	2 P. M.
	17	1 A. M.
	19	1 P. M.
	22	1 A. M.
	24	1 P. M.
	27	1 A. M.
	29	1 P. M.

R CANIS MAJORIS.

May	1	3 A. M.
	2	6 "
	3	10 "
	4	1 P. M.
	5	4 "
	6	7 "
	7	11 "
	9	2 A. M.
	10	5 "
	11	8 "
	12	12 M.
	13	3 P. M.
	14	6 "
	15	9 "
	17	1 A. M.
	18	4 "
	19	7 "
	20	10 "
	21	2 P. M.
	22	5 "
	23	8 "
	24	11 "
	26	3 A. M.
	27	6 "
	28	9 "
	29	12 M.
	30	4 P. M.
	31	7 "

S CANCRI.

May	2	11 A. M.
	11	11 P. M.
	21	10 A. M.
	30	10 P. M.

S ANTLIÆ.

(Every third minimum.)

May	1	8 A. M.
	2	7 "
	3	7 "
	4	6 "

S ANTLIÆ CONT.

May	5	5 A. M.
	6	5 "
	7	4 "
	8	3 "
	9	3 "
	10	2 "
	11	1 "
	12	1 "
	12	12 midn.
	13	11 P. M.
	14	11 "
	15	10 "
	16	9 "
	17	9 "
	18	8 "
	19	7 "
	20	7 "
	21	6 "
	22	5 "
	23	5 "
	24	4 "
	25	3 "
	26	3 "
	27	2 "
	28	1 "
	29	1 "
	30	12 M.
	31	11 A. M.

δ LIBRÆ.

May	3	1 A. M.
	5	9 "
	7	5 P. M.
	10	1 A. M.
	12	9 "
	14	5 P. M.
	16	12 midn.
	19	8 A. M.
	21	4 P. M.
	23	12 midn.
	26	8 A. M.
	28	4 P. M.
	30	12 midn.

U CORONÆ.

May	1	6 P. M.
	5	5 A. M.
	8	3 P. M.
	12	2 A. M.
	15	1 P. M.
	18	12 midn.
	22	11 A. M.
	25	10 P. M.
	29	8 A. M.

U OPHIUCHI.

May	1	1 P. M.
	2	9 A. M.

U OPHIUCHI CONT.

May	3	5 A. M.
	4	1 "
	4	9 P. M.
	5	5 "
	6	1 "
	7	9 A. M.
	8	6 "
	9	2 "
	9	10 P. M.
	10	6 "
	11	2 "
	12	10 A. M.
	13	6 "
	14	2 "
	14	11 P. M.
	15	7 "
	16	3 "
	17	11 A. M.
	18	7 "
	19	3 "
	19	11 P. M.
	20	7 "
	21	4 "
	22	12 M.
	23	8 A. M.
	24	4 "
	24	12 midn.
	25	8 P. M.
	26	4 "
	27	12 M.
	28	9 A. M.
	29	5 "
	30	1 "
	30	9 P. M.
	31	5 "

Y CYGNI.

May	1	12 M.
	2	12 midn.
	4	12 M.
	5	12 midn.
	7	12 M.
	8	12 midn.
	10	12 M.
	11	12 midn.
	13	12 M.
	14	12 midn.
	16	12 M.
	17	12 midn.
	19	12 M.
	20	12 midn.
	22	12 M.
	23	12 midn.
	25	12 M.
	26	12 midn.
	28	12 M.
	29	12 midn.
	31	12 M.

PRACTICAL SUGGESTIONS.

26. What preparation in Mathematics and Mechanics is necessary for the study of Chauvenet's Practical and Spherical Astronomy?

Answer: This query may best be answered by referring to the work done in graduate courses in mathematics and astronomy at Goodsell Observatory of Carleton College. Graduate students only have attempted this work, and those who have had a good training in the elements of the calculus and college physics have advanced with greater rapidity. The student should have a preparation in trigonometry equal to that given by Chauvenet; in analytic geometry, that of Howison or Smith, including three dimensions; the differential and integral calculus complete, as given by Hardy, or equivalent; thorough work, by laboratory methods in light, heat, sound, electricity, magnetism; and analytic mechanics equivalent to that given by Wood. This schedule embraces nearly a year of work for a graduate student before he is ready to undertake Chauvenet's practical and theoretical astronomy and expect to read from fifteen to thirty pages a day and do all the work faithfully that is indicated in the text. In our practice, it has seemed best when we came to the illustrative examples under any topic, not only to perform those given, but also to offer other simple ones that would require the use of the astronomical instruments to obtain the necessary data, thereby giving the student practice with the instruments in connection with the application of important mathematical formulæ. In connection with other study the two volumes of Chauvenet's practical and spherical astronomy are pursued 47 weeks continuously in the special course above referred to.

27. Was Mercury visible to the naked eye during the last days of February?

E. E. M.

Answer: It was. The bright object referred to in the letter of the above querist was Mercury.

28. Will you suggest a suitable glass adapted to the use of beginners already having a field glass? It is wanted for occasional use and moderate power only is expected.

W. R.

Answer: It is difficult to answer the above query definitely and briefly, because so much that is useful may be done with small instruments, if they are only adapted in unimportant particulars to the special lines desired. A telescope of 3 or 4 inches aperture if properly mounted will give a wide range of visual observation. It is of the first importance that the mounting be heavy enough to hold the telescope steadily. If the mounting be portable, (as is usual with such a size of glass) it must be heavy enough for out-of-door use when the wind blows moderately to prevent unsteadiness, which is a common and a serious fault with small telescopes.

If the observer wishes only to look at celestial objects for the purpose of satisfying himself as to their casual appearance in the telescope, and nothing more, then a battery of eye-pieces adapted to the size of the glass is all that is necessary. If he wishes to do some study of any particular class of objects, then his instrument should be conveniently adapted to the special line of his choice. This suggestion is quite important. The student or observer who uses a telescope without any method or aim will soon tire of it, for that reason. But if he has some object before him to work out carefully and in a methodical way, he will never lack interest in it if he has wisely chosen his theme. That is the way Burnham, Barnard, Dawes, Swift and a multitude of others have worked, and become famous without, at all, seeking notoriety, but rather industriously laboring to master the details of everything they wanted to know, so that when any given piece of work was done there was a belief that the best was done that could be accomplished under the circumstances. This is the only way to gain confidence, and, every one knows that such methods of acquiring skill are not peculiar to the study of astronomy alone. What is worth doing at all is worth doing well. This partial answer may be used in directing thought somewhat in regard to first things in answering this broad query.

29. Are large observatories heated in winter? If so, how are the currents overcome? C. F. H.

Answer: The observing room should be kept at the same temperature as the outside, as nearly as possible, to avoid currents of air of varying temperature which will affect the "seeing" unfavorably. Even the radiation of the walls of the Observatory in rooms without fire make it almost impossible to keep the inside temperature the same as that outside. In good observing rooms it is likely to vary 2° or 3° one way or the other.

30. Will the same eye pieces made for a 3-inch objective do for a 6-inch? C. F. H.

Answer: Yes.

31. What do astronomers think of that Chicago man's idea of building large objectives in sections? Has it ever been tried before? C. F. H.

Answer: We have not heard that any astronomer or physicist has expressed an opinion at all in regard to the so-called discovery of Mr. Gotham of Chicago. For ourselves we have not thought it worth while to inquire about the matter further than the casual reading of the reports that appeared about the 10th of last month in Chicago and New York daily papers. The proof of the claim will be accepted when a single good telescope on that plan is made by any one.

32. How is it that astronomers differ so widely in the estimates of the distances of the stars obtained by parallax? F. A. S.

Answer: For fuller answer to this query than space will here allow the reader is asked to consult the November number of this publication which contains an article titled "The Distance of the Stars," (page 129), and the frontispiece of the same number which was designed especially to show the degree of accuracy possible to this kind of astronomical work. The main reasons why our best knowledge of such data is apparently so discordant are there set forth.

33. If the Sun's equator inclines to the plane of the ecliptic 7° 15′, and the north pole of the Sun leans in the direction of the position of the Earth in its orbit on Sept. 13, what would be the angle between the Sun's equator and that of the Earth? How is the problem solved? Toward what place in the heavens would the solar axis point? Give right ascension and declination. J. D. D.

Answer: Professor Young, in his book, "The Sun," p. 139, gives the right ascension of the north pole of the Sun as $18^h\ 44^m$ and its declination as 65°. The axis of the Sun is directed toward a point in the constellation of Draco, not marked by any conspicuous star. This point is almost exactly half way between the bright star α Lyræ and the polar star.

As to the process by which the inclination of the Sun's equator to that of the Earth is determined, from data given as indicated in the query, it is simply the solution of a spherical triangle by the ordinary rules of trigonometry. Imagine a great sphere surrounding the Sun. The axes of the equator, the ecliptic and the Sun extended to the north will cut this sphere in three points which we will designate A, B and C in the order named. These three points form the vertices of a spherical triangle of which the sides AB and BC are known, the former being the distance between the poles of the ecliptic and equator or the *obliquity of the ecliptic*, 23° 27′, the latter the inclination of the Sun's equator to the plane of the ecliptic, 7° 15′. The third side AC is the desired inclination of the Sun's equator to the celestial equator. We know also the angle at B, which is 180° — the longitude of the point where the Sun's equator crosses the ecliptic. The last mentioned longitude is now about 74° 20′. Knowing the two sides and the included angle of the spherical triangle, the other parts may be easily found.

One can determine these roughly by measurement upon a large globe. Draw a great circle on the globe and take any point A as the north pole of the celestial equator. From A measure off 23½° to B, the pole of the ecliptic. At B construct the angle 106⅛°, counting around from A in the direction of movement of the hands of a watch, and measure off an arc of 7¼° to C, the north pole of the Sun. The arc AC may then be measured, giving the inclination of the solar equator to the celestial equator, which is also 90° — the declination of the solar axis. Measure the angle between the arcs AB and AC and add 270°. This will give the right ascension of the solar axis.

GENERAL NOTES.

Subscribers sometimes suggest themes for information that have so wide a range, as to require the preparation of an article to make the meaning sought entirely clear. Such queries may take more time to answer them promptly than we have at command. Under such circumstances we often apply to our friends to help us. Such a case occurred a few days ago. A scholarly reader asked information about the apex of the Earth's Way, and we requested Professor T. J. J. See of the University of Chicago to prepare a brief article on that topic that would explain all in plain language. He has done so, and the excellent statement will be found elsewhere in this issue. We ought to say for Professor See that this writing was done because we asked it, and because he was kindly willing to help popular readers to find out what they wanted to know. No one who knows the elements of astronomy will suppose, we are sure, that Professor See's intention was to give an original paper on that theme.

Naked-Eye Sunspots.—Mr. Morris Peck of Red Bank, O. in a recent letter gives an account and drawing of a large sunspot seen Feb. 22. By the aid of a field-glass three spots could be seen, one of them was visible to the naked eye on each of the two days. It was not visible March 1.

This great spot was first seen and photographed at Goodsell Observatory of Carleton College on Feb. 15, when it was just visible on the east limb of the Sun. It was also photographed on the 16, 17, 21, 22, 23, 24, 26, 27. In comparing Mr. Peck's drawing with our photographs there is no doubt but that he has drawn the some spot that we photographed. We were also interested in the Greenwich observations of this sunspot. It was there seen and measured February 18. It was then 1900 millionths of the solar hemisphere, and the *Observatory* gives the following in regard to magnetic disturbance during the life of the spot: "A considerable magnetic disturbance was observed to begin very sharply at 8^h 15^m P. M. on Feb. 20, and the movements continued to be pretty active till 11^h P. M. on Feb. 21. The magnets remained fairly quiescent for 24 hours, when the disturbance recommenced with greater intensity than before, continuing until 2^h A. M. on the 26th with another quiescent period between 7^h A. M. on Feb. 24 to 7^h A. M. Feb. 25."

Minor Planets.—Since our last issue we have to record the discovery of four new minor planets. as follows:

A. T. Jan. 29, Charlois, Nice.

A. U. Jan. 29, Charlois, Nice.

A. V. Feb. 16, Courty, Bordeaux.

A. W. Feb. 18, Wilson, Northfield.

In the March number of this publication an account of the photographic discovery of the last named planet was given by Dr. Wilson. In the March number of *Astronomy and Astro-Physics* a fuller account will also be found. It is an interesting fact that the planet had passed opposition about four months at the time of discovery, and was then probably a little less than the 12 magnitude. At opposition it would of course be somewhat brighter.

From the last *Observatory* we learn that " the following six planets, all discovered by M. Charlois in 1893, have received permanent numbers: AJ = (373), AK = (374), AL = (375), AM = (376), AN = (377), AP = (378). AO does not receive a permanent number, not having been sufficiently observed."

Celestial Motions, A Handy Book of Astronomy, by William Thynne Lynn, appears in its eighth edition under date of Feb. 1, 1894. This is an attractive little Fcap octavo of 125 pages. It contains eleven chapters on the following subjects:—The Earth, The Moon, The Sun, The Solar System, The Planets, Comets, Meteoroids, The Fixed Stars, The Constellations, The Refraction, Propagation and Aberration of Light, The Calendar. It is illustrated by the following plates: Comparative Sizes of the Sun and Principal Planets, Diagram illustrating the Motions of the November Meteors, Diagram illustrating the Relative Positions of the Seven Principal Stars of Ursa Major. The above contents fairly represent the scope of this book which gives in compact form much valuable information on the subjects treated. This edition differs from those which have preceded it, in that additional matter is introduced in the chapter on the fixed stars, and some details on periodic comets are omitted. A few pages at the close of the book are given to the explanation of technical terms. Publisher, Edward Stanford, 26 & 27 Cockspur St., London, S. W. Price 2s.

Remarkable Comets, by the same author as the above, is an Fcap octavo of 40 pages. This is a very readable book and is valuable for reference. It treats of "those comets which may be considered remarkable either for their brilliant appearance, their periodic returns or any other circumstance respecting them." Beginning with the comet recorded by Aristotle which appeared when he was about thirteen years of age, the writer names and briefly states interesting details in regard to the best known comets to the present time. Incidentally and without burdening the text, remarkable historic events which were coincident with the appearance of comets are mentioned. There is also presented a condensed history of the progress made in the knowledge of cometary motion and character. The book closes with "a list of the dates in order of the next returns of the comets which may fairly be expected to reappear." Publisher Edward Stanford. Price 6d.

Celestial Objects for Common Telescopes.—This well known book by the Rev. T. W. Webb has already reached its fifth edition. Its fourth edition was published in 1881, in one volume, containing 493 pages of excellent matter conveniently arranged for reference, and in every respect well adapted to supply the place it was intended to fill. When the edition became exhausted, the friends of the work considered what should be done to bring it to date and to the present wants of Amateur Astronomy. The preparation of the fifth edition was undertaken by Rev. T. E. Espin, and it was decided to bring out the same in two volumes instead of one with Messrs. Longmans, Green & Co. of London and New York, as publishers. The first volume has been issued and it is before us. It has nearly the same appearance as formerly, the type essentially the same and the size of the page the same, although its shape is slightly different. It has been the purpose of the reviser to make as little change in the text as possible, omitting, or adding new matter, when really necessary to make the new edition what the present state of science demands The first 18 pages are almost identical with those of the fourth edition. Then follow lengthy notes on celestial photography and the spectroscope as applied to the telescope. Part II, The Solar System is taken up in the same order as before. To the Sun is given a little less space than before, although a number of new notes are furnished by Miss Brown who has been asked to contribute for this topic. The planets Mercury and Venus have about the usual space with notes concerning late work on the rotation periods of each, although we notice that the weight of authority is claimed for the 24 hour period for the latter planet, instead of that advocated by Schiaparelli. Terby's work is later, but is it more exhaustive ar decisive?

A few pages have been added to the matter given concerning the Moon. Mr. Elger, who has been consulted in this part of the revision, thinks that if the matter were to be brought to date many alterations and insertions in the text would be necessary. He has given a good note (on page 79) of Professor Pickering's work at Arequipa on the streaks around Tycho with the 13-inch telescope. We do not notice any reference to the study of the varying temperature of the Moon's surface as related to its phase which has been recently shown by the aid of the bolometer at the Allegheny Observatory.

In the notes on Mars reference is made to the so-called "canals," as observed in 1881–2 and since, and Professor W. H. Pickering's observations of as many as 40 lakes at the intersection of the "canals," and the evidence of the peculiar seasons on the planet as derived from the markings of the planet's surface. The narrow, dark zone surrounding the south polar spot, as seen by several observers in 1892, is also noticed. Its deep shade, its wonderful changes indicating a process of violent dissolution on the one hand, and on the other a change of size in the brief time of 24 hours affecting an area as great as 2,500,000 square miles that had the appearance of a fall of snow; also the dark line across the north polar cap and its divisions as seen in 1888 by several observers.

The new matter for Jupiter is supplied by Rev. W. R. Waugh, and in all consists of about four pages, having reference mainly to later studies of the surface markings of the planet and the fifth satellite by Barnard. Saturn, Uranus and Neptune are without important new notes. About three pages are added to the subject of comets, and Mr. Denning has supplied about nine pages pertaining to meteors which is new matter and of course important. Two general appendices follow which give brief additions to subjects already considered. This revision seems to be excellently done.

NORTH
CEPHEUS
CASSIOPEIA
CAMELOPARDALUS
PERSEUS
AURIGA
TAURUS
Pleiades
Jupiter
ORION
LEPUS
URSA MAJOR
LYNX
GEMINI
Ecliptic
LEO MINOR
CANCER
CANIS MINOR
Procyon
MONOCEROS
CANIS MAJ
Sirius
LEO
Regulus
Pallas
SEXTANS
URANIÆ
HYDRA
Alphard
Malus
ANTLIA PNEVMATICA
ARGO
Vela
WESTERN HORIZON
SOUTH

Popular Astronomy.

Vol. I. MAY, 1894. No. 9

THE FIXED STARS.

W. H. S. MONCK.

III.

One of the most fundamental problems in connection with the fixed stars is that of their distances from the Earth; but the solution is beset with a number of difficulties many of which are, I believe, known only to those who have dealt with the subject practically. Others, however, can be made intelligible to all. The general principle is the same as that adopted in the case of distant or inaccessible objects on the Earth. We measure a base line and observe the angles made by the lines joining each end of this base line to the object, from which the length of the sides of the triangle thus found can be computed by the ordinary formulæ of trigonometry. If the base line is very short compared with the sides, the latter are nearly equal to each other. The formulæ used rest on the assumption that the three angles of a triangle are always equal to two right angles (or to 180°). If, as some metaphysical mathematicians maintain, this principle may fail us in the region of the fixed stars, our efforts to ascertain the distance of any of them would prove fruitless; but I know of no reason, astronomical or philosophical, for doubting its truth. But this principle at once shows us one difficulty in the problem. We cannot measure angles with absolute accuracy. Suppose that the real value of the vertical angle of our triangle was half a second, if we made an error of half a second in measuring the base angles, the vertical angle might altogether disappear with the result that the distance of the star would appear to be infinite; or, on the other hand, we might make the vertical angle double what it really is, which with angles as small as this would reduce the distance by one-half. Again the star is displaced by refraction and if our base line was a pretty long one the amount of refraction might be considerably different at the two ends. Moreover, as the earth is moving and the star may be moving also, an error might arise if the two angles were not measured at the same instant. Finally a base line measured on the earth would be really an arc of a great circle instead of a right line, and computation would have to be resorted to in order to find the real measurements of the base line and base angles of the plane triangle with which we were dealing. It has been found impossible, however, to measure any base line on the earth which will give a sensible angle at the star. The two base angles as measured may not be exactly equal to two right angles, but they are as likely to be greater as to be less, and the angle found manifestly depends only on errors of observation and calculation.

We must therefore find a longer base-line to start with, and such a line is afforded by the diameter of the earth's orbit. Its length indeed is not exactly known, though the error of the most recent determinations cannot be very large. But even if it were not known, we could at all events find the proportion between the distance of the star and that of the Sun. The distance of the Sun is indeed our real unit of measurement as regards the distances of the fixed stars, and it is from it that any other units of measurement that we may adopt must be derived. At the end of six months (or rather a little more or less than six months, depending on the eccentricity of the earth's orbit) the earth will be at the opposite end of the diameter of its orbit. We thus obtain a base line of over 180,000,000 miles in length and if we can ascertain the vertical angle we can measure the distance of the star. Half of this vertical angle is known as the parallax (or annual parallax) of the star; and therefore investigating the parallax of a star is the same thing as trying to measure its distance. But the difficulties which meet us in this inquiry are even more numerous than before. First the position of the star is affected by the aberration of light as well as by refraction. Then its position is ascertained by its right ascension and declination, the first of which depends on the exact position of what is known as the first point of Aries, and the second on that of the pole—neither of which points are precisely fixed—while any error in the sidereal time of the observation, from whatever cause arising, may also lead us astray. The angle to be computed is so minute that errors arising from these and other sources may completely conceal it. All that we can say in most cases is that it is extremely small. There is strong reason to believe that of no star hitherto attempted does the parallax amount to as much as one second. Let us see what this means. With angles as minute as this, the arc may be considered as equal to its chord, and there being 206,265 seconds in an arc equal to the radius of a circle, the distance of the star is at least 206,265 times that of the Sun. From this principle that the arc is equal to the chord another result follows. If we could determine the parallaxes of two or more stars their distances would be inversely as their parallaxes. If we adopted as our unit of distance that of a star with a parallax of one second (in other words 206,265 times the distance of the Sun), the distance of any other star will be $\frac{1}{p}$, where p is the parallax expressed in fractions of a second. This would I think be a more convenient unit of distance than that usually adopted by astronomers; viz., a year's light-passage or the distance which light travels in a year. I find the expressions for the distances of stars on this latter scale cumbrous, besides involving in every case an unnecessary arithmetical computation.

The mode of measuring parallaxes which I have mentioned has been to a great extent superseded by another. If we take two near stars we may regard refraction and aberration as the same for both, and in considering their *relative* parallax we get rid of the necessity of these corrections. Now if one of these stars is so far away that the lines joining it to the end of the base line may be regarded as parallel, the vertical angle at the other star is equal to the difference between the angles which apparently separate the two stars when we are at opposite ends of the base line. We could thus obtain the parallax of one star if we were certain that the distance of the other star was enormously greater. But in any case we can get the *difference* between the parallaxes of the two stars, as will be easily seen, if we suppose a third star at a really infinite distance and the parallaxes of both stars measured in relation to it. This method has been frequently tried in recent times. A particular star is supposed, on account of its brightness, or for other reasons to be mentioned hereafter, to be nearer to us than its neighbors. We compare its position with one or more of these at intervals of six months (or some other calculable period) and determine the relative parallax. Of course, as the brightness of a star does not depend solely on its distance, the fainter star may be the nearer of the two. In this case if our measures were sufficiently accurate we should obtain a *negative* parallax for the brighter star. Or the small star may be a satellite of the larger one. In such cases it is certain that the difference in their distances would elude any means of observation that we now possess, and the relative parallax would be 0. A positive parallax indicates that the star is nearer than the companion or companions with which it is compared, and if the distance of the faint star is enormously great that of the brighter one may be deduced from the relative parallax almost as confidently as if it were an absolute parallax. Suppose for instance that we obtain a parallax of 0″.40 on comparing with a star whose parallax we have reason to believe does not exceed 0″.02, we have as much accuracy as we can expect under present circumstances. The grounds for thinking that certain stars are very distant will be mentioned hereafter.

Recently a method has been introduced in which instead of measuring the distances between the stars in the sky we measure the distances between their images on a photographic plate. In this way we can use several comparison stars, and measures may be made by different persons and repeated as often as is thought desirable. Relative parallaxes only of course can be obtained in this manner, and if we obtain different results from different comparison stars we can take a mean. These different results however may arise from the fact that some of the comparison stars are nearer to us than others—in which case the largest parallax obtained from any comparison star is most likely to be the correct one.

Hitherto we have supposed the stars to be motionless; but in reality they are all moving—or at least moving relatively to the solar system—and unless we know their motions our researches on parallax may lead us altogether astray. The proper motions of a considerable number of stars are now pretty well known and can be allowed for, while a sufficient number of observations might enable us to make a simultaneous determination of the parallax and the proper motion. The proper motion of stars being very small may be usually regarded as taking place in a right line or arc of a great circle and with uniform velocity. But to this rule there are exceptions. Double stars revolve round their common centre of gravity in orbits that have only been accurately determined in a few instances—the pair having usually a rectilinear motion on the celestial sphere in addition to this motion of revolution. A puzzling case arises where no companion star is visible, yet the bright star moves as if its motions were controlled by a dark companion. Sirius was long in this condition. Procyon is so still, and many other stars whose motion is now supposed to be rectilinear may prove to be really influenced by invisible companions.

Having regard to these difficulties it is not surprising that we should possess very few reliable determinations of parallax. Indeed it has more than once happened that after two or three fairly coincident determinations giving a sensible parallax, another observer arrived at a totally discordant result. But I think it may be affirmed that the parallax of the bright Southern star, *α* Centauri does not differ very much from 0″.75: that 61 Cygni, a star scarce visible to the naked eye, has a parallax of about 0″.45, Sirius probably about 0″.40 and Procyon about 0″.25. Some other examples might be given, and I think, while it may be asserted that no known star has a parallax of one second, it may be equally affirmed that several known stars have parallaxes exceeding one-tenth of a second. The distances of the nearest stars thus range from 200,000 times to 2,000,000 times that of the Sun. That the distances of many stars, though very great, does not even approach the infinite, we have other reasons for believing. One of these is afforded by the case of the double stars already alluded to. When we find two stars easily separable by our telescopes and yet revolving round each other in a limited time, it is plain that either their distance from us must be (comparatively speaking) moderate or else the mass of the system must be enormous. *α* Centauri is such a double star. The period of revolution is under a century and the pair can, I believe, be separated (I have never seen them) with a good field glass. Here we have a remarkable confirmation of the parallax otherwise determined. The case is not very dissimilar with Sirius. The glare of the great star indeed usually conceals the faint one but otherwise in most situations the separation would not be very difficult, while the period of revolution is shorter than that of *α* Centauri. 61 Cygni is also an easily separable double star but its period is probably long. It gives, however, another evidence of nearness which the other three stars mentioned also exhibit though in a minor degree, *viz.*, large proper motion. It changes its position among the neighboring stars by about five seconds every year. If its parallax was only one-tenth of a second this would mean that it travels at least 50 times the distance of the Sun from the Earth every year—a velocity of not less than 150 miles per second. Such a result would be rather startling especially if we had to assign immense masses to the bodies which are flying through space at this rate. And we have other reasons for concluding that such enormous velocities are altogether exceptional. For by means of the spectroscope we can measure with greater or less accuracy the velocity with which a star is approaching or receding from us in miles per second, and we do not find in this way, at least so far as observations hitherto made on ordinary stars extend, any such velocities as these. The average rate of motion in the line of sight of some fifty stars examined by Vogel is only about ten miles a second and none of the fifty exceed three times this figure. A star with a motion of one second per annum on the celestial sphere will therefore probably have a parallax of not less than one-tenth of a second. We know of over eighty such stars, and I think we may conclude that there are at least that number of stars whose distance does not exceed 2,000,000 times that of the Sun, or 10, if we adopt the unit of distance which has been suggested. Not of course that proper motion is a decisive test of the nearness of a star. A near star may have small proper motion because it is moving directly towards us or away from us, or if the Sun is also moving because its motion is nearly equal and parallel to that of the Sun. So the motion of a comparatively distant star may be exaggerated because it is moving nearly at right angles to the line of sight and is situated in a part of the sky where the Sun's motion is most influential in producing apparent motions in the stars; while, finally, different stars no doubt differ in velocity as well as in mass and brilliancy. No one symptom of nearness can be relied on as conclusive, but when several of them combine we may feel pretty confident of comparative nearness without actual measurement. Take for instance the double star γ Virginis whose parallax has not, so far as I am aware, been hitherto measured. It consists of two stars easily separable, with a moderate period of revolution. It is fairly bright and, judging from the quality of the light, its brightness does not appear to be due to an unusually high temperature. Its proper motion though not very large is also considerable. I think I may venture to predict that its parallax will be found to exceed one-tenth of a second.

Now take another case—the star 6 Cygni for which Sir Robert Ball found a parallax of nearly half a second while Professor Asaph Hall found a negative parallax. Comparing it with 61 Cygni, it is also a double star somewhat fainter but not very much. But the quality of its light indicates that it is at a much higher temperature. The pair is very easily separable but though observed for years no motion of revolution can be positively asserted. The system is probably binary but the period seems to be very long. Its proper motion is far less than that of 61 Cygni yet by no means insignificant. On the the whole I have little doubt that Sir R. Ball's parallax is largely in excess of the true one, while Professor Hall's probably errs on the other side. I would not venture to predict the ultimate result, but perhaps one-tenth of a second may not again be very far from the truth and perhaps rather in excess than defect. Thus on the one hand the distances of all the stars are such as to elude accurate measurement with our present appliances, but on the other hand there are many cases in which they do not surpass our powers of estimation. And faint telescopic stars may have considerable parallaxes —their faintness being due to their small masses and low temperatures.

Sirius, according to the estimate which I have adopted, is about 500,000 times as remote as the Sun. At that distance the Sun's light would be reduced in the proportion of 250,000,000,000 to 1. The number of stars visible in the great Lick telescope is estimated at 100,000,000 millions, of which about one-half would be above the horizon at one time. What would the illumination of our midnight sky be if every one of these hundred millions of stars was as bright as Sirius? Yet Sirius, if brought as near to us as the Sun, would (according to my estimate) give 5,000 times as much light as this.

I might fill—and waste—pages in illustrating the vast distances of the stars compared with those of terrestrial objects. We are in fact dealing with magnitudes of a different order and require to commence with a different unit of distance. Taking such an unit the range of distances with which we have to deal is not so very great. On the scale which I have suggested the distance of the nearest known star, α Centauri, is about 1.3, and there is probably not a single star visible in the Lick telescope whose distance exceeds one million. Doubtless there are stars much more remote than this, but they are beyond the range of our present telescopes. The distance of Sirius is about 2.5. Remove it to the distance 25,000 and it would become fainter by twenty magnitudes which would render it invisible in any known telescope. And in this estimate I have assumed that no light is lost in transmission. If light is lost—and it is pretty certain that *some* light is—the decline in brightness with distance would be even more rapid than this. A million is therefore probably rather a liberal estimate for the maximum distance of the stars with which we have to deal in Astronomy.

CONSTELLATION STUDY.

WINSLOW UPTON.

VII.

We will consider in this article the constellations which are in the third division of the sky—that lying between 12 and 18 hours right ascension. The circumpolar groups, Ursa Minor and Draco of this division, were described in the IVth paper of this series. The zodiacal constellations of the division are Virgo, Libra and Scorpio.

Virgo. This name is given to a very large area lying southeast of Leo. It contains a number of bright stars which can be readily recognized, though they do not form any special geometrical figure. The southernmost conspicuous star, α Virginis, also named Spica, is of the first magnitude and is recognized without difficulty because it is quite solitary. Or, it makes with Arcturus and Denebola a triangle whose sides are roughly 30° in length, Spica the southernmost. (In May, 1894, the planet Saturn is about 5° north of Spica.) Starting from Spica there are six third magnitude stars to be found. 11° north of Spica is ζ, 13° east of ζ is γ, and 6° still further east is η. 8° further east and 2° further north of η is β. Returning to γ (which is a beautiful double star in a telescope), and looking northeasterly, we find δ and ϵ not quite in line, 6° and 8° respectively separated from each other. North of β are three fourth magnitude stars which mark the position of the virgin's head, her body extending in a southeasterly direction through the area. There is also a fourth magnitude star, θ, between α and γ, which will attract attention in tracing the stars. The lines on the chart show a different way of identifying the stars, including those fainter than the ones just mentioned. The star η is not far from the autumnal equinox, and this part of the equinoctial colure may be roughly drawn by passing a line from it to the pole star. It will go through δ Ursæ Majoris, the fourth star in the Great Dipper.

Libra. The characteristic figure of this group, which lies southeast of Virgo is two second magnitude stars lying in a northeast-southwest line about 10° apart. Parallel to this line and about 5° further southeast are two fainter stars somewhat nearer together, which seem to imitate faintly the two first mentioned. This constellation is the only one in the zodiac which does not bear the name of a living creature or living creatures. In Ptolemy's catalogue it is called *Claws*, and was therefore apparently taken out from the next group Scorpio, to complete the number 12 for the zodiacal constellations.

Scorpio. This is one of the few constellations which bear a rough resemblance to the object suggesting the name. It is a splendid group, easily traced. Southeast of Libra is the bright red star α Scorpii or Antares which is the central one of the three about 3° apart. These three stars point northwestward to δ

which is the central one of the three conspicuous stars β, δ, π, in a curved line convex towards the northwest. Though the claws of the primitive scorpion may have been long enough to extend to α and β Libræ, the reduced claws of the classical figure are of no mean size and are marked each by a star near the extremity. The southern claw stretches westward from δ to γ, a third magnitude star about 15° west of δ, and the northern claw stretches northward from β to ξ, a fourth magnitude star 8° north of β. Another way to trace this part of the figure is shown on the chart. The figure should be completed by following towards the south and east the long tail of the scorpion curving northward to the two stars near together, λ, υ. In the northern part of the United States the southernmost of this line of stars are seen with difficulty.

In naming the constellations it is customary to use the form Scorpio as the nominative, but the form Scorpii instead of Scorpionis for the genitive, the latter formed from a poetic equivalent Scorpius.

North of these zodiacal constellations are seven groups which we will take up beginning with the northwestern one.

Coma Berenices. This group is readily recognized as a cluster of twenty-five or thirty faint stars northeast of the triangle marking the eastern part of Leo.

Canes Venatici. This name was given by Hevelius to the rather vacant space south of the handle of the Dipper. Two hunting dogs were depicted with a leash held in the hand of Boötes. There is only one bright star in the area, which is about half way between the handle of the Dipper and Coma Berenices and is in the collar of the southern of the two dogs.

Boötes. The conspicuous star of this group is the brilliant gem noted in primitive and classical writings as Arcturus. It can readily be found by following the curved line made by the handle of the Great Dipper outward from the bowl. A coffin shaped quadrilateral made by this star, α, with η, ε and ρ is the characteristic figure of the area, and is in the body of the herdsman. Northeast of the line ε, ρ, are three third magnitude stars which mark the head and shoulders, β, δ and γ. A different plan for tracing this group is given on the chart.

Corona Borealis. This pretty group lies just east of the central part of Boötes, and consists of a curved line of seven stars which may be readily imagined to constitute a garland or wreath.

Hercules. This large area is occupied by a giant form whose head is at the south, and whose legs extend the one over Corona

Borealis and the other to Draco at the stars γ, β, of that group. The characteristic figure is a quadrilateral of third magnitude stars η, ζ, ε, π which are about 15° or 20° northeast of Corona Borealis. 2° east of π is ρ, which may be thought of as a short handle to the rather deep dipper made by the quadrilateral. In the side η ζ about one-third the way from η, and about at the point at which the line ρ π if prolonged would meet it is the great star cluster in Hercules. This quadrilateral is in the giant's body. Other stars in the group can be found from it thus; From η, the northwest star of the quadrilateral, the star τ lies northwest about 10°. Several fainter stars west of it are in the leg of the hero. The line π ρ if prolonged eastward leads to θ, a fourth magnitude star from which ι, a star somewhat brighter, lies about 10° north and marks the other leg. The diagonal line η ε leads to δ in one shoulder, and μ which lies about 8° northeast from δ marks one arm. The other shoulder is marked by two stars β and γ about 3° apart, the former in the prolongation of the line μ δ. The head is marked by a third magnitude star which makes an equilateral triangle with the two stars of the shoulders, δ and β. It must not be confounded with the brighter star about 5° east of it which is α Ophiuchi. A little group of fourth magnitude and fainter stars occupies the southeastern part of the area, about 20° south of the bright star in Lyra known as Vega.

Ophiuchus and *Serpens*. These constellations cross each other, the latter consisting chiefly of a line of stars representing the serpent which the serpent carrier holds in his hands. The head of Ophiuchus is at the star α which is about 5° east of α Herculis. As in the case of the two other gigantic figures just described, Boötes and Hercules, a triangle of stars marks the head and shoulders. The triangle in Ophiuchus is lettered α, β, κ. The eastern shoulder β has a fainter adjacent star γ, and similarly the western shoulder κ has a companion ι. The serpent's head is marked by a number of faint stars about 10° west of the two stars, β, γ, in Hercules' shoulder. Following the line southward, β, δ, α, ε, μ, all in Serpens as on the chart, we reach the place where the serpent is hidden by the western leg of Orphiuchus. Continuing the line of stars, we have δ, ε Ophiuchi marking one hand, ζ one leg and λ the other leg. The line of bright stars just named, beginning with δ Serpentis and omitting μ Serpentis, is quite straight and conspicuous. A fourth magnitude star 10° south of η marks the direction of the eastern leg of Ophiuchus. The serpent appears again near η Ophiuchus and can be traced, but not as plainly as before, by the stars lettered ξ, ζ, η and θ Serpentis. Between ξ

and ζ is a fourth magnitude star lettered ν Orphiuchi marking the other hand. These constellations illustrate the difficulties under which the revisers of the ancient system of constellations labored in adapting them to modern needs. It would have been simpler to have given one name to the whole area, retaining the figures of the serpent and his holder, and revised the letters so that the same letter would be used but once. Argelander's division, adopted in these articles, does not agree exactly with those on Poole's chart.

South of the zodiacal group in this division are three constellations wholly or in part visible in the United States.

Corvus. This is a small but conspicuous constellation southwest of Spica, and readily found. It consists of four stars forming a quadrilateral whose sides are of unequal length. South of the southwestern star is a fifth star, 2° distant from it, much fainter than the others though lettered α.

Centaurus. The greater part of this constellation is below the horizon of northern observers for whom these articles are prepared. The head and shoulders however can be seen, the former consisting of three fourth magnitude stars near together, and the latter marked each by a star, the one of the second and the other of the third magnitude, the two about 11° apart. These stars are quite plainly seen when the constellation is on the meridian. They are about 20° southeast of Corvus. Two other third magnitude stars, lettered η and ζ as given on the chart, may also be seen as far north as latitude 40° — 45° under specially favorable circumstances.

Lupus. This constellation also is mostly concealed from northern observers. Its characteristic figure is a triangle of third magnitude stars in south declination 40° — 47°. Faint stars seen south of the body of the Scorpion belong to the northern part of this area in which the head of the Wolf is drawn.

The zodiacal constellations of this division are those through which the Sun passes in the autumn, and are therefore south of the celestial equator. The ecliptic passes near Spica, α Libræ and β Scorpii, and through the southern extension of Ophiucus, which at this place comes between the zodiacal constellations Scorpio and Sagittarius. The celestial equator passes very near η, γ and ζ Virginis.

The constellations of this division are favorably situated for study in the evenings of spring and summer.

The following table gives the magnitudes and approximate positions of the stars in each group.

Approximate Positions of the Leading Stars in the Constellations Between XII^h and XVIII^h Right Ascension, Omitting Circumpolar Constellations.

Coma Berenices.

No bright Stars.

Canes Venatici.

Name.	Magnitude.	Right Ascension. h.	m.	Declination. °	′
12	3.1	12	51	+ 38	51

Boötes.

Name.	Magnitude.	h.	m.	°	′
η	2.9	13	50	+ 18	54
α	0.0	14	11	+ 19	42
ρ	3.6	14	27	30	48
γ	3.1	14	28	38	44
ε	2.6	14	41	27	30
β	3.6	14	58	40	47
δ	3.5	15	12	+ 33	41

Corona Borealis.

Name.	Magnitude.	h.	m.	°	′
β	3.8	15	24	+ 29	27
α	2.4	15	30	27	3
γ	4.2	15	39	26	37
δ	4.6	15	45	26	22
ε	4.1	15	53	+ 27	10

Hercules.

Name.	Magnitude.	h.	m.	°	′
τ	3.9	16	17	+ 46	33
γ	3.8	16	17	19	23
β	2.8	16	26	21	42
ζ	3.1	16	38	31	46
η	3.7	16	40	39	6
ε	4.0	16	56	31	4
α	3.2	17	10	14	31
δ	3.3	17	11	24	58
π	3.4	17	11	36	56
ρ	4.0	17	20	37	15
υ	3.9	17	37	46	3
μ	3.5	17	43	+ 27	47

Ophiuchus.

Name.	Magnitude.	h.	m.	°	′
δ	2.8	16	9	− 3	26
ε	3.4	16	13	− 4	27
ζ	2.8	16	32	− 10	22
κ	3.4	16	53	+ 9	32
η	2.6	17	5	− 15	36
θ	3.4	17	16	− 24	54
α	2.2	17	30	+ 12	38
β	2.9	17	38	+ 4	36
υ	3.5	17	54	− 9	45

Serpens.

Name.	Magnitude.	h.	m.	°	′
δ	3.9	15	30	+ 10	53
α	2.7	15	39	+ 6	44
β	3.8	15	42	+ 15	44
μ	3.5	15	44	− 3	8
ε	3.7	15	46	+ 4	46
η	3.4	18	16	− 2	56

Name.	Magnitude.	Right Ascension.		Declination.	
		h	m	°	′
		Virgo.			
β	3.7	11	45	+ 2	19
η	4.0	12	15	− 0	7
γ	2.8	12	37	− 0	54
δ	3.7	12	51	+ 3	56
ε	3.0	12	57	+ 11	29
α	1.2	13	20	− 10	38
ζ	3.5	13	30	− 0	5
		Libra.			
α	3.0	14	45	− 15	38
β	2.7	15	12	− 9	1
		Scorpio.			
γ	3.2	14	58	− 24	53
π	3.1	15	53	− 25	50
δ	2.5	15	54	− 22	21
ξ	4.0	15	59	− 11	6
β	2.9	16	0	− 19	33
σ	3.0	16	15	− 25	21
α	1.1	16	23	− 26	13
τ	2.9	16	30	− 28	1
ε	2.2	16	44	− 34	5
υ	2.8	17	24	− 37	13
λ	1.7	17	27	− 37	2
θ	2.1	17	30	− 42	56
κ	2.6	17	36	− 38	58
		Corvus.			
α	4.3	12	3	− 24	11
ε	3.1	12	5	− 22	3
γ	2.8	12	11	− 17	0
δ	3.1	12	25	− 15	58
β	2.8	12	29	− 22	51
		Centaurus.			
ι	3.0	13	15	− 36	11
ζ	2.7	13	49	− 46	48
θ	1.7	14	1	− 35	53
η	2.5	14	29	− 41	44
		Lupus.			
α	2.6	14	35	− 46	57
β	2.8	14	52	− 42	44
γ	3.2	15	28	− 40	50

VARIABLE STARS.

J. A. PARKHURST.

VII.

A number of amateurs have been preparing to coöperate in the work of observing variable stars. Some have already begun and others are nearly ready. It is my intention to use this space for the publication of specimen observations, the discussion of points which they suggest, hints in regard to methods, and whatever will aid the observer in this interesting work. To this end, correspondence is invited from all who are engaged in such observations or who wish to undertake them, and frequent reports are requested in regard to progress in the work or any difficulties which may arise. It is hoped that no one will refrain from reporting for fear that his work is not perfect, for perfection in this line has not yet been attained.

Mr. W. Dearden of Trinidad, Colo., has lately received a 9½-inch reflector with driving clock and circles, from the works of J. A. Brashear at Allegheney, Pa. He has been perfecting the adjustments of the instrument and has begun using it on variable stars. His observations of the recent maximum of 2815 U Geminorum will be mentioned later. Mr. Dearden writes: "It seems to me that it takes a pretty good eye and lots of practice to appreciate eleven steps between *f* and *h* in the U Geminorum group." This point is worth a suggestion. The magnitudes of *f* and *h* according to Baxendall are 11.2 and 12.3. As stated in the December Popular Astronomy, page 163, the value of a step for experienced observers is generally about one tenth of a magnitude, but it would not be well to attempt to regulate your step value by any such arbitrary quantity. Let your own eye determine what your personal step value shall be—don't attempt to see through another man's eyes. Quite likely your step value will be two or three tenths of a magnitude to begin with, and gradually and unconsciously grow smaller by practice.

Mr. J. D. Devor of Elkhart, Ind., has had a low power eye-piece fitted to his 3-inch refractor and expects to begin work before April 1. He writes: "I have enlarged about a dozen of your little star charts in the Popular Astronomy, the first larger charts I enlarged four times, and the smaller nine times." A word about enlargements and the scale of charts. All the charts so far given, except those in the December number and the enlargement for 2815 U Geminorum in this number, are on the same scale, ¾-inch to 1° declination. This is the scale of Argelander's Durchmusterung charts and will generally be sufficient for use with a magnifying power of 20 to 40. Where the stars are crowded or the variable becomes faint it is often an advantage to use a higher power after the field has become familiar. In such a case the scale of the enlargement should be adapted to the power used. If a power of 25 is used with the original charts, a two-fold enlargement will be best for 50, a four fold for 100, etc.

Mr. David Flanery of Memphis, Tenn., asks for an illustration of the method of predicting a maximum from the " elements " such as the following (see February number, p. 264):

107 T Cassiopeiæ. 1871 March 31 + 445.0 E.

I failed to state on the page above cited that the length of period is given in days. In practice astronomers compute such maxima by the aid of the "Julian Period" which is a consecutive numbering of the days, beginning 6607 years ago. The following table gives the Julian number of the first day of each month for the years 1891–97:

JULIAN DAYS.

		1891	1892	1893	1894	1895	1896	1897
Jan. 1	241	1734	2099	2465	2830	3195	3560	3926
Feb. 1		1765	2130	2496	2861	3226	3591	3957
Mar. 1		1793	2159	2524	2889	3254	3620	3985
April 1		1824	2190	2555	2920	3285	3651	4016
May 1		1854	2220	2585	2950	3315	3681	4046
June 1		1885	2251	2616	2981	3346	3712	4077
July 1		1915	2281	2646	3011	3376	3742	4107
Aug. 1		1946	2312	2677	3042	3407	3773	4138
Sept. 1		1977	2343	2708	3073	3438	3804	4169
Oct. 1		2007	2373	2738	3103	3468	3834	4199
Nov. 1		2038	2404	2769	3134	3499	3865	4230
Dec. 1	241	2068	2434	2799	3164	3529	3895	4260

The first three figures are omitted after the first column but in use must be prefixed to each. By the aid of this table we can calculate the maximum of T Cassiopeiæ as follows—Chandler's Second Catalogue gives the Julian date of 1871, March 31,

240 4515.

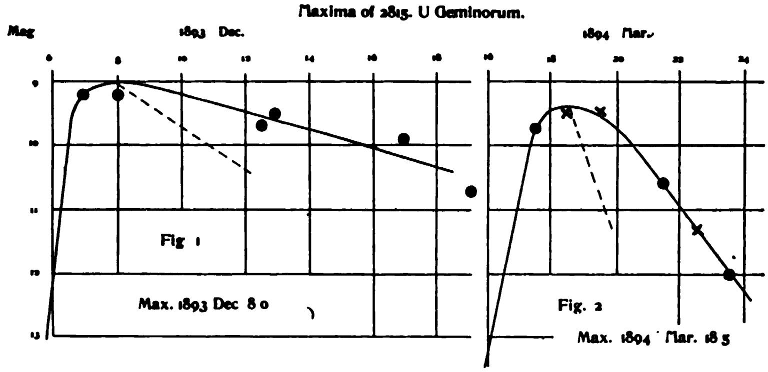
To find the maximum occurring in 1894, take for instance from the table the Julian date of 1894, March 31 = 241 2919.

The interval between the two dates is 8404 days, which divided by the length of period, 445 days, gives 18 periods and 394 days or nearly 19 periods. To find when the 19 periods will be completed add to the date of the epoch the number of days in 19 periods—

$$\begin{aligned} \text{Epoch} &= 240\ 4515 \\ 19 \times 445 &= 8455 \\ \hline &\ 241\ 2970 = 1894,\ \text{May } 21. \end{aligned}$$

The date of maximum published in the April number, p. 378, is 1894, May 24. Whether the difference arises from a misprint or the use of a different set of elements I do not know, as the editor does not give his authority for that table.

Maxima of 2815. U Geminorum.



I give this month an enlarged chart for 2815 U Geminorum, the scale, (1½ inches = 1° Decl.), being large enough to show the group of 11 to 13 magnitude stars near the variable. These comparison stars are lettered according to the notation of Baxendall, who assigns the following magnitudes: $a = 8.6$, $b = 9.3$, $c = 9.2$, $d = 10.3$, $e = 10.6$, $f = 11.2$, $g = 12.3$, $h = 12.3$, $k = 13.3$, $l = 13.7$. As was predicted in the March number, p. 318, this remarkable variable passed a maximum in March, and furnished a good illustration of the advantage of coöperation in this work. After looking for it every clear evening since Feb. 27, I found it bright ($9^m.7$) March 17, $7^h\ 45^m$. It had been invisible March 15, and March 16 was cloudy. The question was—had it begun its rise the 16th? Fortunately Mr. Dearden at Trinidad, Colo., had been observing the locality with his new 9½ inch reflector, and on March 16th had not seen the variable although *l* was seen. So the rise from below 13^m to $9^m.7$ occupied less than 24 hours, at the rate of at least $\frac{1}{8}^m$ per hour. I asked Mr. Dearden for a copy of his observations, and though he had not begun using Argelander's method he kindly furnished the desired report. It is as follows:

1894 March	16	U not seen.
	18	Not quite as bright as *b* or *c*, estimated about 10 mag.
	19	Could not note change.
	20	Snowing.
	21	Snowing.
	22	A trifle brighter than *h*, estimated 12 mag.
	23	A little above *k*, equal to *x*.

These observations are especially valuable for locating (in connection with mine) the time of the sudden rise, so although Mr.

Dearden did not see the variable on the 16th, his observation of that date is very important.

My own observations are as follows:

1894 March	17	7^h	45^m	*c* 2 — 3 *v*, *v* 2 — 3 *d*
	21	7	40	*d* 2 — 3 *v*, *v* 4 *f*
	23	8	0	*f* 4 *v*, *v* 1 *h*
	26	8	20	*k* 3 *v*, *v* 1 *l*

Combining the two sets of observations gives the following magnitudes of the variable, expressed in terms of Baxendall's scale:

	Date	Mag.
1894 March	16.5	< 13
	17.5	9.7
	18.5	9.5
	19.5	9.5
	21.5	10.5
	22.5	11.3
	23.5	12.0
	26.5	13.6

The light curve is given in Fig. 2, Mr. Dearden's observations being indicated by crosses, mine by dots. It will be interesting to compare this curve with that described by the same star at the preceding maximum in December, 1893. Fig. 1. The decline in March is three times as rapid as that in December. In the figures the magnitudes are given in the vertical column at the left, the dates in the horizontal line at the top.

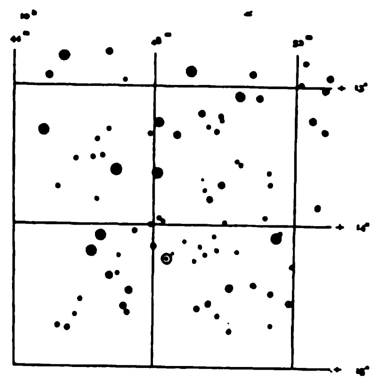
A maximum of this star is predicted for 1894, May 17, in the April number, p. 378, but as its period varies from two to five months, little dependence can be placed on such a prediction. I should be glad to have copies of any other observation of this past maximum.

Charts are also given for 3890 W Leonis, 4300 X Virginis and 6005 S Draconis, all of which will be in position for evening observations this spring and summer, and of which observations are needed. 3890 and 4300 were discovered by the late Professor Peters at Litchfield Observatory of Hamilton College, and the charts are taken from his splendid series of charts. The variability of 3890 was confirmed by Henry M. Parkhurst, who found the elements:

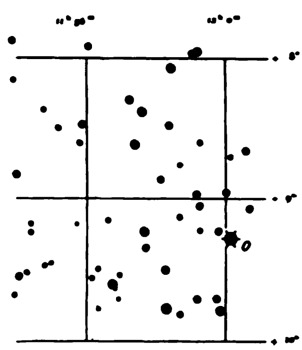
1872 Feb. 12 + 394 d. 3 E.

According to these elements the maximum in 1893 was due Sept. 15, but a maximum was observed by Paul S. Yendell 1893, April 12. The elements above given would make the star become visible next September Mr. Yendell's maximum would indicate that it might become visible this spring. 4 or 5 inches aperture will be needed to deal with it.

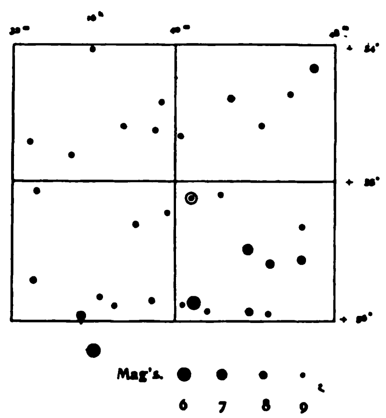
3890 W Leonis.



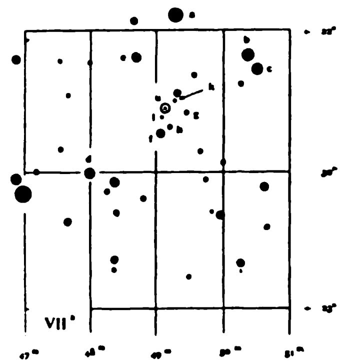
4300 X Virginis.



6005 S Draconis.



2815 U Geminorum.



The other Peters' star, 4300, has not been carefully observed and its period is uncertain. It is 3 mm. preceeding, 20′ north of the 4th magnitude star *o* (omicron) Virginis. March 23 it was 10.5 magnitude so that 3 inches will now show it well. There is an 11.5 magnitude star 2 seconds following, 0′.4 north of the variable.

6005 was discovered by Espin in 1892 and its variability confirmed by Yendell, who observed a minimum 1893, July 7, and a maximum 1893, Nov. 16. Its period is not known. Two inches aperture will suffice to observe it.

I take the following from Chandler's Second Catalogue:

No.	Star.	Place for 1900.		Redness	Magnitude.		Period days
		R. A.	Dec.		Max.	Min.	
		h m s	° ′				
3890	W Leonis	10 48 21	+ 14 14.9	3.5	9	< 14	394.3
4300	X Virginis	11 56 44	+ 9 37.7		8 – 10	12	?
6005	S Draconis	16 40 46	+ 55 7.2		7.3	9.2	?

Mrs. Fleming's new variable in Ophiuchus, B. D. + 1°, 3417, (see page 363) is brightening, and is now $7^m.5$.

MARENGO, Ill., 1894, April 3.

A LESSON IN PARALLAX.

ORRIN B. HARMON.

A short time ago I was in conversation with a surveyor concerning solar eclipses. In the course of our talk, I remarked to him that in order to deduce the Moon's path over the Sun's disc, it is necessary to compute the Moon's parallax for times near the beginning and ending of the eclipse. He at once asked me what I meant by "parallax."

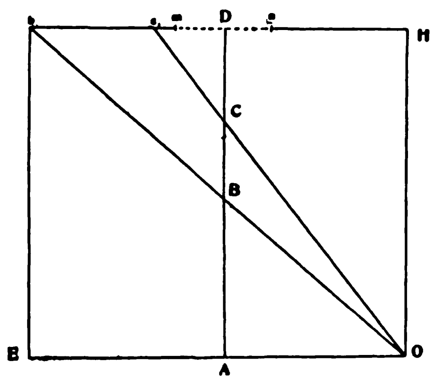
If this question comes from one whose occupation is essentially mathematical in its nature, how much more likely is it to be asked by those whose business is less closely related to the math ematics.

Indeed, I think it is not asserting too much to say that there are many intelligent people, and among them surveyors and teachers, who have not a clear idea of the meaning of parallax. Called by some other name, they might know what it is. In fact, there is scarcely a term used in astronomical science whose meaning is more clearly illustrated by every day experience than this one. The surveyor uses it whenever he computes the distance of an inaccessible object, and we all see it illustrated in our walks along the street or through the field. To explain the principle of parallax, I will present a diagram in which the idea can be carried out in the school room, at home, on the playground, and in many other places:

This figure represents a room, with a window whose sides are *m n*. On the side opposite the window, at A, stands a boy, and between him and the window stand two other boys, B and C who are in a line with A and the center of the window D.

Now A sees B and C in a line at right angles to the side of the room where he stands.

Suppose a fourth boy placed at O, the corner of the room, and on the same side with A. How do B and C appear to O? They are not in a line with him as they are with the boy at A. Nor does either of them appear in a line at right angles to the side E O. C has shifted his position so that he appears beyond the window at *c*; and B appears in line with the opposite corner at *b*. Their directions have changed. How much is this change of direction? C has changed from a right angle by the angle COH; and B by the angle BOH. Which has changed the most? You at once answer, the nearer one B.



Now, this change of direction, caused by shifting the view from A to O, is the parallax of B and C, with respect to the line AO. B's parallax is the angle BOH, or its equal ABO; and C's parallax is the angle COH, or its equal ACO.

Notice also that B, the nearer one has the larger parallax. The greater the distance the smaller the parallax; and this is true whether the distances of B and C be taken from either A or O.

It follows that if we know the length of AO and the change of direction of B or C, as seen from the extremities of the line, the triangle having the vertex B or C can be constructed. Put in an algebraic expression, if $p =$ the parallax, a the length of AO, and d the distance BO, or CO, then $d \sin p = a$,

$$\text{or } d = \frac{a}{\sin p},$$

where the abbreviation "sin" denotes the sine of the parallax.

So the problem of determining the distance of a heavenly body an easy one, when once the parallax is known.

In locating the position of the heavenly bodies, the Earth's center is taken as a standard point. It would seem, then, that the direction of a heavenly body should change, when our point of view is changed from the Earth's center to the surface of the Earth. If we take a station on the Earth's surface where the Moon's center is in the horizon, that is when she is either rising or setting, and imagine a line to join our station with the Moon's center, this line will be perpendicular to a plumb line, or the Earth's radius. This, of course, supposes the Earth to be a perfect sphere. In this case the Earth's radius becomes the base line, AO with the boy at A, to use our diagram. If we could change our position to the Earth's center, we would see the Moon (if she could be seen) with the boy at O, and her direction would be changed by an angle varying from 53′ to 61′, depending on the Moon's distance from the Earth. The same thing would happen with the Sun or planets, only the change of direction would be very much smaller on account of their greater distances.

When a heavenly body is on the horizon, its parallax is then called its horizontal parallax, and is the greatest parallax it can have. At any altitude, except in the zenith, there is always some parallax with the Sun, Moon and planets. In the zenith, the parallax is zero with respect to an observer, because he stands in a straight line joining the heavenly body with the Earth's center.

So immensely distant are the fixed stars, that they defy any measurement of parallax from any points on the Earth's surface. The diameter of the Earth's orbit affords a base line, from whose extremities, at intervals of six months, the astronomer can attempt the measurement of stellar parallax. But even a base line of 185,000,000 miles, appears so small seen from the nearest fixed star, that it is only by the most refined methods astronomers have succeeded in measuring the parallax of the nearest fixed stars.

In practical astronomical work, the Moon's parallax is an important element. In any calculation involving the Moon's position in the heavens with respect to an observer on the Earth, her parallax is an annoying visitor, and, like Banquo's ghost, will not down. For the purpose of showing the difference between the parallaxes of the Sun and Moon, I will cite a few facts related to recent solar eclipses.

In the recent eclipse of October 9, 1893, the magnitude of the eclipse at Seattle, Washington, was .29, with a duration of $2^h\ 4^m$. At Spokane in the eastern part of the state the magnitude was .22 with a duration of $1^h\ 51^m$. Seattle and Spokane are about 225 miles apart; and we see that in this change of 225 miles eastward from Seattle, the eclipse lost .07 of its magnitude. Taking Seattle as our starting point, the eclipse must lose .29 of its magnitude in order to fail entirely. At the rate of loss as above stated, we would have to go about 900 miles eastward from Seattle, for the magnitude to become zero. This brings us to the western part of North Dakota. In fact, the eastern limit of the eclipse in the United States was defined by a line running from the northwest corner of North Dakota to Savannah, Georgia. The loss or gain of magnitude is not always proportional to the distance and I do not pretend to give it as a governing law. But in this case it is approximately correct.

In the eclipse of October 20th, 1892, the western limit was marked by a line running from Northwestern California to the Gulf of Tehauntepec.

If, therefore, we take our station at the western extremity of the boundary line between California and Oregon, we are where the eclipse is zero. Changing our station to Portland, Oregon, the magnitude of the eclipse becomes .08 and the duration 1^h 10^m; and going to Albany, New York, we find the magnitude 0.6 and the duration 3 hours.

Now, what causes these variations of magnitude and duration? Clearly, it is the Moon's parallax; and this changes for every place of observation. Not only does her parallax affect the magnitude and duration of a solar eclipse, but also the course of her path across the Sun's disc. This path is different, for different places; and hence a calculation of phases is necessary for each location of the observer.

Another very beautiful illustration of the Moon's parallax in solar eclipses is afforded by the eclipse limits on the meridian where the eclipse is central at noon. In every total or annular eclipse, there is always some place where the axis of the shadow lies in the plane of the meridian. At such a point the axis passes through the eye of the observer when both the Sun and Moon are on the meridian, and there we have "central eclipse at noon." The observer at this place sees the eclipse at its greatest magnitude; and if the eclipse is annular, the annulus appears in full splendor.

Having found the place of "central eclipse at noon," it is evident that if we travel south of this point, there will be some place where the eclipse fails. At such a place the Moon appears just north of the Sun; for in virtue of her parallax, she appears to move in a direction opposite to that in which we are travelling.

In like manner, there is a place north of the point of the central eclipse where the eclipse fails; and there the Moon appears to be just south of the Sun.

For example, in the solar eclipse of June 16, 1890, the eclipse was central at noon in latitude 36° 40′ N. and longitude 30° 31′ E. This place is in the southern part of Asia Minor. Here, at the instant of apparent noon, the observer would have stood in line with the axis of the shadow. At the same instant, an observer, in latitude 75° 24′ N. and on the meridian of the central eclipse, would have seen the Sun and Moon in contact, the Moon being *south* of the Sun; while an observer in latitude 3° 53′ N. and on the meridian of the central eclipse would also have seen the Sun and Moon in contact, the Moon being *north* of the Sun. Between these limits the eclipse had all degrees of magnitude.

In lunar eclipses there is no variation of magnitude and duration for different places. Why?

Because, in lunar eclipses, the Moon actually passes into the Earth's shadow; and whatever change in direction the Moon may undergo by being seen from different stations, the shadow undergoes the same change. Hence, the Moon retains the same position relative to the shadow whatever may be the location of the observer. To return to our diagram. A ball in the middle of the window at D, appears just the same with respect to the window, seen from any part of the room. So a spot on the Sun, at the same instant, has the same position on the Sun's disc, whether seen from London or San Francisco. But the Moon being nearly 400 times nearer to us than the Sun, shifts her position with reference to the Sun for every station of observation. Hence the astronomer's vision of parallaxes in solar eclipses.

CHEHALIS, Lemis County, Wash.

STAR CLUSTERS.

ROGER SPRAGUE.

Among the many good things that have already appeared in POPULAR ASTRONOMY I have found but few which interested me more than Dr. Swift's "Suggestions to Amateurs." When I obtained the April number, the first thing which I turned to, after finishing Mr. Burnham's paper on double star orbits, was the article on "Nebulæ and Clusters." A good deal of originality is shown in the list of objects given, and I shall certainly examine Nos. 4 and 7 of said list at my earliest opportunity. But while I gained some new ideas, by reading Dr. Swift's article, I saw room for further remarks in the same line, and have accordingly prepared a brief list of clusters with which that much-advised individual, the amateur, could make himself familiar to good advantage.

No. 1. $7^h\ 14^m - 24^\circ\ 44'$. This cannot be enjoyed with a telescope of less than 8 inches aperture. I picked it up accidentally with the 8-inch at Napa, Cal., while trying to catch the beautiful double star in $7^h\ 11^m - 23^\circ\ 5'$. It consists of a brilliant star (magnitude 5.4) surrounded by a small flock of faint ones. The bright central star is followed by two faint companions at distances of 8″ and 15″. There was never any difficulty in seeing these with the 8-inch, and they added much to the interest with which visitors viewed the object, but with our 6-inch I am scarcely able to do anything with them.

No. 2. $7^h\ 36^m - 14^\circ\ 32'$. This is a truly beautiful object, and is especially interesting on account of a small nebula which is here seen with the stars as a background. This beautiful contrasting of star-cluster and nebula makes this object specially valuable to one who is teaching a class in general astronomy. An 8-inch telescope, such as the high schools of Fall River, Mass., and Oakland, Cal., possess, brings out this object splendidly, but with a smaller glass, a careful adaptation of magnifying power to aperture is necessary in order that visitors may see the nebula at all. I find that a power of 100 diameters on our 6-inch shows it well.

No. 3. $15^h\ 12^m + 2^\circ\ 32'$. M 5. A gorgeous object, comparable in beauty with the cluster in Hercules, M 13. It is of about the same brightness as the latter, being faintly visible to the naked eye. As it is about half way between Arcturus and the upper part of Scorpio, and is on a line with two stars to the west of it (109 and *t* Virginis), it can be readily found again after having been once located.

No. 4. $17^h\ 46^m - 34^\circ\ 47'$. M 7. Visible to the naked eye. With the 8-inch refractor of Napa College Observatory, this was a favorite object among visitors, partly on account of its brilliancy. It is as bright to the naked eye as the Præsepe, and much more attractive in the telescope. It contains some 60 stars. A low power is necessary in viewing it, as it requires a field of 40′.

No. 5. $17^h\ 57^m - 24^\circ\ 21'$. Visible to the naked eye. This is in the constellation of Sagittarius and is one of the most interesting objects in the whole sky on account of the intermingling of stars and nebulosity. We see in the field of view a bright nebulous mass which is intersected by several dark channels, and is followed by a coarsely scattered star cluster.

The objects mentioned in the above list are not much inferior for interest and beauty to those given by Dr. Swift. Nor does this list contain any of those time-worn and hackneyed objects towards which the telescope of any Observatory is usually directed on a public night.

Dr. Swift mentions the famous cluster in Hercules. This requires a rather higher power than most faint objects in order that it may be well seen. I have found a power of 25 diameters to the inch of aperture (200 for an 8-inch) to give the best results provided the altitude of the object was high. Many amateurs, and some professional astronomers as well, fall into the habit of doing all their star-gazing with one eyepiece, whereas a careful adaptation of magnifying power to object examined is as important in this sort of work as in any other. Four eyepieces, giving powers of from 7 to 25 diameters per inch of aperture, should be kept on hand for this sort of work. When any object is examined, it will be found that one of them will give a more pleasing view than any of the others.

Dr. Swift calls the cluster in Hercules one of the *six* visible to the naked eye. This number seemed to me to be a mistake and I have examined the matter sufficiently to find eight which can be seen by observers in the northern hemisphere, not to speak of others, as ω Centauri, which are reserved for southern observers. These eight are;—M 5, M 7, M 8, M 13, Præsepe, Pleiades, clusters in sword handle of Perseus, and a cluster in Argo Navis $7^h\ 31^m - 14°\ 12'$.

CHAMBERLIN OBSERVATORY,
Denver, April 7, 1894.

THE ETHER AND GRAVITATION.

BY W. H. S. MONCK.

The question whether gravitation is propagated by means of the ether which (so far as we know) occupies all space is one of no slight interest. The contrary—the instantaneous propagation of gravity—is supposed to be established on mathematical grounds. I plead guilty to never having studied Laplace's proof of the great rapidity of its transmission. But I always hesitate to accept a statement that some great mathematician has proved this or that in astronomy. I know enough of mathematics to be aware that pure mathematics can throw no light on such a subject. There must be physical data to start from or else we cannot make any progress at all. I also know enough of astronomy to be able to say that all our data have been greatly improved since Laplace's time, and therefore without questioning the accuracy of his mathematics I think I may entertain a reasonable doubt as to the correctness of his conclusions. I may illustrate this by Professor Darwin's theory of the moon and the earth. The whole of his mathematical computation rests on the assumption that the earth possessed a particular degree of viscosity at the time. What evidence have we that it really possessed this degree of viscosity?

Sir Robert Ball's argument on the Ice Age strikes me as even more objectionable. He shows that when the Earth's orbit was more eccentric the total amount of solar heat was much more unequally distributed between summer and winter than at present. But instead of proving that this unequal distribution of heat would produce a permanent ice-cap he takes it for granted that it would do so—or else assumes that Dr. Croll's reasonings are satisfactory, which I think they are not. We could, I believe, reproduce the Ice Age at any moment if we could prevent our northern latitudes from receiving heat (by water or air) from the equatorial regions. But greater inequality of temperature would only produce stronger currents to and from the Equator.

So far my objections are of rather an abstract character and aim only at dispelling that unreasoning faith in supposed mathematical results which many astronomers entertain. But it seems to me that the theory of the instantaneous propagation of gravity has led to results which observation does not bear out except on the unproved hypothesis of undiscovered perturbing bodies. The motions of the Moon do not exactly conform to the present gravitation theory. Those of Mercury are even more astray. Periodic comets often depart both as regards the date of arrival and the orbit from the predictions of astronomers; and in the case of variable stars of the Algol type—eclipse stars—the present gravitation theory is rarely found to work satisfactorily without supposing a disturbance from some unknown cause. These last are the kind of cases which afford the best test of the instantaneous theory, for if there is a time propagation the variation in the direction of the acting force will as a rule be greatest when the revolution is most rapid. For this reason Mercury is the most likely body in the solar system to exhibit traces of time-propagation, excepting perhaps some of the inner satellites of the planets. The most probable mode of solving the problem however will be by means of careful observations on variables of the Algol type and spectroscopic double stars like β Aurigæ and Spica Virginis.

I may perhaps remark that Sir Isaac Newton believed that gravity acted through a medium from which its time-propagation follows almost as a matter of course. Subsequent research seems to have proved that a medium apparently suited for the purpose really exists. I hope some able mathematician will compute the effect of this time-propagation on the orbit of a binary star. We should of course remember that neither member of the pair is in the place where we see it. We see it where it was several years ago. As regards Mercury the matter rests on a somewhat different footing. No doubt we do not see Mercury and the Sun at the same moment, but the difference in time is inconsiderable. We do not see the Sun where it is but where it was a little more than eight minutes ago. Gravity unless propagated in time is never directed towards the center of the visible Sun.

One of my reasons for thinking that gravity is propagated in time is that collisions among the heavenly bodies occur so rarely, and that these bodies have not by this time been congregated into a comparatively small number of large masses. Collisions do not occur, I apprehend, because gravity never acts in the line joining the centres of gravity of two moving objects. The pull is not towards the place which the attracting body occupies now, but towards that which it occupied some time previously. For this reason even a very slow original motion at right angles to the joining line might suffice to avert a collision.

NEWTON'S COMET.

JOHN B. WOOD.

There are but four curves of motion admissible under the operation of the principle of gravitation. These are the circle, the ellipse, the parabola and the hyperbola, as proven by Sir Isaac Newton.

Theory had reached this conclusion before the comet of 1680, which is also known as Newton's Comet. Being of large size and visible for more than three months it quite naturally attracted attention, while its motions as observed by astronomers, had all the effect of an experiment which had been arranged to prove the Newtonian doctrine. Great must have been the influence of this apparition upon the minds of astronomers, while holding pause over the gravitation philosophy of Newton.

According to a determination of the orbit made by Encke we are enabled to represent it after the following manner. Our scale of distance is one inch for the radius of the Earth's orbit treated as a circle. We select wire one-hundredth of an inch thick, to make a model of the comet's path, the outside of the wire being the line of its motion. Our ellipse will be over seventy feet measured lengthways but not five inches across its width. The Sun would be at one end of the line of length, in the substance of the wire.

When the comet was nearest the Sun it had been falling to it for some 4300 years in its real curve, having the shape of our excessively elongated wire ellipse. It can be seen that the solar pull for most of the time was almost as if the line of approach were a straight one pointed for the solar center. Its velocity therefore was almost entirely due to the accumulated pulls exerted from second to second for this long time. The speed at perihelion was over 327 miles a second. In aphelion the rate of motion will be less than 16 feet in the same time.

From this supposed model two lessons can be learned. That astronomers should not agree as to whether an orbit is a parabola or an ellipse or as to whether it is an ellipse of one length or another, will no longer seem a reproach to them; for only in the very small part of the curve near the Sun, say at the most some five inches on our scale, is the comet visible. And as absolute accuracy in the places of the comet is unattainable the real departure from the supposed curve may be of such nature as to change the magnitude and even the character of the curve.

Also, as the time of revolution depends on the long axis, a very small error near by may count for very much out in space. So that instead of a short period we may really be dealing with a very long one. Or perhaps, contrary to prediction, the comet may move in a parabola and never return.

This is seen in the case of our comet. One estimate makes its time some 8700 years. According to Halley, Newton's Comet is to be identified with that of about 43 B. C. of 531 A. D. and of 1106, A. D. which would make its period some 574 years. Professor Mitchell observes concerning it that a parabolic orbit fitted the observations and that its period was nearly six hundred years.

THE CARE OF THE TELESCOPE.*

As a valuable and delicate instrument the telescope demands, and should receive, the most solicitous care. In particular does

* From the Amateur Telescopist's Hand-book by Frank M. Gibson.

the object glass require the most tender treatment. It should be kept covered with its cap whenever it is not in actual use; the dew-cap should never be forgotten; and the glass should never be brought from a cold into a warm atmosphere without first covering it to prevent its becoming bedewed. If the damp gets between the glasses it will produce a fog—a *sweat*, in optician's language—and, according to Proctor, even a seaweed-like vegetation, by which a valuable glass may be ruined. Should any moisture unluckily get upon the object glass, the telescope must be put in a warm place until the enemy has fled.

When it is necessary to clean the object glass—and it should only be touched when cleaning *is* necessary—a soft camel's-hair brush should first be used for removing the coarser particles of dust, which may be followed by a very careful sweeping with either a piece of very fine clean chamois-skin, or, better still, an old soft silk handkerchief. Mr. Franks recommends soft tissue paper aided by the breath. A little space near the edge of the glass is first cleaned, and from that point the dust is gently swept away. But let it be noted that a few specks of dust are of much less moment than irremediable scratches, and polished optical glass scratches very easily. Should any "refractory stains" get upon the object glass, they may be removed by a few drops of alcohol on perfectly clean absorbent cotton; but, as Mr. Chambers dryly observes, a careful observer will never allow any refractory stains to get upon his object glass. Should fine dust ever cake, as it sometimes will, upon the glass, breathe on it and wipe very gently from the edges with a soft cloth, which is then thrown away. This may sound alarming, but it is the precept of no less high an authority than Sir Howard Grubb.

Everything used for cleaning lenses should be kept in a tightly closed box when not in use, to preserve it from dust.

Never touch the polished surface of any lens with your fingers. The insensible perspiration, always present in small quantities, appears to have a corroding effect upon optical glass, and will destroy its polish.

All of the foregoing remarks as to cleaning lenses apply to eyepieces as well as to object glasses. Particularly must it be remembered that every scratch or speck on the field glass of a negative eyepiece will appear in a magnified form on looking through the eyeglass. Eyepieces should be kept, when not in use, in a dust-tight box; one provided with compartments is by far the best.

Under no circumstances should the two glasses composing the objective be separated or taken out of their cell by the amateur. Should circumstances make it necessary to separate them, let it be done by the maker or by a competent optician: otherwise the glass may be rendered worthless. Another rule, with an example is given by Mr. Proctor, which I will quote in his own vigorous language: "Suffer no inexperienced person to deal with your object glass. I knew a valuable glass ruined by the proceedings of a workman who had been told to attach three pieces of brass round the cell of the double lens. What he had done remained unknown; but ever after a wretched glare of light surrounded all objects of any brilliancy."

Should the brass-work of the telescope or stand become dull or dirty, it may be cleansed with a piece of chamois-skin moistened with sweet-oil. Care should be taken in cleaning an equatorial stand, not to press hard upon the circles lest they be bent out of "true." For protecting bright metal surfaces from oxidation, and also for lubricating purposes, ordinary vaseline is by far the best preparation, as it is free from the gumminess which is apt to attach to common oils.

METEORS AND STELLAR SCINTILLATION.

S. E. CHRISTIAN.

It seems to me that stellar scintillation is largely caused by occultations of the stars by small meteoric bodies passing between them and ourselves.

Lord Rayleigh in his excellent article on this subject admits that it is difficult to see how that atmospheric disturbances could take place suddenly enough to produce such sudden results.

The opposite temperatures of the atmosphere producing no difference in scintillation seems to be another difficulty in the theory of "atmospheric disturbances."

Both of these difficulties are easily overcome when we consider scintillations to be only momentary occultations of the stars by opaque bodies revolving either around the Sun or around the Earth outside of the atmosphere.

Of course if we account for it in this way it is necessary to admit of almost inconceivable numbers of these bodies continually passing between ourselves and the stars: but in the light of recent investigation such an admission is quite easy.

Sufficient numbers of these bodies, once admitted, it is easy to see what results would follow; momentary occultations precisely such as we see in scintillations would really be unavoidable.

I think it is quite probable that immense swarms of these small bodies continually revolve around the Earth at no very great distance from the atmosphere or at least inside of the orbit of the Moon. Immense swarms of them we know, revolve around the Sun, and as we see the satellites revolving around the planets, corresponding to the planetary revolutions around the Sun, we see no good cause why these swarms of meteors should not also have their corresponding swarms revolving around the planets. In fact we really know this to be the case in regard to Saturn. Why not then use analogy again to prove that other planets have or at least may have, corresponding swarms, though of course of more tenuity than those of Saturn. Telescopes of course could never render them visible and our only means of becoming sensible of their presence there would be the momentary occultations that they would cause in the tiny points of light from the stars, producirg scintillations.

It is not necessary, however, we think, to show that these bodies really revolve around the Earth to produce this phenomena—sufficient numbers revolving around the Sun would be sufficient—even bodies outside of the solar system would produce the same effect if sufficiently large. The increase in the scintillations of stars near the horizon seems to show that the cause, whatever it may be, is situated, at least in part, at no very great distance from the Earth. It might be possible however to account for this differently, as very small bodies might cause many partial occultations that would only be noticeable under certain favorable conditions offered near the horizon. What seems to offer more proof of these partial occultations is the increase in the scintillation of stars when viewed through a good glass. I think this is because many partial occultations that are not noticeable by the naked eye become apparent when viewed through a good glass.

The difference in scintillation between different stars, although hard to reconcile with any theory, is somewhat accounted for by this theory, from the fact that although the stars being mere points of light have no apparent disk, yet theoretically it would certainly be easier to raise a disk on some of them than it would on others, so that a small body that would be sufficient to totally occult some of them would only partially occult others.

Before closing I would say that some information might be gained by a careful observation of stars when in the immediate neighborhood of the planets. If any increase could be found in their scintillation there it would evidently be the result of metoric bodies revolving around the planets. However the small size of these bodies might not be sufficient at that distance to produce any perceptible occultations, even if their close proximity to the planets should not interfere with a proper observation. However I think it would pay to try, and if any one should do so I would be pleased to hear the result.

OCEANA, W. Va.

PLANET NOTES FOR JUNE.

H C. WILSON.

Mercury will be "evening star" during June. On the 22d he will be at his greatest distance (elongation) east from the Sun, and will set about an hour and a half later than that body. This month will be a good time both for daylight and evening observations of this planet. Its phase will be gibbous during the first half and crescent during the last half of the month. The moon will pass by Mercury on the evening of June 4, conjunction in right ascension occurring at $10^h\ 32^m$ central time.

Venus will be "morning star" rising about two hours before the Sun. She is getting around toward the farther side of her orbit so that her brightness is decreasing considerably. At the same time her phase is becoming more gibbous. At the beginning of the month 0.67 and at the end 0.76 of her disc will be illuminated.

Considerable has been said lately about the dark part of the disc of Venus being visible, just as the dark part of the new Moon is visible. Several observers claim to have seen the complete outline of Venus' disc a few days before she disappeared in the rays of the Sun this past winter, when her crescent was very narrow. We may say, I think, that this visibility is not from the same cause that renders the dark part of the moon visible, viz.: reflected earthshine. Venus is more than 100 times as far as the Moon from the Earth and therefore would receive less than the ten-thousandth part of the light thrown upon the Moon. The most probable explanation is that Venus has a dense atmosphere, possibly more extensive than that of the Earth, so that her twilight is longer, and extends far enough into the dark hemisphere to become visible from the Earth as a complete ring of light when the crescent of direct illumination is small. The observer discerning the outline of the dark part of the planet, by this faint ring, would naturally have the impression of seeing it all.

Mars will be at quadrature, 90° west from the Sun, June 17, and will be in position to be observed after midnight during this month. Mars will move northeast during June, from Aquarius across a little corner of Pisces into Cetus. The phase of the planet will be smaller this month than at any other time in the year, only 0.84 of the disc being illuminated. Mars will be in conjunction with the Moon, about 3° south of the latter, 48^m after midnight, June 25.

Jupiter and *Neptune* are not to be seen during June.

Saturn is making the turn of the loop in his apparent path among the stars of Virgo. He will begin to move eastward after June 21. The amateur should not fail to make the most of these summer months in the study of this planet. The surface markings on so bright a planet are almost as likely to be seen with a small telescope as with a large one. The Moon will pass by Saturn, 4° south of the latter, June 12, at $2^h\ 41^m$ P. M. central time.

Uranus will be in his most convenient situation for observation during June, being near the meridian during the evening hours. He ought to be easily found by means of stars α and μ Libræ (see Poole Bros. map). Look about 1° 30′ west and 30′ north, *i. e.*, 3 diameters of the Moon west and 1 diameter north, of α, for a star with a dull green disc a little brighter than the star μ.

Planet Tables for June.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

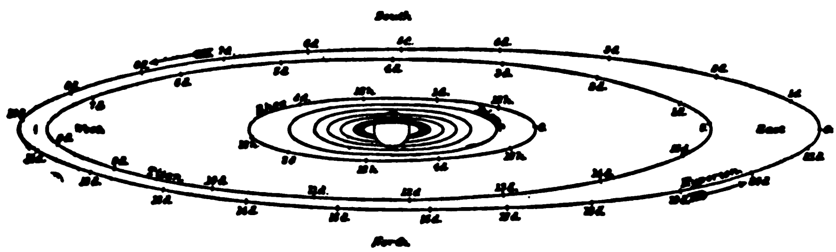
Date.	R. A.	Decl.	Rises.	Transits.	Sets.
1894.	h m	° ′	h m	h m	h m
			MERCURY.		
June 5	6 12.1	+25 31	5 19 A. M.	1 15.3 P. M.	9 11 P. M.
15	7 20.7	+23 47	5 58 "	1 44.4 "	9 31 "
25	8 05.7	+20 21	6 21 "	1 50.0 "	9 19 "
			VENUS.		
June 5	2 04.5	+10 13	2 24 A. M.	9 08.3 A. M.	3 53 P. M.
15	2 48.2	+13 49	2 13 "	9 12.6 "	4 12 "
25	3 33.9	+17 01	2 05 "	9 18.8 "	4 32 "
			MARS.		
June 5	23 20.7	− 6 51	12 49 A. M.	6 25.0 A. M.	12 01 P. M.
15	23 45.6	− 4 26	12 24 "	6 10.5 "	11 56 A. M.
25	0 09.6	− 2 03	12 00 "	5 55.2 "	11 50 "
			JUPITER.		
June 5	4 51.5	+22 03	4 17 A. M.	11 55.0 A. M.	7 33 P. M.
15	5 01.4	+22 19	3 46 "	11 25.5 "	7 04 "
25	5 11.2	+22 32	3 16 "	10 56.0 "	6 36 "
			SATURN.		
June 5	13 12.7	− 4 50	2 30 P. M.	8 14.7 P. M.	1 59 A. M.
15	13 12.0	− 4 49	1 50 "	7 34.7 "	1 19 "
25	13 11.9	− 4 51	1 11 "	6 55.3 "	12 40 "
			URANUS.		
June 5	14 38.8	−15 04	4 38 P. M.	9 40.6 P. M.	2 43 A. M.
15	14 37.7	−14 59	3 57 "	9 00.1 "	2 03 "
25	14 36.7	−14 55	3 17 "	8 19.9 "	1 23 "
			NEPTUNE.		
June 5	4 48.4	+20 58	4 20 A. M.	11 51.9 A. M.	7 24 P. M.
15	4 49.9	+21 01	3 42 "	11 14.2 "	6 57 "
25	4 51.5	+21 04	3 04 "	10 36.3 "	6 09 "
			THE SUN.		
June 5	4 54.9	+22 37	4 17 A. M.	11 58.3 A. M.	7 40 P. M.
15	5 36.3	+23 21	4 15 "	12 00.3 P. M.	7 46 "
25	6 17.9	+23 23	4 17 "	12 02.4 "	7 48 "
			THE MOON.		
June 2	3 25.6	+22 32	2 54 A. M.	10 41.0 A. M.	6 45 P. M.
4	5 41.3	+28 19	4 19 "	12 48.4 P. M.	9 22 "
6	8 01.7	+25 22	6 41 "	3 00.6 "	11 06 "
8	10 03.7	+15 22	9 27 "	4 54.5 "	12 05 A. M.
10	11 47.0	+ 2 31	12 00 M	6 29.6 "	12 45 "
12	13 22.8	−10 09	2 21 P. M.	7 57.2 "	1 21 "
14	15 01.3	−20 37	4 40 "	9 27.8 "	2 06 "
16	16 48.3	−27 04	6 56 "	11 06.5 "	3 13 "
18	18 40.3	−28 08	8 49 "	12 50.3 A. M.	4 54 "
20	20 27.6	−23 43	10 05 "	2 28.5 "	6 59 "
22	22 05.1	−15 04	10 56 "	3 58.9 "	9 12 "
24	23 36.0	− 3 46	11 32 "	5 21.7 "	11 24 "
27	1 09.0	+ 8 36	12 07 A. M.	6 46.5 "	1 41 P. M.
29	2 55.4	+20 13	12 50 "	8 24.8 "	4 16 "

Occultations Visible at Washington.

Date 1894	Star's Name.	Magnitude.	IMMERSION Washington M. T.	Angle f'm N p't.	EMERSION Washington M. T.	Angle f't N p't.	Duration.
			h m	°	h m	°	h m
June 15	3 Scorpii	7	7 38	150	8 46	267	1 08

Elongations of the Satellites of Saturn.

[In the diagram the points marked 0 are those of eastern elongation of the several satellites. Their positions at intervals of one day after eastern elongation are indicated by the symbols 1*d*, 2*d*, etc].



MIMAS.

		h		
June	2	12.3	A. M.	W
	2	10.9	P. M.	W
	3	9.5	"	W
	4	8.1	"	W
	5	6.7	"	W
	6	4.3	"	W
	7	2.9	"	W
	8	1.5	"	W
	9	1.9	A. M.	E
	10	12.5	"	E
	10	11.1	P. M.	E
	11	9.8	"	E
	12	8.4	"	E
	13	7.0	"	E
	14	5.6	"	E
	15	4.2	"	E
	16	2.8	"	E
	18	12.8	A. M.	W
	18	11.4	P. M.	W
	19	10.0	"	W
	20	8.6	"	W
	21	7.2	"	W
	22	5.8	"	W
	23	4.4	"	W
	24	3.0	"	W
	25	1.6	"	W
	26	11.7	"	E
	27	10.3	"	E
	28	8.9	"	E
	29	7.5	"	E
	30	6.1	"	E

ENCELADUS.

June	1	7.0	P. M.	E
	3	3.9	A. M.	E
	4	12.7	P. M.	E
	5	9.6	"	E
	7	6.5	A. M.	E
	8	3.4	P. M.	E
	10	12.2	A. M.	E

ENCELADUS CONT.

		h		
June	11	9.1	A. M.	E
	12	6.0	P. M.	E
	14	2.9	A. M.	E
	15	11.8	"	E
	16	8.7	P. M.	E
	18	5.5	A. M.	E
	19	2.4	P. M.	E
	20	11.3	"	E
	22	8.2	A. M.	E
	23	5.1	P. M.	E
	25	1.9	A. M.	E
	26	10.8	"	E
	27	7.7	P. M.	E
	29	4.6	A. M.	E
	30	1.5	P. M.	E

TETHYS.

June	2	11.5	P. M.	E
	4	8.8	"	E
	6	6.0	"	E
	8	3.3	"	E
	10	12.6	"	E
	12	9.9	A. M.	E
	14	7.2	"	E
	16	4.5	"	E
	18	1.8	"	E
	19	11.1	P. M.	E
	21	8.4	"	E
	23	5.7	"	E
	25	3.0	"	E
	27	12.3	"	E
	29	9.6	A. M.	E

DIONE.

June	2	12.7	A. M.	E
	4	6.4	P. M.	E
	7	12.1	"	E
	10	5.8	A. M.	E
	12	11.4	P. M.	E

DIONE CONT.

		h		
June	15	5.1	A. M.	E
	18	10.8	A. M.	E
	21	4.5	"	E
	23	10.1	P. M.	E
	26	3.8	"	E
	29	9.5	A. M.	E

RHEA.

June	5	5.9	A. M.	E
	9	6.3	P. M.	E
	14	6.7	A. M.	E
	18	7.0	P. M.	E
	23	7.4	A. M.	E
	27	7.8	P. M.	E

TITAN.

June	3	7.0	P. M.	I
	7	9.9	"	W
	12	12.4	A. M.	S
	15	7.4	P. M.	E
	19	5.1	"	I
	23	8.0	"	W
	27	10.5	"	S

HYPERION.

June	3	5.8	P. M.	E
	10	2.0	A. M.	I
	15	8.7	"	W
	19	6.2	P. M.	S
	24	11.6	"	E
July	1	8.9	A. M.	I

IAPETUS.

May	17	4.3	P. M.	W
June	6	3.7	A. M.	S
	26	4.0	P. M.	E
July	14	5.3	"	I

Elongations of the Satellites of Uranus.

[The diagram shows the apparent paths of the satellites of Uranus during the summer of 1894. The black dots with the numerals indicate the positions of the satellites at intervals of 1 day after each northern elongation. The points marked 0 are those of northern elongation.]

ARIEL.

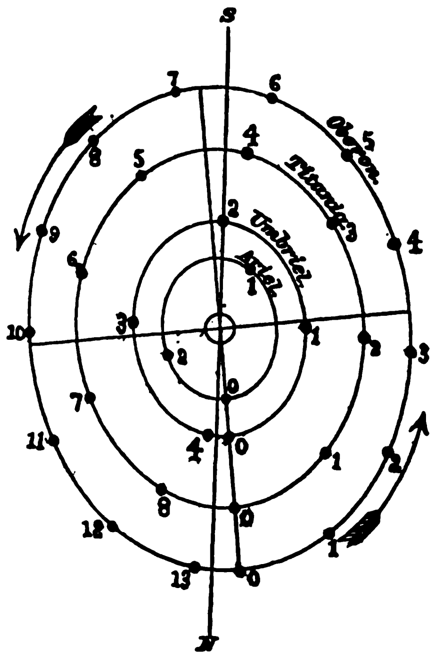
		h	
June	2	5.0 P. M.	N
	5	5.5 A. M.	N
	7	6.0 P. M.	N
	10	6 4 A. M.	N
	12	6.9 P. M.	N
	15	7.4 A. M.	N
	17	7.9 P. M.	N
	20	8.4 A. M.	N
	22	8.9 P. M.	N
	25	9.3 A. M.	N
	27	9.8 P. M.	N
	30	10.3 A. M.	N

UMBRIEL.

		h	
June	1	9.8 P. M.	N
	6	12.4 A. M.	N
	10	3.9 "	N
	14	7.3 "	N
	18	10.8 "	N
	22	2.3 P. M.	N
	26	5 8 "	N
	30	9.2 "	N

TITANIA.

		h	
June	2	7.3 A. M.	N
	6	3.8 P. M.	S
	11	12.2 A. M.	N
	15	8.7 "	S
	19	5.2 P. M.	N
	24	1.5 A. M.	S
	28	10.2 "	N



OBERON.

		h	
June	3	8.3 A. M.	S
	10	1.9 "	N
	16	7.6 P. M.	S

OBERON CONT.

		h	
June	23	1.2 P. M.	N
	30	6.8 A. M.	S

Maxima and Minima of Variable Stars.

[From ephemerides by Dr. Loewy in the "Companion to the Observatory," and by Dr. Hartwig in the "Vierteljahrsschrift der Astronomische Gesellschaft".]

MAXIMA

June	1	R Leonis
	1	W Hydræ
	2	S Aquarii
	2	V Virginis
	3	V Coronæ
	3	R Cygni
	5	R Scuti
	6	R Aquilæ
	7	R Sagittæ
	8	S Boötis
	12	Z Cygni
	13	U Herculis
	17	V Cancri
	17	U Monocerotis

MAXIMA

June	19	R Lyræ
	19	S Camelopardi
	19	S Libræ
	22	R Lyncis
	23	X Boötis
	23	V Boötis
	24	R Cassiopeiæ
	25	R T Cygni
	26	S Pegasi
	26	V Libræ
	29	Z Libræ
	30	U Geminorum

MINIMA

June	4	R Virginis
	4	R Lyræ
	6	R Vulpeculæ
	6	V Cephei
	9	R Draconis
	13	X Libræ
	13	W Herculis
	14	U Piscium
	15	X Cygni
	20	T Aquarii
	21	S Geminorum
	22	X Ophiuchi
	23	R Hydræ
	29	S Vulpeculæ

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

		h
June	2	12 M.
	4	12 midn.
	8	12 M.
	10	12 midn.
	13	11 A. M.
	15	11 P. M.
	18	11 A. M.
	20	11 P. M.
	23	11 A. M.
	25	11 P. M.
	28	10 A. M.
	30	10 P. M.

S CANCRI.

June	9	10 A. M.
	18	9 P. M.
	28	9 A. M.

δ LIBRÆ.

June	2	8 A. M.
	4	3 P. M.
	6	11 "
	9	7 A. M.
	11	3 P. M.
	13	11 "
	16	7 A. M.
	18	2 P. M.
	20	10 "
	23	6 A. M.
	25	2 P. M.
	27	10 "
	30	6 A. M.

U CORONÆ.

June	1	7 P. M.
	5	6 A. M.
	8	5 P. M.
	12	4 A. M.
	15	3 P. M.
	19	2 A. M.
	22	12 M.
	25	11 P. M.
	29	10 A. M.

U OPHIUCHI.

June	1	12 M.
	2	8 A. M.

U OPHIUCHI CONT.

		h
June	3	4 A. M.
	3	12 midn.
	4	8 P. M.
	5	4 "
	6	12 M.
	7	8 A. M.
	8	5 "
	9	1 "
	9	9 P. M.
	10	5 "
	11	1 "
	12	9 A. M.
	13	5 "
	14	1 "
	14	10 P. M.
	15	6 "
	16	2 "
	17	10 A. M.
	18	6 "
	19	2 "
	19	10 P. M.
	20	7 "
	21	3 "
	22	11 A. M.
	23	7 "
	24	3 "
	24	11 P. M.
	25	7 "
	26	4 "
	27	12 M.
	28	8 A. M.
	29	4 "
	29	12 midn.
	30	8 P. M.

Y CYGNI.

June	1	12 midn.
	3	12 M.
	4	12 midn.
	6	11 A. M.
	7	11 P. M.
	9	11 A. M.
	10	11 P. M.
	12	11 A. M.
	13	11 P. M.

Y CYGNI CONT.

		h
June	15	11 A. M.
	16	11 P. M.
	18	11 A. M.
	19	11 P. M.
	21	11 A. M.
	22	11 P. M.
	24	11 A. M.
	25	11 P. M.
	27	11 A. M.
	28	11 P. M.
	30	11 A. M.

S ANTLIÆ.

(Every third minimum.)

June	1	11 A. M.
	2	10 "
	3	9 "
	4	9 "
	5	8 "
	6	7 "
	7	7 "
	8	6 "
	9	5 "
	10	5 "
	11	4 "
	12	3 "
	13	3 "
	14	2 "
	15	1 "
	16	1 "
	17	12 midn.
	17	11 P. M.
	18	11 "
	19	10 "
	20	9 "
	21	9 "
	22	8 "
	23	7 "
	24	7 "
	25	6 "
	26	5 "
	27	5 "
	28	4 "
	29	3 "
	30	3 "

Phases and Aspects of the Moon.

	Central Time.			
		d	h m	
New Moon	June	3	4 56	P. M.
Perigee	"	4	11 40	P. M.
First Quarter	"	10	7 14	A. M.
Full Moon	"	18	1 06	A. M.
Apogee	"	20	4 50	A. M.
Last Quarter	"	26	4 03	A. M.

COMET NOTES.

Discovery of a New Comet (a 1894, Denning).—A telegram from Mr. John Ritchie, Jr., Boston, March 28, announced the discovery of a faint comet by Mr. W. F. Denning of Bristol, England, the following being the discovery position:

March 26.396 Gr. M. T. R. A. $9^h 55^m$. Decl. $+ 32° 15'$.

The comet was observed at Northfield on the evening of March 28, and found to be a very small object, very difficult to see in the 5-inch finder, but easily seen and measured with the 16-inch telescope. It had a well defined nucleus of the 11th magnitude, with nebulosity surrounding it between 1′ and 2′ in diameter. It had a short, slightly spreading tail, 2′ or 3′ long. From our own observations on the dates March 28, April 1, and April 5, we have computed the following parabolic elements of the comet's orbit:

Time of perihelion	= 1894 Feb. 14.1900 Greenwich mean time.	
π = Longitude of perihelion	= 133° 26′ 15″	Mean equinox 1894.0
Ω = Longitude of node	= 75 34 12	
i = Inclination	= 6 31 06	
q = Perihelion distance	= 1.22497.	

These elements do not represent the middle place, the observation of April 1, with a sufficient degree of accuracy, the outstanding residuals being + 8″ in longitude and + 26″ in latitude. These residuals cannot be reduced on any assumption of a parabolic orbit, and it may be presumed that the orbit will turn out to be an ellipse of comparatively short period.

As the comet is growing rapidly fainter it is not probable that those using small telescopes will see it. We therefore give the following ephemeris only to indicate approximately the course of the comet and its increasing distance from us. Its path among the stars during April and May, is shown upon Poole Bros' Map in this number.

EPHEMERIS OF COMET a 1894.

		R. A.			Decl.		log Δ	log r	Br.
		h	m	s	°	′			
Mar.	28	10	02	24	+ 31	01	9.7080	0.1421	1.00
Apr.	5	10	28	36	26	44	9.7632	0.1605	0.71
	13	10	50	16	22	44	9.8201	0.1799	0.50
	21	11	08	28	19	05	9.8778	0.1999	0.35
	29	11	24	36	15	47	9.9345	0.2201	0.25
May	7	11	39	08	12	48	9.9895	0.2403	0.17
	15	11	52	24	10	07	0.0428	0.2601	0.12
	23	12	05	04	7	40	0.0933	0.2797	0.09
	31	12	16	08	+ 5	33	0.1385	0.2965	0.07

A New Comet Discovered in Australia.—A telegram from Mr. John Ritchie April 6 announced the discovery of a comet by Mr. Gale at Sydney, Australia. The discovery position was:

April 2.944 Gr. M. T. R. A. $2^h 30^m 48^s$; Decl. $- 55° 35'$.

The motion is easterly. The comet is described as round with a bright condensation. This comet is too far south to be visible at any of the northern Observatories.

A Comet's Tail Discovered by Holmes.—Another telegram received April 11, announces the discovery of a bright comet's tail by Holmes April 9. Its approximate R. A. and Decl. were $17^h 58^m$ and $+ 71° 30'$.

Ephemeris of Tempel's Second Periodic Comet (1873 II)—Mr. L. Schulhof gives an ephemeris of this comet, in *Astronomische Nachrichten*, No. 3219, for the month May 19 to June 16. The elements used are as follows:

Epoch and osculation: 1894, April 25.0 Paris mean time.

$M = 0° \; 15' \; 27''$ $\qquad \varphi = 36° \; 26' \; 34''$

$\pi = 306 \; 14 \; 22$ $\qquad \mu = 679''.860$

$\Omega = 121 \; 10 \; 02$ $\Big\}$ 1894.0 $\qquad \log a = 0.478392$

$i = 12 \; 44 \; 20$

At the time of the last observation of this comet in 1878 its brightness was somewhat less than that which it should be theoretically during this month. It is therefore to be hoped that the comet will be found at this apparition.

EPHEMERIS.

		R. A. h	m	s	Decl. °	'	log Δ	$1 : r^2\Delta^2$
May	19	0	18	39	−2	48.6	0.22119	0.190
	20		21	43	2	37.5		
	21		24	46	2	26.6	0.22049	
	22		27	48	2	15.7		
	23		30	50	2	04.9	0.21982	0.188
	24		33	50	1	54.2		
	25		36	50	1	43.6	0.21917	
	26		39	49	1	33.1		
	27		42	47	1	22.7	0.21853	0.186
	28		45	44	1	12.4		
	29		48	40	1	02.3	0.21791	
	30		51	35	0	52.3		
	31		54	30	0	42.3	0.21730	0.184
June	1	0	57	24	0	32.5		
	2	1	00	16	0	22.8	0.21670	
	3	1	03	07	0	13.3		
	4		05	58	−0	03.9	0.21611	0.182
	5		08	48	+0	05.4		
	6		11	37	0	14.5	0.21552	
	7		14	25	0	23.5		
	8		17	11	0	32.3	0.21492	0.179
	9		19	56	0	41.0		
	10		22	41	0	49.6	0.21432	
	11		25	25	0	58.0		
	12		28	08	1	06.3	0.21371	0.177
	13		30	50	1	14.4		
	14		33	31	1	22.4	0.21309	
	15		36	11	1	30.2		
	16	1	38	49	+1	37.9	0.21246	0.174

Mr. Schulhof says that the uncertainty of the time of perihelion passage can not be more than ± 2 days. Should this occur two days early the R. A. of the comet would be increased $3^m \; 35^s$ May 15 and $2^m \; 55^s$ June 16, and the declination would be increased 10′ May 15 and 11′ June 16. If the perihelion passage should be 2 days later than calculated the R. A. would be decreased $3^m \; 43^s$ May 15 and and $3^m \; 02^s$ June 16, and the Decl. decreased 10′ May 15 and 11′ June 16. The observer searching for the comet may need to sweep over a space 20′ wide, extending 1° each way, east and west, from the predicted place of the comet.

Comet *b* 1894 (Gale).—From Science Observer Circular No. 105, we take the following:—A later message received April 15, contained the elements as given below, which were computed by Kreutz. From these an ephemeris has been computed by the Rev. G. M. Searle, which is given below.

ELEMENTS.

T = 1894 April 13.82 Greenwich M. T.
ω = 324° 18′ }
☊ = 206 9 } Mean Eq. 1894.0
i = 87 24 }
q = .9856

EPHEMERIS FOR GREENWICH MIDNIGHT.

	R. A.			Decl.		Light.
	h	m	s	°	′	
April 28	7	14	40	− 27	35	5.47
May 2	8	5	28	− 11	36	
6	8	47	32	+ 2	44	
10	9	21	0	+ 15	15	3.21

Light, April 2 = 1.

The object announced as a new, bright comet, by Holmes, in the position, R. A. 17^h 58^m, Decl. + 71° 30′, proves not to have been a comet.

The comet discovered by Denning on March 26 was observed here the next night, March 27, 8 hours 75 Meridian time, in approximate position, R. A. 9^h 58^m + 31° 29′. It was an easy object in the 10-inch refractor, having a very small but sharply defined nucleus, so close to the edge of the nebulosity that it was somewhat doubtful at first sight whether it belonged to the comet or was a star. A few minutes watching showed that it was a part of the comet. From the stellar nucleus extended a short, broad fan-shaped tail. Many fruitless searches were made here for the bright comet reported to be discovered by Holmes, of England on April 9. As neither direction or rate of motion were given in the announcement, a large region of the sky in the place indicated was swept over until it became evident that some mistake had been made by Mr. Holmes, and this, I have just learned, was really the case. This experience emphasises once more the importance of *always ascertaining motion* beyond the possibility of a doubt before making a public announcement. If this is not possible at discovery, then the suspected comet should be telegraphed to some leading observatory, preferably to Harvard by American observers, with instruction to with hold the public announcement until verified by the observation of motion, either at the observatory so notified, or by the discoverer himself. This simple precaution would often save the very considerable expenditure of a world wide announcement, and what is often of far greater importance, the waste of many hours of valuable time. To all of us, at times, a *clear night* is above riches.

WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y., April 18, 1894.

A man weighing 12 stone on the Earth would, if transported to the surface of the Sun, weigh no less the than two tons! and would be wholly unable to sustain his own weight. A certain insect which possesses enormous muscular power in proportion to its weight might be able to move about with much difficulty; but all the larger animals would at once be deprived of their powers of locomotion. A projectile from even a Hotchkiss gun would be utterly useless on the Sun, as owing to the increased force of gravity it would be rapidly drawn to its surface, and its range would be reduced to only a few yards from the cannon's mouth.—Gore in "Scenery of the Heavens."

PRACTICAL SUGGESTIONS.

34. I would like to know where I can find something of the work of the Lick telescope, its powers and possibilities? C. R. P.

Answer: A description of Lick Observatory and its instruments including the large telescope, of course, is given in the Hand-book of the Lick Observatory, published by Professor E. S. Holden, the director, some years ago. The powers of the instrument are known in theory by the size of the object glass and the eye-pieces it will carry in doing different kinds of astronomical work, and in practice, by the use of such tests. The defining power has been shown in revealing very minute details on the Moon's surface, in the discovery of faint new stars in the Trapezium of Orion, in the details of faint nebulæ, the surface markings of planets, in the discovery of the 5th satellite of Jupiter, in the separation of very faint double stars, and other difficult visual work. The great instrument has an equally interesting record in the lines of photographic and spectroscopic investigation. Its light-gathering power has given it great advantage in the study of faint celestial objects. For a few years past it has been the court of last resort in the decision of hard astronomical questions. It would be impossible to point to any one source for information in regard to all the important work accomplished by the great Lick telescope. There is not an important magazine in this country or Europe that has not given something of its work or power during the last five years. Professor Holden is a very able and a very ready writer, and the calls on him, from every part of the civilized world, for information and help in astronomical work have been simply enormous. On this account the literature pertaining to the Lick Observatory has been very widely scattered. In a more formal way it will be found in the publications of the Observatory, the publications of Astronomical Society of the Pacific, in volumes of the *Sidereal Messenger*, volumes XI and XII of *Astronomy and Astro-Physics*, in the *Astronomical Journal*, *Nachrichten*, *Knowledge* and the *Journal of the British Astronomical Association*. It is also true that much of the work of the great telescope is not yet published, because yet in course of observation or reduction.

35. What are the possibilities of the unfinished Yerkes telescope? C. R. P.

Answer: It is yet too early to say much about the Yerkes telescope. Its great objective is quite finished though not yet turned over to the authorities of the new Observatory. The mounting by Messrs. Warner & Swasey was completed nearly a year ago and was exhibited at the World's Fair in Chicago last summer. For brief description of it see *Astronomy and Astro-Physics*, Vol. XII, page 571, Vol. XI, page 790.

36. When the classical writers speak of a star or constellation as rising at a certain time of the year, is it the *heliacal* which is referred to? C. F. T.

Answer: The ancients had no telescopes. The horizon was the only scientific instrument they possessed. They spoke of the stars as rising cosmically, achronically and heliacally. Cosmic rising was at the same moment with the Sun. Achronical rising of a star was at the time of the Sun setting, and heliacal rising of a star was in advance of the rising of the Sun. The term "heliacal" rising was coined to represent a star rising visibly in the dawn, therefore before the Sun. Generally throughout Egypt the Sun was supposed to be something like 10° below the horizon when a star was stated to rise "*heliacally.*" A good chapter on this theme will be found in *Lockyer's Dawn of Astronomy*, published by Macmillan & Co., New York, 1894. The early writers used these three different kinds of the risings of the stars. Bright stars only could have been seen in the case of cosmic or achronic rising, in heliacal rising fainter stars could also be seen. It is very probable that the latter rising was generally referred to by the classic writers.

37. When the approximate position of the Moon in the heavens is given in almanacs, etc., is the zodiacal constellation or zodiacal sign meant? C. F. T.

Answer: The latter.

38. When astrology was in vogue, was it customary in casting a horoscope to employ zodiacal constellations or zodiacal signs? C. F. T.

Answer: The groups of stars we now call constellations were formerly called signs, especially those of the zodiac and others adjacent. It was not until about the first century before Christ that the signs of the zodiac as distinguished from the constellations of the zodiac were used. They were introduced by Hipparchus because the groups of asterisms, now called constellations, were too indefinite for the exact astronomical references which he wished to make in the records of his observations. The celestial bodies, the Sun, Moon, planets and stars and signs as groups of stars were the objects of study of the astrologist. In the life of Tycho Brahe by Dreyer, will be found the abstract of an oration on astrology by Tycho in his early life.

39. In what direction does the Sun rotate on its axis? C. O. T.

Answer: If our querist will think of this page as the plane containing the paths of the planets and the Sun in the center, and will then lay his watch down on the page, face up, the revolution of the planets around the Sun will be in a direction contrary to that of the hands of the watch. The rotation of the Sun on his axis (which is nearly perpendicular to the plane before mentioned) is in the same direction as that of the revolution of the planets. The Sun's rotation is determined by the motion of spots seen on his surface, also by the aid of the spectroscope.

40. Will a six-inch telescope show the shadows of the satellites of Saturn's moons on the disc of the planet?

Answer: I think not. They are too faint. I know of no such record.

41. Please give me a list of your lantern slides and quote price. J. S. T.

Answer: We have not a printed list of lantern slides made at Goodsell Observatory. This work has been done entirely from negatives of various celestial objects taken during the course of regular work. The few illustrations that have been sent out have been made at the request of friends interested in our work and who know something of the objects photographed and the value of the negatives. We could furnish from 40 to 50 good slides with or without color from our own negatives if desired. Those without color in lots of a dozen or more at 75 cents each. Those in color will cost more according to the work required. The principal subjects are the Sun, Moon, Clusters, Nebulæ, portions of the Milky Way, Star trails, Asteroid trails etc.

42. Will you explain to us why it is that while the day begins to increase at sunset about December 16 and continues to do so, it keeps on shortening in the mornings, the Sun rising later and later till about the middle of January when the Sun begins to rise earlier. Very few persons even observe this—but it continues until the day is longer in the evening by about a half hour ere it be-

gins to lengthen on the morning end. And the same is observable at the summer solstice. Explanations are made that remind one of "Explaining Metaphysics to the Nation!" "Who can explain his explanation?" HOLT.

Answer: It would seem, at first thought, as if the days ought to lengthen alike at both ends, as the Sun increases in declination. This would be true if we reckoned time by means of the sundial, or if the Sun crossed the meridian at 12 o'clock every day. But anyone by referring to an almanac will find the Sun recorded as "fast" or "slow" at different times in the year. The solar day (by day we now mean the interval from noon to noon) varies throughout the year. For the purposes of time-keeping a measure of uniform length is necessary and for that the *mean solar day* has been adopted, having the length of the average of all the true solar days. We may regard this day as measured by the revolution of a fictitious Sun moving at a uniform rate about the Earth and in the plane of the equator. It will be easily seen that when the real Sun is to the east of this fictitious Sun the hours of daylight in the forenoon will be shortened and the afternoon lengthened and when the real Sun is west of the fictitious one the reverse will be true.

In December the real Sun is moving toward the east with reference to the fictitious Sun so that the afternoons begin to lengthen before December 21, the date when the Sun begins to move northward, while for the same reason the forenoons continue to shorten after that date until the increase due to the more northern declination balances the relative easterly movement. In a similar manner in June the real Sun is moving to the eastward of the fictitious Sun, so that the forenoons begin to decrease before June 21 and the afternoons continue to increase for a few days after that time.

43. In considering the subject of Stellar Evolution, I have met with a difficulty which perhaps you may be able to clear up. Professor E. C. Pickering in his article on "The Constitution of the Stars," (*Astronomy and Astro-Physics*, Vol. XII p. 718.) says that in stars like α Aquilæ the H lines are broad and diffuse. He remarks that this could be accounted for by supposing these stars to have a rapid axial rotation, but that this would imply an equatorial velocity of over 100 miles a second, and is therefore improbable.

This sets me thinking; is it so very improbable? We know that many of the stars differ very much from our own Sun in mass, constitution, etc. Is there not a reasonable presumption that they may also enormously exceed it in velocity of rotation?

It seems to me, that on *any* hypothesis of stellar evolution, whether the nebular, the hypothesis of meteoric aggregation, etc., just before consolidation into a single mass, the detached masses which are about to constitute the visible photosphere, *must* be rotating with planetary velocity around the common centre of gravity, and therefore at first formation the photosphere would be rotating with this enormous velocity. I do not see any escape from this conclusion. This would mean, for a star equal in size and mass to our own sun, a rotation in about 3^h, or an equatorial velocity of over 200 miles a second. So that the supposed velocity of 100 miles a second does not seem *a priori* so very unlikely to occur *somewhere* in the universe. At the same time, there is reason to believe it would be somewhat exceptional. Thus the photosphere of Sirius cannot be rotating with anything like this velocity, the mass being only about twice that of our sun, and the distance from the centre enormously greater.

Now comes in my difficulty; if stars at their first formation were rotating with this enormous velocity, why should they not continue to do so? Obviously, in stars like Algol, which had a close companion of considerable magnitude, the enormous tides raised in the primary, would soon reduce the velocity of rotation. (But even here there is a limit; thus I can understand the rotation-period of Algol being equal to the period of the companion or 2d 20^h 49^m, or being still less than this, but I cannot understand its being much greater.) Now, in the case of all the bodies in the solar system, *except the Sun*, there is no difficulty in accounting for the rotation-periods. The outer planets by reason of their great mass had much shorter original periods than the inner. In the case of these latter, the reduction was principally effected by the solar tides; in the case of the former the tides raised by the satellites. The longer period of Jupiter with regard to Saturn may be ascribed to the fact that the solar tides had still some effect on Jupiter, but hardly any on Saturn. But in the case of the Sun itself, the reduction seems inexplicable. And it is not that I have brought forward a theory, to which the Sun is an irreconcilable exception. The only hypothesis I urge, is that it does not seem to me by any means impossible that the widening of the H lines in the spectrum of α Aquilæ may be due to a very rapid rotation. That all stars originally rotated rapidly, and would still be rotating rapidly unless the velocity was in some way reduced, seems to me a necessary consequence of any hypothesis as to stellar evolution. I suppose it is wrong; in fact if the Sun is really irreconcilable, it *must* be wrong; but I cannot see how.

Another way in which the rotational velocity may have been reduced is internal friction; the layers internal to the photosphere having a longer period, because although nearer to the centre, the included mass is less. For stars like our sun this method has the advantage of not depending on any external body. But I feel doubtful as to whether this cause could have been so effective, because if, as seems probable, the mass increased in density towards the centre, the retardation due to this cause would evidently have been less.

In any case, if we admit that in stars when first formed the photosphere is rotating with planetary velocity; it follows that in large diffuse stars, as Sirians, where, owing to the rarity, friction can have but little effect, this velocity is very great; not indeed 100 miles a second, but much greater than the velocities we are accustomed to in our own Sun. J. R. HOLT.

Answer: There does not seem to be anything improbable in the supposition that *some* of the stars are rotating with great axial velocities; but we could hardly expect that this would always be the case. The velocity of rotation of a star would depend upon many circumstances.

(1) Supposing a nebulous mass to be endowed originally with a given angular velocity of rotation, it is evident that this angular velocity will steadily increase as the mass contracts, since the axial moment of momentum of the mass is constant, and the radius of gyration diminishes as the mass condenses. Hence the angular velocity of rotation will depend upon the stage of development. It is well known that such an increase in angular velocity as we have indicated would also give rise to an increase in the *linear velocity* of the periphery of the nebulous mass.

(2) The angular velocity with which the mass started would depend altogether upon the manner in which the matter composing it came together. If all the nebulous matter fell straight towards the centre, there would be no rotation about that point; the figures of some of the planetary nebulæ would seem to indicate that they have no rotatory motion. On the other hand, if any of the nebulous matter did not fall straight towards the centre, but rather to one side of it, the result would be a rotation in some direction. For the new mass would thus in its formation acquire a given moment of momentum about its center of inertia,

and this moment of momentum would always be preserved however much the nebula contracted. Thus there might arise all possible initial velocities of rotation. Besides, as we have seen in (1), the velocities would increase as the masses condensed.

Hence we conclude that all possible velocities probably exist among the stars, and we can see no inherent improbability in supposing the stars to be rotating in many cases at a velocity of 100 miles per second. But at present all positive knowledge on this point is wanting. (σ).

GENERAL NOTES.

We are disappointed that some of our engraving of recent photographic work could not be completed in time for this number. It will be in readiness for our next issue.

The Peters-Borst Star Catalogue.—About 1889, the manuscript of a catalogue of 35,000 stars was completed at Litchfield Observatory of Hamilton College and made ready for publication. The observations and reductions were made in the main by Charles A. Borst, then assistant to Dr. C. H. F. Peters, director of Litchfield Observatory, who, it was claimed, planned the work and directed it in the beginning. When the manuscript was completed Mr. Borst refused to give it up, claiming it as his own. The matter was taken to court and tried before Judge Williams in Utica in the spring of 1889, and it was decided that the catalogue belonged to Dr. Peters. This trial attracted wide attention in consequence of the scientific features in the case and the prominence of the witnesses called to testify. Since the death of Dr. Peters which occurred in 1890, the contest has been maintained by Hon. Elihu Root of New York as administrator in the appeal made by Mr. Borst to the Court of Appeals of New York. From the Utica *Herald*, April 14, we learn that the Court of Appeals hand down a decision reversing that rendered in 1889 by Judge Williams and ordering a new trial.

While neither of the parties claimed that the star catalogue had commercial value, it was shown by the testimony of Professors Hall of Washington, and Boss of Albany, that the cost of work was not less than $12,000. For a statement of the case in important particulars, see Vol. VIII *Sidereal Messenger*, pp. 138, 455.

Brilliant as the Sun is, and all-important as he may appear to the ordinary observer, he is to astronomers only one of the hosts of heaven, in fact the nearest of the fixed stars . . . seen from the nearest of the stars, α Centauri, the Sun, together with the whole solar system, would appear as a star of about the 2nd magnitude near the Chair of Cassiopeia about 5° north of η Persei.—GORE: "Scenery of the Heavens."

The Sun rotates in twenty-five or twenty-six of our days,—I say twenty-five or twenty-six because (what is very extraordinary) it does not turn all-of-a-piece like the Earth. but some parts revolve faster than others,— not only faster in feet and inches, but in the number of turns,—just as though the rim of a carriage wheel were to make more revolutions in a mile than the spokes, and the spokes more than the hub. Of course no solid wheel could so turn without wrenching itself in pieces, but that the great solar wheel does, is incontestable; and this alone is a convincing proof that the Sun's surface is not solid, but liquid or gaseous.—LANGLEY in "New Astronomy."

Authority for Variable Star Maxima.—In our tables of prediction for variable star maxima under the title of Current Celestial Phenomena we have used the tables of Ernst Hartwig in the main, as they appear in the "*Viertel-jahrsschrift der Astronomischen Gesellschaft.* These have been compared with other good tables and have been found to agree well generally, though not in all cases. Hartwig is regarded as good authority and this mention is made because of a statement involving some uncertainty by one of our correspondents found on pages 399 and 401 of this number.

The Poole Star-Charts.—We have received a copy of the Poole star-chart of the same size as the Poole Planisphere, on a circle 17 inches in diameter, the north pole of the heavens at the center, and extending to 50° south of the celestial equator. The constellations are all nicely shown with easy and definite boundaries, just as given on smaller scale in the star-chart of this number. The stars to the fifth magnitude and under are also given.

These large star-sheets can now be secured by astronomers, observers and students who may want to keep a record of celestial phenomena of special interest such as the paths of comets, planets, shooting stars, etc., etc.

This is an excellent idea, because all such records that are made neatly and accurately will be of great value. On the blank map everything is done except that which the observer wants to record, and the value of his record is in the fact that he has everything to a scale and all records are uniform. Every observer interested in good records of this kind to accompany the note-book will want to examine these star-sheets.

The Dawn of Astronomy—In *Astronomy and Astro-Physics* for March a full notice was given of the new book bearing the above title. It is written by J. Norman Lockyer and published by Messrs. Macmillan & Company of London and New York. It is attractive in appearance with large page, clear type, wide margin, very heavy paper, 121 illustrations and a contents of 425 pages. Price $5.

The design of the author is to determine the bearing of recent discoveries, as far as possible, on the early history of astronomy. The earliest civilizations from which information is now sought are those of the Nile Valley and adjacent countries in western Asia. India and China with paper records but no monuments of high antiquity are undoubtedly of more modern origin. If we can go back in China's and India's history 4000 years, and by Babylonian tablets 5000 years, those of Egypt may carry the inquirer back as far as 6000 or 7000 years. The key to this important investigation is in the worship of these ancient peoples, and as it consisted largely in deifying the heavenly bodies and in dedicating to them great temples and shrines without number, it is important to know which of the celestial bodies were chosen as objects of worship for these temples respectively, whose foundations have been uncovered extensively by the archeologists in modern times. During the last three years one important point of study has been to learn as accurately as possible, the directions in which the foundations of the various shrines lie in regard to the points of the compass. For, it is believed, that the worshippers who built them carefully placed them to face the rising point of the Sun, planet or star to which they were respectively dedicated. Now, it will readily be seen that the ancient tablets connected with these facts of orientation and the astronomer's knowledge of the places of the celestial bodies in very ancient times may give new and important information about the dawn of astronomy. This new book fairly opens the field and directs attention to lines of study that may be pursued very profitably without doubt to gain valuable information.

Mt. Lowe Observatory.—I desire to inform the readers of your widely read journals that my future address will be Lowe Observatory, Echo Mountain, Los Angeles Co., California.

My instruments, which for the past twelve years have done service at the late Warner Observatory, Rochester, N. Y., are now *en route* to Pasadena, from which city they will be transferred to the Mt. Lowe Railway which will elevate them to the site of the Observatory, 3500 feet above the Pacific Ocean. This road, a trolly to Rubio Canyon the first station, and an electric cable road to Echo Mountain, has been in successful operation for nine months.

Work on the new mountain Observatory will be begun immediately upon my arrival. Already there are established there the telegraph, telephone and express offices, a post office and mammoth hotel, and an illustrated daily newspaper, the Mt. Lowe Echo, is published.

With nine degrees of southern declination not visible from this latitude nor from most of the observatories of the world, and having an assurance of nearly three hundred clear nights per year, I am hoping for a continuance of my nebulæ work begun in this city, and successfully prosecuted until stopped by the electric street lights. LEWIS SWIFT.

Rochester, N. Y., April 12, 1894.

Casual observers are referring the fine aurora of Friday, March 30th, to the spots on the Sun which happened to be most conspicuous at the time, which in this case were east of the meridian and far north. There was, however, a disturbance marked by two spots smaller it is true, but in the precise location which has been found to be characteristic when there is an aurora at this season of the year, namely at the eastern limb and south of the equator. In other words it is the position and not the size of the spots that determines the auroral effect and its recurrence at the precise interval of the rotation period of the Sun.

M. A. VEEDER.

Aurora.—During the display of aurora borealis on the evening of March 30th, a prominent feature was the converging of the streamers and waves of light to a point on the meridian about 15 degrees south of the zenith. When first seen here, a few minutes before 8 o'clock, the light was pretty evenly distributed over the sky from east to west and extending from the north towards the south as far as a line parallel with the horizon running through Sirius. This, at first was quiescent and very similar in appearance to a stratum of luminous cirrus clouds. This soon broke up, however, into streamers and filaments of light, some of which were bright pink in color, all pulsating rapidly towards a point which at 8:30 P. M. was apparently on the meridian, nearly on a line with northerly star in the sickle of the Lion. The most remarkable part of the display was the unmistakable flashing of streamers from the *south*, as well as other quarters, to the point referred to. In fact I do not remember to have ever seen an aurora whose southerly limit was so near the horizon, and which showed from *all* directions a movement towards a definite point. It would be interesting to know if this was observed elsewhere and what explanation can be given of the phenomenon referred to. J. H. EADIE.

Bayonne, N. J.

The Sun-heat falling on one square mile corresponds to over 750 tons of water raised *every minute* from the freezing point to boiling. The Sun's heat falling on the Earth in each *minute* would raise to boiling 37,000,000,000 tons of water.—LANGLEY in "New Astronomy."

Mira Ceti.—Observations of this variable star have shown that it has continued to brighten since the predicted date of maximum (February 17). At the present time (March 4) it is a trifle brighter than δ Ceti, a star of magnitude 4.2, and is quite a conspicuous naked-eye star for a little while after darkness sets in. There are no indications that it has even yet reached the maximum. On some previous occasions it has reached the second magnitude. The predicted date of maximum was no doubt calculated on the basis of the period of 333 days deduced by Argelander, but it is well known that the period, like the maximum brightness, is not always the same. There is evidence of a regular irregularity to the extent of twenty-five days. The present apparition is anything but favorable, owing to the proximity of the star to the sun.—*Nature*, March 15, '95.

BOOK NOTICES.

The Amateur Telescopist's Hand-book by Frank M. Gibson, Ph D.; L. L. B. New York; Messrs. Longmans, Green & Co., publishers, 15 East Sixteenth St. 1894. pp. 163.

This is a plain, unpretentious little book intended for those who have telescopes under 4 inches of aperture, and who wish to learn the proper care and use of such an instrument. The first eighty pages is given up to the consideration of the telescope under nine chapters. The first chapter deals with the telescope in regard to its principles and powers. The small telescope has a useful place in the study of astronomy if the young observer knows how to apply it. He shows the principles of the instrument. They are plainly presented and illustrated The eye-pieces are given also, and the number and power of each adapted to apertures varying from 2 inches to 6 inches. Brief statements are given showing what is meant by the magnifying, defining and illuminating powers of the telescope. The second chapter treats of testing the object glass, eye-pieces and tubes. It is excellent as far as it goes. The illustrations of deformed images with explanations of causes are definite and helpful. Chapter third particularly describes the equatorial stand, and fourth has to do with the accessories. The fifth chapter, on the care of the telescope, we have given elsewhere in this number, in full, and and it will serve to illustrate the way the author deals, not only with the subject in hand, but also indicate somewhat of the character of the book as a whole. The sixth treats of the use of the telescope in seven pages; the seventh, is concerned with the observations of the stars, nebulæ, Sun and Moon to which twelve pages is devoted. Then follows chapter ninth which gives the prices of small instruments of various sizes by different makers, mounted, unmounted and portable.

The remainder of the book consisting of 80 pages is given up to a list of celestial objects arranged under the constellations to which they belong, the constellations themselves being arranged in alphabetical order. This list contains 468 celestial objects consisting of double stars, clusters, variables, peculiar stars and nebulæ. This book will be of real service to the amateur who has had little experience with the telescope.

Total Eclipses of the Sun. By Mabel Loomis Todd. Illustrated. Boston: Roberts Brothers, publishers. No. 1 Columbian Knowledge Series. 16mo, cloth, pp. 244. Price $1.

Mrs. Todd's neat little book is the first of the *Columbian Knowledge Series*, under the editorship of Professor D. P. Todd of Amherst College, and is certainly attractive at first sight, whether it be in the thoughtful taste of cover decoration handsomely designed by the gifted Mrs. Huggins of London, or the varied and ample illustration of the text, which numbers 223 cuts and full-page plates.

The author begins with a chapter on eclipses and eclipse tracks in general, showing how the path of total shadow would look to one so placed to view it as a whole, if it were a fixed trail on the Earth's surface. The figures of the shadows, the comparative sizes of the Sun, Moon and Earth, and the easy, clear way of associating a multitude of interesting facts pertaining to these bodies, their orbits and their specific relations in important eclipses, will enlist the interest of the reader at once in the plan and purpose of the book. The especial value of the text for the careful student or instructor in the elements of astronomy is the abundant references to authority and useful books on almost every page. This has cost labor and much of it, on the part of the author, for very much of this useful information will not be found in text-books or other works easily accessible to the popular reader. For example, the description of the total eclipse in the second chapter very aptly and fully illustrates, by cut and word, the singular crescents visible under foliage during the partial eclipse, and the fleet shadow bands as they curiously painted the side of an Italian dwelling seen in the total eclipse of 1870.

The following are titles of other chapters:—Minor phenomena, interimercurian planets, the solar prominences, the corona, eclipses in the remote past, mediæval and later eclipses (A. D. 5 to 1842), modern eclipses (1842—1880), recent eclipses (1882—1893), eclipses and the telegraph, Automatic eclipse photography, the predicting of eclipses, selecting stations, future eclipses, lists of eclipses with charts, biographical sketches and an index.

This number makes an auspicious beginning for the Columbian Knowledge Series, and ought to find ready sale as its *merits* are known.

Bibliography of Astronomy for February, 1894.

GLYDÉN (H.) Traité analytique des orbites absolues des huit planètes principales. 1. Théorie générale des orbites absolues. 4to. Stockholm, 1894. $7.50.

JOHNSON (S. P.) Notes on astronomy: a complete elementary handbook, with a collection of examination questions, edited by J. Lowe. 8vo. 1894. 90 cents.

LYNN (W. T.) Remarkable comets. Second edition. 12mo. 1894. 15 cents.

LYNN (W. T.) Celestial motions: a handy book on astronomy. 8th edition. 3 plates. 12mo. 1894. 50 cents.

MARTIN (P.) Untersuchungen über die wahrscheinlichste Bahn des Cometen 1825 I und über seine Identität mit dem Cometen 1790 III. 4to. Goettingen. 1894. f1.

PRATT (H.) Principia nova astronomica. 4to. 1894. $2.65.

PROCTOR (R. A.) The orbs around us. New edition. 8vo, cloth. 1894. 90 cts.

The above works can be purchased from Wm. Wesley & Son, 28 Essex Street, Strand, London, England.

Errata.—Page 301, line 8, for "Techner's" read "Fechner's." Page 304 line 5 from end for "increases" read "is multiplied."

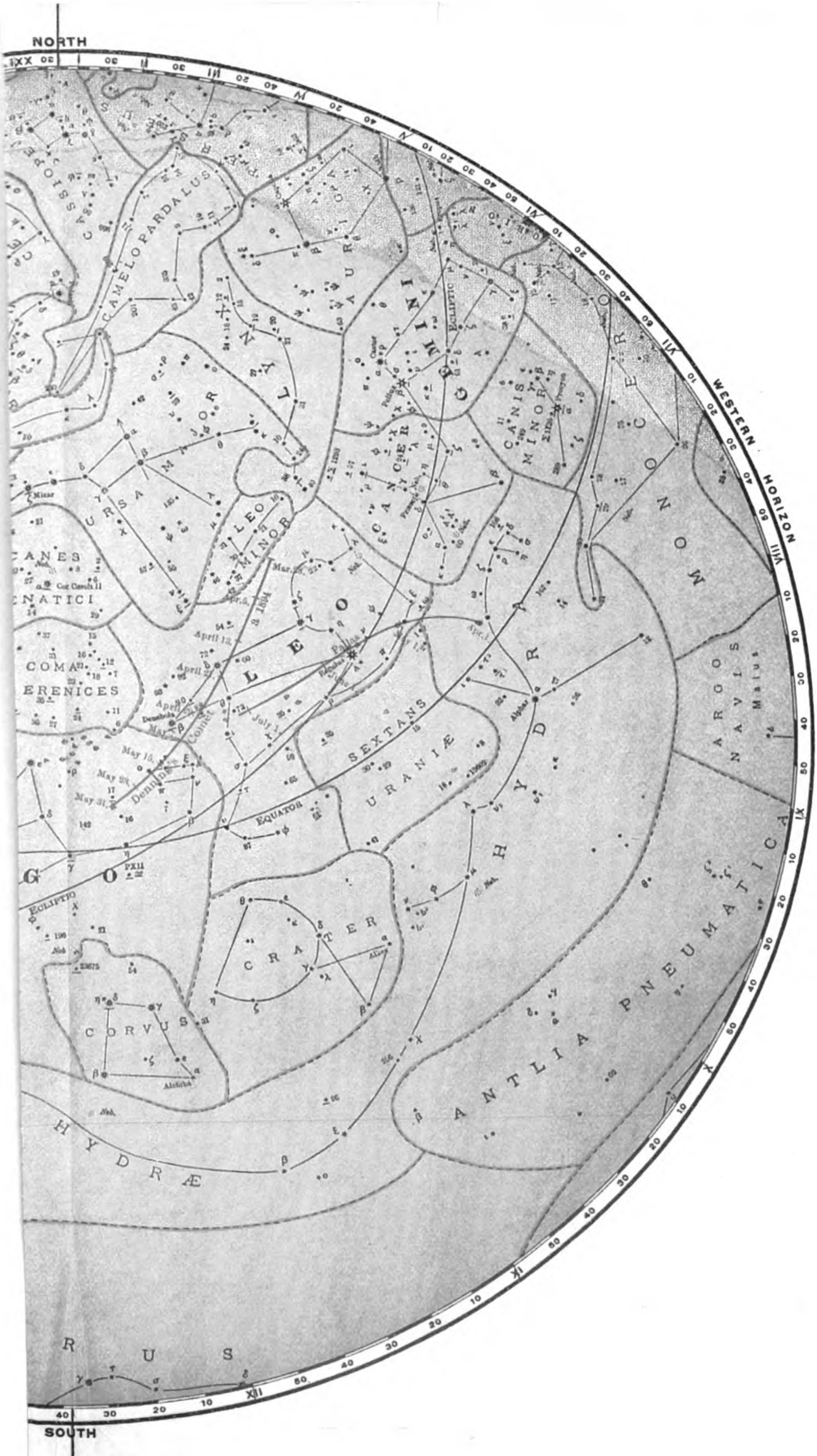
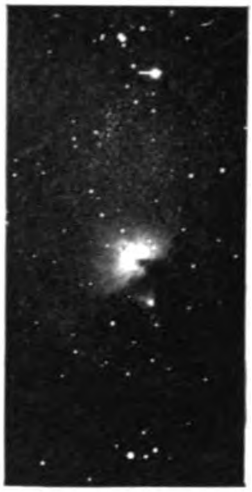
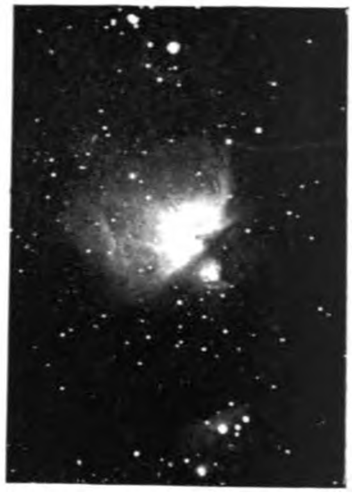

NORTH
CAMELOPARDALUS
URSA MAJOR
LEO MINOR
LEO
CANES VENATICI
COMA BERENICES
CANCER
GEMINI
CANIS MINOR
MONOCEROS
HYDRA
SEXTANS URANIÆ
CRATER
CORVUS
ANTLIA PNEUMATICA
ARGO NAVIS Malus
HYDRÆ
EQUATOR
ECLIPTIC
Cor Caroli
Alphard
WESTERN HORIZON
SOUTH

PLATE XXI.



No. 1. Exposure 15^{m}.
Nov. 6, 1893.



No. 2. Exposure 2^{h}.
Jan. 25, 1892.

No. 3. Exposure 9^{h}. Feb. 5 and 6, 1894.

THE GREAT NEBULA IN ORION.

From photographs taken at Goodsell Observatory by H. C. Wilson and A. G. Sivaslian.

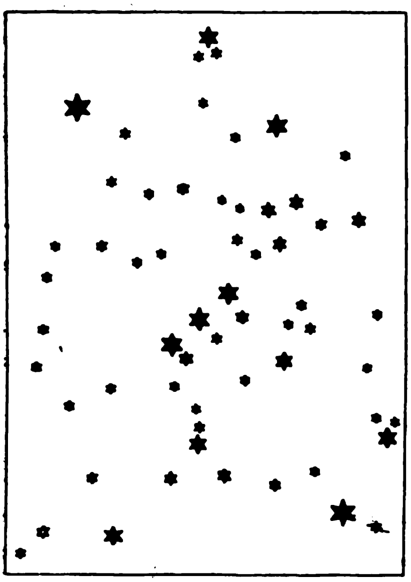
Popular Astronomy.

Vol. I. JUNE, 1894. No. 10

THE GREAT NEBULA IN ORION.

H. C. WILSON.

The finest nebula in all the heavens, at least in that part of the sky which is visible to our latitude, is the great nebula in the Sword of Orion. The constellation of Orion is a conspicuous winter constellation, which doubtless all of our readers have noticed many a time during the past three or four months. It consists of a rude rectangle of bright stars, with a belt of three bright stars, through the middle and hanging from this a line of fainter stars called the Sword or Dagger. The naked-eye stars of the constellation are shown in the accompanying cut. On a clear night anyone with good eyesight can see that the middle star in the sword is surrounded by a nebulous haze. An opera-glass shows this very plainly and with a small telescope what seems to the eye to be a single star is broken up into a group of several stars surrounded by a bluish green haze.



THE CONSTELLATION OF ORION.

This nebula appears to have been first seen by Cysat of Luzerne in 1618. Galileo failed to see it, although he made a map of this region of Orion containing 400 stars. The earliest drawing of the nebula is given by Huyghens in his *Systema Saturnium* published in 1659. Since that time this object has been more studied than perhaps any other in the sky. The wonderful details of its structure have led many observers to attempt to depict them. Numerous drawings have been published and have been carefully compared, to see if they would give any evidence of change in the form or details of the nebula. It is very difficult, however, to make an accurate drawing, especially where many of the details are almost at the limit of vision. If one compares the drawings made by different observers at about the same time he will hardly be able to recognize them as pictures of the same object. Professor E. S. Holden in his "Monograph on the Central parts of the Nebula of Orion" published as an appendix to the Washington Observations, 1878, has given reproductions of a large number of drawings by the most eminent astronomers of the past two centuries. These vary very greatly, and although Professor Holden thinks that there is evidence of some changes in the brightness of certain parts of the nebula, the great differences are the result of personality, incorrect drawing and differing instruments, and on this account grave doubts are thrown upon conclusions drawn from them.

Photography, although it has some faults peculiar to itself, gives a means of depicting the delicate details of nebulæ far more accurately than can be expected of the best drawings. It is free from personal error, except as the latter may affect the development of the sensitive plate, and photographs taken with very different telescopes, different sensitive plates, and developed by different methods show essentially the same details. The one defect is that the contrast between bright and faint portions is heightened, so that, if there are very great differences in brightness, the extremes cannot be shown upon the same photograph. This defect is quite marked in all the photographs which we have seen of the nebula of Orion; when the central, bright part is shown the outer portions are lost, and *vice versa*, when the exposure and development are sufficient to show the very faint parts the details of the center are lost because of over-exposure and over-development.

The first photograph of the Orion Nebula, and this was the first of any nebula, was taken by Dr. Henry Draper, at Hastings, N. Y., on the night of Sept. 30, 1880. It was taken with a refracting telescope of 11 inches aperture, the exposure lasting fifty-one minutes. It showed about what may be seen in the first photograph presented in the frontispiece of this number of POPULAR ASTRONOMY. In March of the following year Dr. Draper secured another photograph with an exposure of 104 minutes, showing stars down nearly to the fifteenth magnitude.

In 1882 and 1883 Mr. Common, in England, obtained a number of excellent photographs of the nebula with a 37-inch reflecting telescope, for which he was awarded the Medal of the Royal Astronomical Society. Quite recently he has obtained still better results with his new 5-foot reflector.

The best photographs which have been reproduced for publication thus far, are those obtained by Mr. Isaac Roberts, in England, with a 20-inch reflector. A series of nine photographs, with exposures varying from 5 seconds to 3½ hours duration, was reproduced by photogravure in *Knowledge*, May 1, 1889. Mr. Roberts' reflector has a comparatively short focal length, only 100 inches, so that the angular aperture is large and the light is concentrated upon a small image. This makes the instrument very effective for the particular work for which it was designed.

The photographs, which we present in the frontispiece of this number, were taken with a refracting telescope of 8¼-inches aperture, and 109 inches focal length. It was originally designed as a visual telescope, and a third lens was afterward added to the objective, correcting it for the photographic rays of light. A guiding telescope, of 5 inches aperture and the same focal length with the larger one, is rigidly attached to the latter, and the observer, while the exposure is being made, looks through this at some star, in or near the object to be photographed. This star is kept continually at the intersection of two cross wires of coarse spider web. Whenever it begins to deviate from this position, either from irregularities in the driving apparatus or the constantly changing atmospheric refraction, the observer at once brings it back by means of adjusting screws which move the two telescopes together. In this way the exposure can be prolonged indefinitely, *i. e.*, while the object is above the horizon. For objects north of the equator too, the construction of the mounting is such that the telescope cannot pass the meridian without being changed in declination.

Our photograph No. 1 was taken on the night of Nov. 6, 1893. The exposure lasted one hour, but the plate was not fully developed so that it shows no more of the nebula than other plates which we have given exposures of only 15 minutes. In order to give the reader an idea of the scale of the picture let me say that it takes in the row of three naked eye stars in the Sword of Orion. The group of stars at the top of the picture form one naked eye star ι, the group at the bottom another *c*, and the nebula with its involved stars the middle one δ. All the pictures are inverted, so as to give the telescopic view.

The first thing which catches the eye of an observer on looking through a telescope at this nebula is a group of four bright stars, commonly called the Trapezium, in its midst. In the photograph these stars are so over-exposed that they run together and form a single bright patch in the nebula. The row of three bright stars, just above and to the right of the brightest part of the nebula, will be easily recognized by those familiar with its telescopic appearance. Another conspicuous feature is the great dark opening in the right side, likened by Herschel, I think it was, to a fish's mouth. The brightest part of the nebula is approximately square except for the opening on the right side, and is broken up into cloud-like patches. Outside of this the tendency of the nebulosity is toward the form of streamers curving away from the central portion. But the reader can see these details better than I can describe them, and I must not take up the space.

Photograph No. 2 was taken on the night of January 25, 1892, with an exposure of two hours. In this the details of the brightest portion are lost, although the original negative shows most of them, and the extent of nebulosity is greatly increased. Details are brought out and given definite form which can be traced with difficulty in a telescopic view. It is hard to say which are the most interesting, the great double curves up to the right, the mass of irregular curves to the left, or the detail about the star just below and to the right of the central portion. Traces of nebulosity appear about the group ι at the bottom of the picture.

Photograph No. 3 was taken on the nights of Feb. 5 and 6 of this year, the total exposure being 9 hours. This brings out a very great extension of the nebula, so that the upper and lower groups of stars are involved. There can be no doubt, I think, that the two nebulæ around ϑ and ι are parts of one greater nebula. The curious convolutions of the upper portions of the nebula remind one very much of the smoke rising from a great conflagration. The dark notch in the upper part of the lower nebula and the lanes through it are very strange and interesting. At first sight the appearance of this nebula seems quite different from that of the great nebula, but on closer inspection the characteristic curves and bright patches of the other will be recognized.

Now I know that some readers have been asking what the straight lines are which run out of the bright stars. Let me say that once during the exposure the driving clock ran down and before the plate could be covered the stars had trailed part way across the plate, the bright ones only having sufficient intensity to leave their mark. The ring around the brightest star near the top of the plate was produced by the reflection of the light which penetrated through the film to the back of the sensitive plate. Although we used a nonhalation or double coated plate, the light of that one star was sufficient in the long exposure of 9 hours to penetrate through the film.

What is the nebula? How far is it from us? Does it move? Does it change in form? These are questions which the reader would naturally like to have answered and no one would more gladly answer them definitely than the writer, if he could.

The visible spectrum of the Orion nebula consists of four bright lines, one in the violet which coincides with one of the four prominent hydrogen lines in the solar spectrum, and three in the portion of the spectrum where the green and blue colors meet. One of these latter is in the place of a hydrogen line, while the others do not coincide exactly with the lines of any known substance, although they are very close to those of magnesium. Mr. W. W. Campbell has recently, with the powerful spectroscope of the great Lick telescope, been able to see and to photograph several other bright lines and also a faint continuous background in the spectrum of this nebula. So far as we are able to draw any conclusion from this evidence, it would seem that the nebula is principally gaseous, a mixture of hydrogen and other gases unknown as yet, in a glowing state. The faint continuous spectrum would seem to imply that there is also some solid matter there. It is not safe, however, to infer that, under the unknown conditions which exist in the depths of space, the different substances will give the same spectra that they do in our laboratories.

As to the distance of the nebula nothing is known except that it is not measurably nearer or more distant than the stars. No measures have shown as yet any motion of the nebula with reference to the stars, and the latter seem to be stationary and immeasurably distant from us.

We can see from this that the dimensions of the nebula must be enormous, beyond our powers of conception, and that it is not strange that the changes, which must be going on, cannot be detected from year to year to year.

There is food for the imagination here and room for question to satisfy the most speculative minds. To what end is this vast expanse of fiery mist? What mighty and mysterious forces are at play? Are those gigantic outer wreaths moving outward or are they falling in toward the center? Is this the beginning of worlds or is it the end?

Directions in the Sky.—Young observers are sometimes troubled about directions in the sky. In the celestial sphere the points of compass have, of necessity, a meaning which may seem different from that which we attribute to them on the Earth. *North* always means toward the north pole; *south*, from it; *west*, in the direction of diurnal motion; *east*, in the opposite direction.

SHOOTING STARS.

How to Observe Them and What They Teach Us.

W. F. DENNING.

IX. Fireballs.

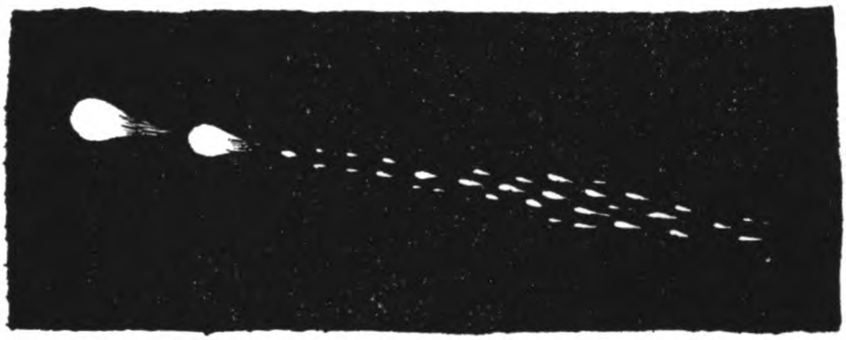
There is no doubt that Fireballs constitute an extremely attractive and striking class of meteoric phenomena. It is a pity that the times of their individual apparitions cannot be definitely predicted, for a remarkable degree of interest would then centre round them and the public would witness their outbursts with intense pleasure. Unfortunately, however, these brilliant objects come suddenly and unannounced, for the conditions under which they appear do not permit their times of appearance to be exactly foretold. In a general way it is quite possible to indicate a night (as for example August 10) when large meteors will certainly come into view, but the precise minute or position of appearance of the individual objects cannot be predicted.

Fireballs exhibit great variety in their visible features. Some move slowly, others are rapid; some pass silently athwart the sky, others produce violent detonations; some traverse their courses in the form of a pear-shaped ball of fire leaving no luminous track behind, others either throw off trains of sparks or generate the enduring phosphorescent streaks so characteristic of meteors which move swiftly. In color, too, and in visible length of path and direction of motion, great differences are met with, in fact it may be safely said that no two fireballs are precisely similar in all their observed features. Sometimes they are brighter than the Moon and abruptly light up the sky and landscape in a manner which cannot fail to startle the beholder. Nearly every one sees, at one time or another, a brilliant example of these phenomena and the effect is generally so sensational as to leave an indelible impression on the memory.

It is highly probable that fireballs are practically identical with ordinary shooting stars, the distinction being only one of size. Fireballs represent the largest class of meteors and probably have a community of origin with the tiniest shooting stars seen in powerful telescopes. Showers like the Perseids of August display the most brilliant fireballs as well as the faintest shooting stars, and they appear to be indiscriminately mixed together though there is certainly a great preponderance of the latter class. That they all belong to the same parent stream is manifest from their having a common radiant point.

The average height at which fireballs become extinct is about

30 miles, but in some instances it is considerably less than this, and not infrequently below 15 miles. Many instances might be adduced to show that the elevation at disappearance is sometimes as low as 5 or 10 miles, but the material of these bodies is generally exhausted before it is enabled to penetrate so deeply as this into our atmosphere. One of the largest fireballs of recent years appeared over England on Jan. 25, 1894 and burst, with a report like thunder, at a height of 16 miles. Just before its disappearance it exhibited a double nucleus and created a brilliant effect which can scarcely be described.



FIREBALLS OF JANUARY 25, 1894.

It is most unsatisfactory to reflect that though fireballs form events which, if properly utilized, are capable of greatly extending our knowledge of meteoric astronomy, they are seldom observed with sufficient accuracy to enable their real paths to be exactly determined. Every year there are scores of fireballs recorded, but it is only in rare cases that an investigation affords a good result. The observers of these apparitions are generally of a very miscellaneous character and their descriptions are often contradictory and untrustworthy. A definite and reliable path can seldom be extracted from such records. Two observations alone, if made by experienced eyes, are of far greater value than a mass of observations of an imperfect and erroneous nature. No doubt the sudden and unexpected way in which these bodies appear tends to confuse the ordinary spectator, and he retains a very hazy impression as to their paths and durations of visibility. With regular observers the case is different, and valuable details are sometimes to be gleaned from a discussion of their materials.

Fireballs are sometimes so astonishingly brilliant as to be visible at noonday in the presence of bright sunshine. A daylight meteor of this character was visible from many parts of England on Febuary 8, 1894. It appeared about 30 minutes after noon and fell from a height of 80 to 20 miles.

There are certain dates in the year when large meteors are particularly numerous and it is desirable to ascertain whether this undue frequency is not in certain cases attributable to active radiants which have hitherto escaped prominent notice. Some years ago I compared many hundreds of observations of fireballs, and the following dates were those of greatest frequency.

January 2, 21, 31; Febuary 3, 7, 10; March 1, 2, 4; April 11-12, 19-20; May 2, 4, 15, 31; June 6-7, 22, 29-30; July 11, 20-21, 25-30; August 3, 5, 7-13, 15, 19-22; September 1-2, 6-7, 11-13, 25; October 13, 15, 17-18, 22, 24, 29; November 1-2, 4, 6-9, 11-15, 19, 27; December 8-9, 11-12, 21.

It will be seen that some of the dates correspond with the well-known showers such as Lyrids, Perseids, Orionids, Leonids, Gemenids, etc.

The following table contains the heights, etc, of some of the largest fireballs of late years, but the list is necessarily very incomplete:—

Date.	Height at Beginning	Height at Ending.	Length of Path.	Velocity; miles.	Radiant Point	Authority.
	miles	miles	miles	per sec.	α ° δ °	
1863, Dec 27	80	25	80	20	81 + 22	A. S H
1864, Aug. 8	106	52	29	29	320 — 15	A. S. H.
Dec. 8	90	30	75	58	95 + 30	A. S. H
1865, April 29	52	37	75	20	73 + 47	A S H.
Sept 24	67	38	91	23	2 + 2	A. S H.
26	107	76	200	57	69 + 25	A. S. H.
1868, Sept 5	250	85	1200	28	14 — 2	G. Von Niessl.
1869, Nov. 6	90	27	170	35	62 + 37	A. S H.
1871, Aug. 31	44	40	42	7	β Herculis	A. S H
1872, July 22	77	37	88	..	246 — 11	I H. Waller.
1873, June 17	101	20½	285	18½	247 — 19	I. G. Galle.
1874, April 10	45	18½	52	14	19 + 57	G. Von Niessl.
Aug 10	66	33	85	19	313 — 14	A. S. H.
1875, Sept. 3	75	40	35	27	311 + 52	G. L. T.
7	83	22	50	18	347 + 15	G. L. T
14	52	18	104	13	348 ± 0	G. L. T.
1876, April 9	100	20	200	25½	17 + 57	G Von Niessl.
July 26	62	27	107	26	258 — 24	A S H.
Aug. 15	69	34	130	19	310 — 10	A. S. H.
Sept. 24	58	16	45	15	285 + 35	A S. H
1877, Jan. 19	75	45	230	35	135 + 27	A. S. H.
Mar. 17	60	29	58	19	146 — 4	G. L. T
April 6	80	20	165	31	275 + 60	A. S. H.
June 14	157	27	170	42½	212 + 12	M. Greecy.
Nov. 23	95	14	185	17½	62 + 21	G L. T
1878, Mar. 25	50	22	130	33	332 — 20	A S. H.
April 2	60	15	50	14	177 + 49	G. L. T.
May 12	78	17	155	15½	214 — 7	A. S. H.
June 7	65	37	160	19	247 — 25	A S. H.
July 29	82	20	70	23	290 + 42	A. S. H.
1879, Jan. 12	40	9	124	18	133 + 19	G Von Niessl.
28	100	26	124	slow	142 + 14	D. Kirkwooo.
Feb. 21	62	6	85	21	140 + 51	A. S. H.
1886, Aug. 4	90	11	168	21	161 + 59	W. F. D.
Nov. 17	96	21	173	17½	34 + 19	W. F. D.
1887, May 8	70	14	110	18	191 — 5	W. F. D.
1888, Aug 18	78	47	46	swift	43 + 56	W. F. D.
1889, May 29	58	23	76	8½	216 — 7	D. Booth
1891, Sept. 30	54	24	56	13	14 + 7	W. F. D.
1893, April 15	99	40	158	slow	15 + 59	W. F. D.
1894, Jan. 25	89	16	160	18	331 + 55	W. F. D.

The abbreviations in the last column are as follows:— A. S. H., Professor A. S. Herschel, G. L. T., Lieut.-Col. Tupman, W. F. D., W. F. Denning.

Some of the results quoted are not very exact, but they are probably as reliable as the circumstances allow. If bodies of this character were only observed with completeness and by persons acquainted with the essential points to be recorded, then a few years would add enormously to our stock of materials. The fireballs included in the list are but a few amongst the many thousands which have appeared during the last quarter of a century. We have selected only a few drops, as it were, from a continuous and widely dispersed shower; but from the few we may perhaps fairly judge of the general character of them all.

At a future time when the science has grown more popular and the general public has become better acquainted with its requirements the exact observation of fireballs will doubtless be more often accomplished than at present. No objects come more often under the public eye or excite more interest than these, and they deservedly occupy a high position whether we regard them as popular spectacles merely or as objects capable of enhancing our knowledge when critically studied.

E. E. BARNARD'S WORK AT LICK OBSERVATORY.*

S W. BURNHAM.

During the observations of comets and stellar systems at Mt. Hamilton, Barnard found many new nebulæ some of them being of more than ordinary interest. One of these is somewhat noteworthy from its situation and history. A good many years ago, in 1859, the Italian astronomer Tempel found that the star Merope, one of the bright stars of the Pleiades, was surrounded by a large diffused nebulosity. This was so difficult to see, principally on account of its large extent as compared with the largest field of view which could be used with ordinary instruments, that many observers doubted its reality. It was subsequently shown that the failures to see it were due to not having a sufficiently large field to give the necessary contrast of nebula and sky; and its existence was verified later by photographs made at Paris, Cambridge and elsewhere, which not only showed a greater extent

* Continued from April number. This is the third of a series of articles, portions of which have already appeared in *Harper's Magazine*, August, 1893.

of this nebula, but also that there was nebulous matter enveloping all the other bright stars of the Pleiades. While looking at this region with the great telescope at Mt. Hamilton, Barnard detected a small, round and well defined nebula, so close to Merope that it was involved in the light of the star. It was very difficult to see for this reason, and on account of its faintness, and it would be overlooked with any instrument by all but the most expert observers in this line of work. It is unique with respect to its proximity to a bright star. The relative positions of the two objects were carefully measured so that any change hereafter can be detected. In the same general locality he also discovered an interesting nebula of the planetary class, comparatively few of which are known.

His long experience in all departments of the photographic art were turned to practical account at the Lick Observatory in the direction of celestial photography. He was the first to photograph the Milky Way and show the wonderful forms of its structure. This work attracted wide-spread attention, and down to the present time it has not been equaled by anyone. Many other specially interesting regions of the sky, as, for example, the Great Nebula in Andromeda, the Pleiades, and other well-known central points of interest, have been photographed by him. This work, it should be remarked, was not done with a large equatorial, or with a telescope of any kind, but with a large portrait lens, fastened to an equatorial telescope with driving-clock in order to follow the objects during the exposure. The driving-clock of the instrument is used to keep the stars at the same general point on the plate, but it is necessary to watch the finder constantly during the whole time to prevent any displacement of the images from accidental or other causes, and this was a very laborious work, since some of the exposures were continued for over five hours.

Among other specially interesting subjects photographed with the same instrument was the comet of March, 1892. This was discovered by Dr. Swift of Rochester on March 6th. It rapidly increased in brightness and became somewhat prominent in the morning sky in the early part of April. It was photographed several times with exposures varying from one to two hours, and remarkable results were obtained, showing the division of the tail into several distinct streams of cometic matter, invisible except in the photographic plate, which took place in the structure and appearance of the tail which at this time was more than twenty degrees in length. These are the most successful photographs ever taken of a comet. This was the largest comet visible in the northern hemisphere since the great comet of 1882. The motion of the object during the exposure is shown by the elongated discs of the stars.

The total eclipse of the Sun of January 1, 1889, which was visible in Northern California, was photographed very successfully with a non-photographic telescope of three inches aperture, and the pictures obtained of the corona have not been surpassed at any time. Comparatively few eclipse pictures in the last fifteen years have been very successful from either a technical or scientific point of view.

The photograph of the Great Nebula in Andromeda and the region surrounding it was from an exposure of more than four hours. This shows the complete structure of the nebula, and the myriads of stars surrounding it. The negative contains not less thar 64,000 stars, and of this number less than half a dozen are visible to the naked eye.

The visual observations at Mt. Hamilton during the four years he has been connected with it, embrace a wide range of subjects. Asteroids, nebulæ, double stars, planets, the Moon, Sun-spots, meteors, occultations, eclipses, etc., have all received a good deal of time and study. In many instances these observations will have a greater value a century hence than they have to-day.

In November, 1889, the rare phenomena occurred of an eclipse of Iapetus, the eighth satellite of Saturn, in the shadows of the Ring System of the planet, and it was carefully observed by Barnard for the purpose of determining the nature and density of the so-called dark or crape ring of Saturn. The observation established the remarkable fact, which had been long suspected but not entirely proved, that this mysterious ring discovered by Bond in 1850 is really transparent, and therefore possibly composed of minute portions of matter surrounding the planet like a dense swarm of satellites. It is not probable that these particles will ever be seen separately by any telescope. The effect in the most powerful instrument is simply that of a surface with the power to reflect a feeble amount of light. This very rare phenomenon of the eclipse of Iapetus was the first ever seen, and was witnessed by no other observer in the world.

In 1888 when the 36-inch telescope was first mounted, Mr. Alvan G. Clark discovered an exceedingly faint star within Trapezium of Orion. A good many mythical stars had been placed here by people with little experience in this kind of work; but it was long ago shown that they were purely imaginary stars, and that instruments like the 18½-inch at Chicago and the 26-inch at Washington, both of them more powerful than any used in the alleged discoveries, failed to show under the most favorable conditions the least trace of any star within the famous Trapezium. The Lick telescope revealed this star, and the writer, after having repeatedly measured its position with reference to the bright stars around it, has no hestitation in saying that no other telescope in the world can show it. In looking at this, Barnard added a still fainter star, within the Trapezium, and also detected just outside of this area, a double star so excessively faint and difficult that it could be measured on only one night during the period covered by the other measures referred to. No other double star like this is known in the heavens.

In February, 1892, a new star suddenly appeared in the constellation of Auriga, and attracted the attention of astronomers everywhere. It was readily visible to the naked eye, but soon faded, and by the last of April it could be seen only in the most powerful telescope. Its position in the evening sky prevented astronomers from longer following it, but as its decrease in light had been uniform, it seemed almost certain that it would continue down the scale of magnitudes, and pass beyond the limit of human vision forever. As soon as this region could be again examined in the early morning hours, it was found by a number of observers to have increased in magnitude, so that it was within reach of an instrument of not more than three inches aperture. When Barnard turned the great telescope upon this object, he saw at once that the previous star had become the nucleus of a small bright nebula. This wonderful change, the transformation of a star into a nebula in less than five months, and which defies all theories offered in explanation of the original outburst, has been confirmed by spectroscopic observations at Mt. Hamilton and elsewhere. The history of astronomy presents no authenticated instance of a similar transformation, where the resulting nebula has been actually visible in the telescope.

If has been already stated that from the beginning of his work with the telescope, Barnard has given special attention to the planet Jupiter. In 1890, the planet was observed by him on forty-nine nights with the 12-inch equatorial and careful measures made of all the markings on the planet. In September of that year he observed the singular phenomenon of a double transit of the first satellite across the disc of Jupiter. Projected on the face of the planet it appeared distinctly double resembling a close double star, the components being slightly unequal. This remarkable appearance has not yet been accounted for. It was probably due to a bright belt on the satellite, similar to some of those on Jupiter. The observations would imply that the satellite in its revolution about Jupiter, rotates on an axis nearly perpendicular to its orbit, as in the case of our own moon. The observations might also imply that the first Moon of Jupiter is really double, though this explanation is hardly probable.

In July, 1892, he commenced to use regularly the large telescope on one night each week, and naturally began systematic observations of the great planet. It was but a short time before the superiority of the largest telescope in the world for this work was made manifest. In due course of mail the writer received at Chicago a letter from Professor Barnard written on Saturday morning, September 10, stating that on the previous evening (Friday) at about midnight he had observed an extremely faint speck of light very close to Jupiter; that it seemed to be moving with the planet; and that he strongly suspected it was a new satellite. He said that it was so difficult with the large telescope, that he was unable to see it except by shutting out the light of the planet. The suspected star was found by the observations of the following night to be a new satellite, and on Monday morning the whole astronomical world was electrified by the announcement that Jupiter, observed more than any other planet for the past three hundred years, had a fifth moon, revolving about it in less than twelve hours, at a distance from the surface of the planet of about 70,000 miles. Since that time, Barnard has measured its position at every available opportunity to supply the data for accurately computing its orbit. He finds that its periodic time is $11^h\ 57^m\ 23^s.1$ and that its distance from the center of Jupiter is 112,500 miles. From careful observation it seems to shine with the light of a thirteenth magnitude star and is perhaps less than one hundred miles in diameter, which makes it a very minute world indeed as compared with the older moons of Jupiter. The four satellites discovered by Galileo in 1610 vary from 2100 to 3500 miles in diameter, and revolve around the planet in times varying from one and three-fourths days to nearly seventeen days. The distances of these bodies from Jupiter are from 260,000 to 1,162,000 miles. How much more interesting the new satellite is, will be obvious from these comparisons. It will always be beyond the reach of all but the largest telescopes, and can then be seen only when near its maximum distance from the primary. At the present time it has been seen by Professor

Hough with the 18½-inch telescope of the Dearborn observatory; by Professor Young and Mr. Reed with the 23-inch at Princeton; by Professor Stone with the 26-inch at the University of Virginia; and at Washington with the 26-inch refractor of the Naval Observatory.

It is hardly necessary to say that this is one of the most important astronomical discoveries of modern times. The most powerful telescopes, and the most skilled observers have been given to the study of this planet, and while the investigation of the surface has revealed new details, no one seems to have hoped to add any new moons to the four discovered by Galileo when he first turned his rude instrument on the planet nearly three hundred years ago.

Still more recently this indefatigable observer made another discovery which is characteristic of the originality and thoroughness of his methods. On the night of October 12, he discovered a new comet by photography. A photograph of the Milky Way in the constellation of the Eagle was being made, and an exposure of four hours and a half was given, and when the plate came to be examined after development, the expert photographer recognized the strange visitor by its motion on the plate during the time of exposure. On the following evening it was verified and its position determined by the micrometer in the usual manner. This is the first comet discovered by photography, and is consequently historical. Singularly enough the comet has been found to be of more than ordinary importance as it has been shown to be periodic, its revolutions round the sun being accomplished in about six years. This has suggested a new field for the discovery of comets, and it is not unlikely that hereafter many such may be found by this method.

The services of Professor Barnard in the line of original astronomical research have been recognized by scientific societies. He has been a Fellow of the Royal Astronomical Society of London, since 1887. He is also a member of the British Astronomical Association, the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and many other learned and scientific Societies. In 1889, the Honorary Degree of M. A. was conferred upon him by the University of the Pacific in recognition of his important astronomical work.

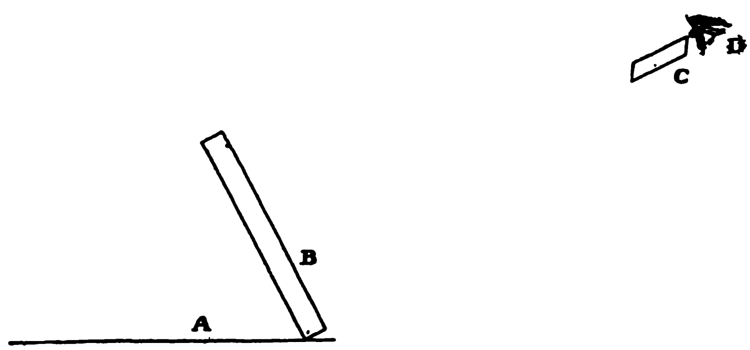
It has been the privilege of the writer to work for four years at the Lick Observatory by the side of the subject of this sketch; and he has learned by a very intimate acquaintance and friendship to have the most profound respect for the personal qualities and scientific acquirements of Professor Barnard. This article does but scant justice to either. The simple-minded nature of the man, his unselfishness, his modesty, and genial nature are most thoroughly understood and appreciated by those who know him best.

[Since the foregoing was written, Professor Barnard's Astronomical discoveries have received the highest recognition of the French Academy of Sciences by the award to him in January of the Lalande gold medal.]

TESTING OPTICAL GLASS FOR THE QUALITY OF ITS ANNEALING.

JOHN. A. BRASHEAR.

Annealing is a term used in a technical sense in reference to almost any material worked in the arts which has a crystalline structure, and which, in the process of manufacture is brought up to high temperature and then allowed to cool slowly.



As stated in one of our former articles, the perfect annealing of large discs of optical glass is a most difficult matter, and the greatest care must be taken, that, at the critical point, the lowering of the temperature shall be graduated with the greatest delicacy to produce the best results.

Annealing means in reality that the molecules shall have plenty of time given them to fall into a natural or normal condition. Just as this condition is conserved will the glass be the better for optical purposes. With small discs and plates the process is not nearly so difficult as with the larger discs.

It is fortunate that the condition of a piece of glass, as far as its annealing is concerned, is easily determined before a lens is made from it. Were it not so and the optician had to work the discs into a lens before he could know for a certainty that the glass was good or bad, many precious hours lost and final disappointment would be the result.

In the figure before us (inadvertently placed on page 293 No. 7, of this Journal,) we have the method illustrated.

A may be a plate of ordinary window glass or plate glass varnished with black varnish on the under surface, or it may be a piece of black muslin or oil cloth, one side of which has some lustre. This should be laid on a table or on the floor so that a strong light from the sky or light clouds shall fall upon it, preferably discarding any direct reflection from the Sun. This black reflecting surface is the source of our polarized light. The plate of optical glass, already polished, is set up on edge at an angle approximately as given, no exactness being required, although the nearer the polarizing angle for glass 56° + the more marked will the effect be.

A small nicol prism C, — one a quarter of an inch on the face will answer, — is now placed in front of the eye D and directed toward the glass and source of light. On rotating the nicols prism, a black cross similar to a maltese cross will appear and disappear, provided the glass is fairly well annealed. If this black cross is symmetrical in shape with relation to the shape of the disc and is faintly marked, we may rest assured we have a fairly well annealed disc, and the less marked the cross the more perfect is the annealing. So feeble is the black cross in the 23″ discs, noted in a former article, that their remains not a shadow of a doubt that the annealing in this case leaves little to be desired.

If the cross is strongly marked, but symmetrical and has no color associated with it, it still promises well, and generally a good objective can be made from it.

It sometimes happens that the cross is distorted; at other times there is no semblance to a cross and the figure is broken up into various shapes. In this case the disc or plate is poorly annealed. It may also show *color* which is fatal to good work, and the glass had better be discarded. It is not our intention to give the *rationale* of these phenomena, as they may be found in any text-book on Optics, but suffice it to say that the one satisfactory answer is this; if the molecules of the glass are in a state of strain, or in an abnormal condition, light cannot pass through it naturally or normally, and hence it is unfit for that class of objectives demanded in astronomical or physical research.

A more delicate method of testing for strains is to use a concave silvered mirror, as described in the method of testing for striæ in the March number of this journal, page 292. The plate or disc to be tested is set up in front of the mirror exactly as there described.

We now need an additional piece of apparatus in the way of a thin piece of selenite. This is mounted in a piece of cork or cemented on a plate with an opening in the plate say five millimetres diameter. This is now placed in front of an opening of the screen covering the lamp, and is placed near the center of curvature of the mirror so that the polarized beam may be returned through the glass to be tested. The lamp is placed to one side so that the returning beam may be observed by the aid of our nicols prism.

Examining this beam which has passed twice through our plate or disc of glass, we can detect very minute strains, indeed few pieces of glass will stand this delicate test without showing some molecular tension. However the first method is sufficient for all practical purposes after one learns how to "diagnose" the appearances brought out by the tests given.

CONSTELLATION STUDY.

WINSLOW UPTON.

VIII.

In this article—the last of the series—we are to consider the constellations of the fourth division of the sky, which is between 18 and 24 hours right ascension. The circumpolar groups of this division, Draco and Cepheus, were discussed in the IVth paper. The zodiacal constellations are Sagittarius, Capricornus and Aquarius.

Sagittarius. There are two prominent characteristics of this group, one independent of the figure and the other marking the position of the Archer's bow. The former is the "Milk Dipper," so called from its position near the Milky Way, and consists of four stars forming the bowl and a fifth for the handle. The dipper is inverted, when the constellation is near the meridian in northern latitudes. The star at the end of the handle, λ, is in the Milky Way and the others, φ, σ, ζ and τ are east of it, 3° to 5°

apart. The group may be found by drawing a line eastward from Antares 30°, or where this line crosses the Milky Way. The lines forming this dipper are not drawn on Poole's chart. The second characteristic is a doubly curved line of stars, running north and south in the Milky Way. The stars are μ, λ, δ, ϵ and η. 4° west of the middle star, δ, is γ, which marks the head of the arrow projecting beyond the bow. The bowl of the dipper is in the Archer's shoulder, and the only other conspicuous star of the group is π, the brightest of a little group marking the head, and situated about 8° north of the bowl. μ is near the southern solstitial point.

Capricornus. The characteristic figure of this group is a large triangle of curved sides, composed of stars which are rather faint but easily traced, and resembling a spherical triangle as it might be projected on a plane. The curvature of the northern side is towards the south or inwards, while that of the others is towards the southwest and southeast respectively, or outwards. The group lies in the relatively vacant region northeast of Sagittarius. The lines are drawn on the chart, but are partly beyond the limits of the maps in this issue of POPULAR ASTRONOMY. The northwestern, northeastern and southern vertices are marked by the stars α, δ and ω respectively, the last named the faintest of the three. In the classic figure the head of the goat is at the northwestern vertex of the triangle.

Aquarius. This group occupies a large area situated both north and east of Capricornus. Its most interesting feature is a little triangle of faint stars with a much brighter one, ζ, in the centre. This lies about half way between the eastern vertex of the triangle of Capricornus, and the southern side of the Square of Pegasus in a northeasterly direction. It forms the Water Pot; and from the southeastern side of the triangle may be traced a curved band of faint stars convex towards the east and terminating in the brilliant star Fomalhaut of the constellation Piscis Australis. The two brightest stars of Aquarius lie west of the Water Pot; α is 6° east of ζ, and β is 8° southwest of α. The stars α and β mark the shoulders of the Water Carrier. The star θ, 7° south of the line $\zeta\alpha$ is in the body, and two stars, τ and δ, a little east of the straight line joining ζ with Fomalhaut, mark the left leg of the figure. One arm is extended toward the west, north of Capricornus, in which several stars may be seen. The chart gives a different plan for tracing the stars of this constellation.

The only constellation readily visible in the middle northern latitudes south of these zodiacal groups is Piscis Australis.

Piscis Australis. This is also called Piscis Austrinus and Piscis Notius. Its chief mark is the first magnitude star Fomalhaut, which is in the mouth of the fish. The water from the Water Pot of Aquarius is represented as flowing into the fish's mouth.

The constellations north of the zodiac will be described beginning with those which adjoin the circumpolar groups.

Lyra. The first magnitude star Vega makes it easy to find this constellation, which lies east of Hercules and south of Draco. Vega with two fourth magnitude stars 2° from it forms a small nearly equilateral triangle; the northernmost, ε, is a famous quadruple star. Ordinarily one star is seen, but a specially keen eye on a favorable occasion will be able to see that it is really a double star, while the telescope shows that each of the components is double also. Two third magnitude stars, β and γ, about 6° southeast of Vega, and forming with it an elongated triangle, complete the main features of the group. Between β and γ is the ring nebula of Lyra,—a beautiful object in the telescope. A number of fainter stars east of those described can be readily traced.

Cygnus. The characteristic figure of this group is the Northern Cross, which lies east of Lyra. It is formed of five stars, four marking the extremities of the bars of the cross, which is of the Roman form, and one their intersection. The star at their intersection, γ, is a little east of the actual crossing point of the two lines $\alpha\beta$ and $\delta\varepsilon$, but the figure is, (for stellar figures), quite exact. A large number of other stars are in the area called by the name, but only one compares with these in brightness, ζ, which is about 7° southeast of ε, the line $\varepsilon\zeta$ being inclined somewhat to the short arm of the cross. The long bar of the cross forms the body and neck of the Swan, and the short arm marks the position of the wings. The latter can be more fully traced by continuing the cross arm by the stars ζ, μ, on the south and θ, ι, κ, on the north, as shown on the chart, and a group of small stars northeast of this broken line and including the star α at the top of the cross, encloses the area occupied by the extended wings. α is important because of a brightness which places it almost exactly on the arbitrary dividing line between stars of the first and those of the second magnitude.

Lacerta. This is the name given to a small area between Cygnus and Andromeda. It contains no conspicuous stars, two of the fourth magnitude marked 1 and 7 on the chart being the brightest.

Aquila and *Antinous.* This double name is given to the area east of the southern part of Hercules and of Ophiuchus. The name Aquila has come down from Ptolemy, and that of Antinous was formally assigned to the southern part of the area by Tycho Brahe, though it seems to have been used also by Ptolemy in designating this region but not as a separate constellation. The eagle is represented as resting upon the youth Antinous who was a favorite of the Roman emperor Adrian. The characteristic figure is a line of three stars about 2° apart, the middle of which is Altair or α Aquilæ, a brilliant first magnitude star. In the northwestern part of the area, where the tail of the eagle is drawn, is a third magnitude star, ζ. In the southern part of the area occupied by Antinous are three third magnitude stars, δ, θ and λ (Aquilæ), which form a right-angled triangle. The line of the three stars first named, γ, α, β, leads to θ about 8° beyond β, and the line $\delta\lambda$ lies west of θ. A different plan for tracing this group is given on the chart.

Sagitta. The line from Altair to β Cygni, the star marking the foot of the Northern Cross, intersects a line of three fourth magnitude stars about 3° apart, the western of which has a companion of equal brightness south of it. These four stars mark the Arrow.

Delphinus. East of Aquila is an easily recognized group, consisting of four stars forming a small quadrilateral and a fifth star south of the four. This is the characteristic figure of the Dolphin.

Vulpecula. This name is given to the area immediately north of Sagitta and Delphinus and south of Cygnus. There is no conspicuous star in the area, the brighest, numbered 1 on the chart, being a fourth magnitude star, and lying near the neck of the Goose which the Fox holds in his mouth.

Pegasus. The characteristic feature of this large area is the Square, composed of three third magnitude and one second magnitude stars, forming a quadrilateral whose sides are about 18° in length. It is in the eastern part of the area, and the eastern side nearly marks the equinoctial colure. The northeastern star is on the boundary between Andromeda and Pegasus and is usually known as α Andromedæ, though Bayer called it also δ Pegasi. Adjoining the northwestern star β is a third magnitude star η, which marks the position of one leg of the Winged Horse. The neck and head are traced by the three stars ζ, θ and ε, the two former in line with the southwestern star of the Square, the line running southwest, and ε bearing northwest from θ and distant about 8°.

Equuleus. This name is retained from Ptolemy for the small area between ε Pegasi and Delphinus. A few faint stars may be noted, marking the head of the Little Horse, which is the only part of the animal represented.

Scutum. This name refers to the shield of Sobieski, and the word Sobieski, Sobieskii, Sobiesii or Sobiescianum is sometimes added. The last named was that used by Hevelius who is responsible for the constellation. It occupies the small area north of Sagittarius, between Aquila and Serpens. West of λ Aquilæ may be seen six or seven faint stars somewhat scattered, which are in the area thus named.

The celestial equator passes through the constellations Aquila and Aquarius. It is about 8° south of Altair and about 1° north of α Aquarii. The ecliptic passes through the constellations in which the Sun moves in the winter months. At the winter solstice the Sun is near μ Sagittarii, and in January he journeys through the northern part of that constellation. In February he passes through Capricornus, crossing the southwestern and northern sides of the triangle marking that area. In the latter part of the same months he is about 8° south of the Water Pot of Aquarius.

The constellations of this division are best studied in the evenings of the summer months. The following are the positions of the leading stars.

APPROXIMATE POSITIONS OF THE LEADING STARS IN THE CONSTELLATIONS BETWEEN XVIII^h AND XXIV^h RIGHT ASCENSION, OMITTING CIRCUMPOLAR CONSTELLATIONS.

LYRA.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
α	0.2	18	34	+38	41
β	3.6	18	46	33	14
γ	3.2	18	55	32	34

CYGNUS.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
β	3.1	19	27	+27	45
δ	3.0	19	42	44	53
γ	2.3	20	19	39	56
α	1.5	20	38	44	55
ε	2.7	20	42	33	35
ζ	3.5	21	9	29	49

LACERTA.

No bright stars.

Aquila.

Name.	Magnitude.	Right Ascension. h	m	Declination. °	′
ζ	3.1	19	1	+ 13	43
λ	3.6	19	1	− 5	2
δ	3.5	19	20	+ 2	55
γ	2.8	19	42	+ 10	22
α	1.0	19	46	+ 8	36
β	4.0	19	50	+ 6	9
θ	3.4	20	6	− 1	8

Sagitta.

No bright stars.

Delphinus.

ε	4.1	20	28	+ 10	58
β	3.7	20	33	14	15
α	4.0	20	35	15	33
δ	4.6	20	39	14	43
γ	4.0	20	42	15	46

Vulpecula.

No bright stars.

Pegasus.

γ	3.0	0	8	+ 14	38
ε	2.4	21	39	9	25
θ	3.8	22	5	5	42
ζ	3.6	22	36	10	18
η	3.1	22	38	29	42
β	2.6	22	59	27	32
α	2.6	23	0	14	40

Equuleus.

No bright stars.

Scutum.

No bright stars.

Sagittarius.

γ	3.0	17	59	− 30	25
μ	4.1	18	8	− 21	5
η	3.0	18	11	− 36	48
δ	2.8	18	14	− 29	53
ε	2.1	18	17	− 34	26
λ	3.1	18	22	− 25	28
φ	3.3	18	39	− 27	6
σ	2.3	18	49	− 26	26
ζ	2.9	18	56	− 30	1
τ	3.5	19	1	− 27	49
π	3.1	19	4	− 21	11

Capricornus.

α	3.8	20	12	− 12	52
β	3.4	20	15	− 15	7
ψ	4.3	20	40	− 25	38
ω	4.4	20	46	− 27	18
θ	4.3	21	0	− 17	38
ζ	3.8	21	21	− 22	51
γ	3.8	21	34	− 17	7
δ	3.0	21	42	− 16	35

AQUARIUS.

Name.	Magnitude.	Right Ascension.		Declination.	
		h	m	°	′
β	3.1	21	26	− 6	1
α	3.2	22	1	− 0	48
θ	4.3	22	12	− 8	17
ζ	3.8	22	24	− 0	32
δ	3.4	22	49	− 16	22

PISCIS AUSTRALIS.

α	1.3	22	52	− 30	9

In these articles, only casual mention has been made of constellations which cannot be well studied by observers in the United States or in similar northern latitudes. It may not be out of place however to allude more fully to the constellations of the southern hemisphere. As the early observers were in the northern hemisphere, only the constellations visible to them have the peculiar authority which dim antiquity gives. Ptolemy gives two constellations only, Ara and Corona Australis, in the southern sky. These are inaccessible to most northern observers. Bayer about 1600 A. D. added twelve, not from personal inspection but probably from records of navigators. In the 17th and 18th centuries many others were added, especially by LaCaille as the result of his own observations at the Cape of Good Hope. While the attempt was made to follow the ancient plan, the new constellations were much smaller than the old and there was no general agreement as to their adoption. Several eminent astronomers of this century have attempted to remove the discrepancies and perfect a system which shall meet with general favor. It should be remembered that while the need of such revision is quite apparent to the student of the skies, the use of the constellations is of such minor importance in the science of astronomy that relatively little interest is taken in the subject, which is so largely of antiquarian value merely. The slow process of "gradual consent" however tends to the acceptance of the groupings of Ptolemy, Bayer and La Caille with few alterations, and to the rejection of nearly all of those suggested by other observers. Even thus, the system is not satisfactory, but there are no difficulties in it which are not inherent in the whole subject of the constellations, formed as they are on the capricious plan of the ancients.

It is not intended to offer any detailed description of the southern constellations, but it may be well to close the subject by giving a simple list of those which are generally accepted. The following table therefore contains their names. The order is from 35° south declination towards the south pole and the groups are given in the four divisions adopted in these articles. The list may be regarded as an extension of the table given on page 59 of this volume of POPULAR ASTRONOMY.

CONSTELLATIONS SOUTH OF DECLINATION —35°.

I.	II.	III.	IV
Caela Sculptoris.	Antlia Pneumatica.	Norma.	Sculptor.
Fornax.	Piscis Volans.	Ara	Grus.
Phœnix.	Chamæleon.	Circinus.	Microscopium.
Equus Pictoris.	(The larger part of this division is occupied by Argo Navis.)	Crux.	Corona Australis.
Horologium.		Triangulum Australe.	Indus.
Dorado.		Musca.	Telescopium.
Reticulum.		Apus.	Toucan
Mons Mensæ			Pavo.
Hydrus.			Octans.

Argelander adds Machina Electrica, Nubecula Major and Nubecula Minor to the first division of this list. Poole's hand-book omits these and also Caela Sculptoris, Norma, Microscopium and Telescopium, according to the decision of Baily in the British Association Catalogue. Gould in the Uranometria Argentina, adds Pyxis Nautica to the IId division. All of the atlases subdivide Argo into three or four parts named Carina, Puppis, Vela, and Malus. The last corresponds with Pyxis Nautica.

As stated in the first paper of this series, it is impossible to state the exact number of the constellations in the sky on account of the differences in the southern sky. Adopting the list as here given, the total number is 85, one of which, Argo, is in four subdivisions. The number given by various writers, based on the work of different astronomers would be upwards of a hundred.*

THE PLEIADES.

WM. W. PAYNE.

As a group of stars the Pleiades has attracted more attention, in ancient or in modern times, than any other cluster known to Astronomy. When above the horizon the group is easily seen by the naked eye, because of its definite outline and its bright and beautiful light. Long ago the sacred writer said of it: "Canst thou bind the sweet influences of the Pleiades?" Whatever that

* See Chambers Astronomy, ed. 1890, III, chap. VII.

PLATE XXII.

THE PLEIADES NEBULA AND TRAIL OF ASTEROID
No. 203 POMPEJA.

**From a Photograph by H. C. Wilson at Goodsell Observatory
Jan. 30, 1894. Exposure 4 hours.**

may mean, in fact or figure, it certainly can not be less than the mystic reveries of those ancient untutored races who saw in them the seven benificent sky-spirits of the Vedas and the Zendavesta, and the abode of Diety himself, became the center of the universe. The time of the Pleiades was the beginning of the year for some primitive peoples, for others, the midnight culmination of the group was the sign for great feasts and royal mercy and favor for every petitioner. Even now savage Australian tribes dance in honor of the "Seven Stars" because they are good to the black fellows.* They are called "the hoeing stars of South Africa and their last visible rising after sunset is, and has been, celebrated with rejoicing all over the southern hemisphere as betokening the waking-up to agricultural activity." The influence of the Pleiades has been wide-spread and unique in all time, and modern science has not yet set a limit to the wonders of their starry realm.

At the present time six stars of the group are easily seen by the naked eye. Their names are: Atlas, Alcyone, Merope, Maia, Taygeta and Electra. By referring to the accompanying plate these and others less bright may be readily identified. The two bright stars on the left hand side are Pleione and Atlas. Pleione is above Atlas and they are midway in the plate from top to bottom. Alcyone is in the middle of the plate with three little stars on the left and surrounded with a faint nebulous halo. The wonderful Merope is next and a little below. It looks somewhat like the nucleus of a telescopic comet with the tail pointing downward and to the right. The star and the nebula bear the same name and are wonderful objects. Notice the numerous parallel channels in that vast nebulous mass. Maia is next above forming nearly a right-angled triangle with Alcyone and Merope. It is surrounded by a nebulous halo. A little to the right and above is Taygeta. The sixth bright star, Electra, is on the right side of the plate about midway from top to bottom. It has a nebulous streak from it to the left. Stronger eyes will see five more stars in the group. Pleione is one, the two stars by the one name, Asterope, looking as one just above Maia make two usually harder to see by the unaided eye. The third is Celæno nearly midway between Taygeta and Electra, and the fourth and fifth, not especially named, are seen respectively at the bottom and the top of the plate. Alcyone is a third magnitude in brightness, Electra and Maia are about 3.8 magnitude, Maia is 4th, Merope and Taygeta

* Clute's System of the Stars, p. 221.

are not so bright as Maia by respectively a quarter and a half magnitude and Celæno is a 7th magnitude.

The word Pleiades is from the Geeek, meaning full or complete, so that it is not certain that the name limits the number of stars visible to the naked eye in ancient times, although the number seven is frequently applied to the group in such records. However it seems probable that seven stars could be as easily seen in the past as the six that are now commonly visible. Professor Pickering suggests the probable explanation from a study of its spectrum that Pleione is the missing Pleiad, as its variable character might account for its fall to 6.2 magnitude. The record of naked-eye observations on this group of stars is an instructive one. Mœstlin in the time of Kepler saw 14 and mapped 11 with surprising accuracy. This was before the time of the telescope. Miss Airy of England has marked the places of 12. Carrington and Denning have counted 14, and Carl von Littrow spoke o seeing 16, and that 11 were frequently perceived.

An opera glass helps the eye amazingly in the study of the group in regard to color and number. Nearly one hundred stars come out at once on the astonished gaze, 25 of which are of the 7th magnitude or brighter, with many others less bright, and yet distinct enough to count with certainty.

In a region about Alcyone covering an area of 135′ by 90′, M. Wolf, in 1876, catalogued at the Paris Observatory, 625 stars to the fourteenth magnitude. M.M. Henry's sensitive plates showed in a smaller space 1,421 in 1885, and by four hours exposure in 1887 the same space revealed the astonishing number of of 2,326, including stars undoubtedly as small as the sixteenth magnitude. The meaning of this statement may be more fully realized when we remember that the sharpest eye unaided can never see well, at one time, more than 2,000 or 3,000 stars. Before the time of telescopes the total number of stars that the ancient observers could see well enough for record was 1,100. The marvelous thing in the count on the Henry photograph is the fact that 2° 15′ by about 1° 30′ of the space occupied by the Pleiades' group contains stars enough to fill the whole sky, if the 2,326 were brought near enough to us and sown broad-cast in the sky as the lucid stars now appear.

The accompanying plate covers a little smaller area than the Henry photograph just referred to, and our reproduction from the original negative has occasioned the loss of many of the stars plainly shown in making positives or pictures of any kind from the original photograph.

Another useful line of work on the Pleiades group is the measurement of the distances and positions of all the principal stars from the central one, Alcyone. This has been very carefully done three or four times during the last fifty years, so as to obtain data for the study of the relative motions of these stars in order to learn something about the physical constitution of the group. Dr. Elkin of the Yale Observatory has also recently done some work of a similar kind by the aid of a fine heliometer, which is sometimes called a survey of the Pleiades by triangulation. His results are useful in getting the exact time of the occultation of stars in the group by the Moon as she moves rapidly through it, by knowing the exact place of each star so occulted.

The most surprising advance in our knowledge of the Pleiades is the discovery of vast nebulous masses scattered over a large portion of the area of this cluster. If we except some earlier accounts that seem doubtful, the first observer that called attention to nebulous matter in the Pleiades was Tempel, an Italian astronomer, in the year 1859. His drawing is found in No 5 of the publications of the Milan Observatory, and represents a hazy, comet-like mass surrounding Merope and extending southward from it to the distance of half a degee. In 1882 Mr. E. E. Barnard then of Nashville, Tennessee, observed this nebula with a small telescope and made a drawing of it which was published in No. 3 of the *Sidereal Messenger* of that year. Quite generally, however, astronomers were in doubt in regard to the existence of this nebula, some claiming that search for it with first class instruments had been fruitless, while others maintained that its extreme faintness made its form and extent very uncertain. In 1886 the Henry brothers of Paris photographed the Pleiades cluster showing plainly traces of the nebula that could not be mistaken.

In the years immediately following the study of the quality of photographic plates was vigorously pushed forward until in the years 1888 and 1889 the highly sensitive film came into use, after which it became possible to get by the aid of such plates most wonderful details in nebular structure never before dreamed of. The strange and complex back-ground of this cluster as seen in our picture is a good example of the progress in astronomical knowledge, which has been made by the aid of photography in many directions.

A few years ago the best telescopes visually gave only hints of what we now photograph easily with small instruments. In this cluster the stars Alcyone, Merope, Maia and Electra are all involved in this vast nebulous mass. Alcyone seems to be separated from the others except by a branch from its surrounding nebula that makes a crooked path to the main nebula, involving the other three stars, and which can be traced right through that nebula, as a line of light, to the star Electra. Another faint line of light may be traced through three stars above Alcyone which is nearly parallel to the streak just mentioned. Other similar features can be seen on the original negative but mention of them here is not necessary in order to give the reader a good general idea of the beauty and excellence of photographs that can be made at the present time with instruments adapted to such kind of work.

As we close this description of the Pleiades, we must call attention to the little planet trail of Pompeja, asteroid No. 203, which will easily be found near the right hand lower corner of the plate. Its place is three quarters of an inch from the bottom and about one-fourth of an inch inward from the right hand side. The trail is about one-sixteenth of an inch long, and although rather faint, when once seen, it will afterwards be recognized at a glance. It ought also to be added that the negative from which this plate was made also contained the trail of another asteroid, which was detected on it by the careful scrutiny of Dr. Wilson of Goodsell Observatory. The last named asteroid proved to be a new one, so Dr. Wilson has been credited with the discovery of it. Its place can not be shown on this plate because it is not large enough.

VARIABLE STARS.

J. A. PARKHURST.

VIII.

The current literature of variable stars indicates that interest in the subject is general and increasing. This interest is not diminished by the fact that a prize of $200 has been offered through the medium of the *Astronomical Journal* for the best series of determinations of maxima and minima of variables, made during the two years ending 1895, March 31. The judges who will make the award are Asaph Hall of the U. S. Naval Observatory, S. C. Chandler, of Cambridge, Mass., and Lewis Boss, of the Dudley Observatory, Albany, N. Y.

Journal of the British Astronomical Association.

In No. 2 of Vol. IV. Mr. C. E. Peek of Rousdon Observatory has an article on the long-period variables 4511 T Ursæ Majoris, and 7779 S Cephei, which have been continuously watched at that Observatory since 1886. For T Ursæ Majoris 10 maxima and 10 minima are given. The period adopted is 255.5 days, the deviations from the mean averaging 17 days for the maxima and 16 for the minima. The magnitudes at maximum range from 5.5 to 8.0, at minimum from 12.3 to 13.6.

For S Cephei 6 maxima and 5 minima are given. The mean period is 488 days (Chandler's Second Catalogue gives 484 days), the deviations therefrom averaging 32 days for the maxima and 31 days for the minima. The magnitudes at maximum ranged from 8.0 to 9.7, and at minimum from 11.5 to 13.7 "with a tendency to become fainter at successive minima." The magnitudes are on the Harvard College photometric scale.—

Astronomical Journal.

Three numbers of Vol. XIV have appeared during March and April. Of the 25 articles in these three numbers, 6 are on variable stars.

In No. 313 Dr. L. De Ball of the Von Kuffner Observatory, Vienna, gives details of a maximum of the new variable 1805 V Orionis, occurring near the middle of February, 1891. In No. 315 P. S. Yendell describes his observations of this star during the past winter, showing a maximum of 8.4 magnitude, 1894 Jan. 13. By comparison with De Ball's observations Mr. Yendell deduces a period of 267 days. No minimum of this star has been observed. I was able to follow it till April 5 when it had fallen to about the 12th magnitude. After that date it was too faint to be seen so near the sun. It will be visible in the morning at its next maximum which will probably occur in October of this year, and in the evening at the following minimum which may be expected about 1895, March 1.

In No. 313 Mr. A. W. Roberts, of Lovedale, South Africa, describes his observations of two new short period variables; the first in R. A. $10^h\ 28^m\ 29^s$, Decl. $-57°\ 51'$, having a period of 3.6 days and a range from 7.8 to 8.6 magnitude; the second in R. A. $15^h\ 56^m$, Decl. $-62°\ 31'$ with a period of 2.5 days and varying from 7.7 to 8.7 magnitude.

In No. 314 Mr. Yendell communicates his observed maxima and minima of seven short period variables for 1893, 316 observations yielding 76 maxima and 55 minima.

There are quite a number of variables of this class with periods from 4 to 12 days and light variations of about one magnitude. They are well adapted to the observer who has a field glass and sharp eyes, One of the best for the beginner is β Lyræ which varies from 3.4 to 4.5 magnitude in 12.9 days. It is coming into good position for evening observation and should be compared with the neighboring stars every clear evening. Another good star of this class is 7149 S Sagittæ, which varies from 5.6 to 6.4 magnitude in 8.4 days. It is in R. A. $19^h 50^m.6$, Decl. + 16° 19′ (1880). It is marked 10 in Proctor's Atlas, and can readily be recognized if the following stars are charted—

Star	R. A.		Decl.		Mag.	Star	R. A.		Decl.		Mag.
	h	m	°	′			h	m	°	′	
α	19	34.7	+17	44	4.3	γ	19	53.4	+19	10	3.7
β		35.7	17	12	4.4	13		54.6	17	11	5 5
δ		42.0	18	14	3.7	14		58.0	15	42	5.3
ζ		43.7	18	51	5.0	15		58.7	16	45	6.0
S		50.6	16	19		η		59.8	19	39	5.4
11		52.3	16	29	5 3						

If several observers with field glasses would practice on these two stars they might soon be prepared to do valuable work.

In No. 314 Mr. Henry M. Parkhurst publishes maxima and minima and the individual observations of 16 long-period variables. These observations were made with his photometric appliances and the magnitudes expressed on his photometric scale.

Astronomische Nachrichten.

Three interesting articles have appeared lately concerning the new variable T Andromedæ, R. A. $0^h 14^m.6$, Decl. + 26° 20′.3 (1855), discovered by Rev. Thos. D. Anderson of Edinburgh. In No. 3213 Professor E. C. Pickering gives measures from the Harvard photographs from 1890, Dec. 29, to 1894, Jan. 2. He deduces a period of 281 days with the photographic magnitudes 9.0 at maximum and 14.5 at minimum (corresponding to 7.5 and 13.0 on the visual scale), and predicts a maximum 1894, March 30. Dr. Ernst Hartwig has a note in the same issue regarding this star, deducing for it a period of 74.4 days and predicting a maximum 1894, March 10. He differs with Professor Pickering by giving an observed magnitude of 8.2, 1894, Dec. 28, only 5 days before Professor Pickering's measure of 12.3 from the photograph, equivalent to about 10.8 visual magnitude.

In No. 3223 Professor Porro of Turin makes a contribution to the subject by giving his observations made in Dec., 1893, and Feb. and March, 1894. For 1893, Dec. 28, he assigns to the variable a magnitude less than 12 (visual). He considers Pickering's period more probable than Hartwig's.

Dr. Chandler suggests as an explanation of the discordant estimates, that the star may be of the U Geminorum type, rising suddenly to a maximum, but this would hardly explain the difference of 4 magnitudes in the estimates of Hartwig and Porro on the same night, 1893, Dec. 28. The simplest hypothesis would be that one or the other erred in identifying the variable. This emphasizes the caution especially needed in beginning this work —*be careful of your identifications.* This star is just coming out of the morning twilight, so that the next two or three months will settle its period. It has been observed here since March 15.

In the same number of the *Nachrichten* Professor Pickering gives a series of measures of 7120 χ Cygni, made with the photometer attached to the 15-inch equatorial at Harvard. The observations are very accordant, the average difference between the observed brightness and that derived from a smoothed light curve being 0.08 of a magnitude. Professor Pickering also mentions the discovery of six variables in the cluster 47 Tucanæ, in R. A. $0^h\ 20^m$, Decl. $-\ 72°\ 40'$, from photographs taken at Arequipa, Peru.

SUGGESTIONS FOR SUMMER WORK.

These are in order now, as Popular Astronomy is not published in July and August. The following stars from the list that have been charted will be suitable for observation, with the apertures given, in June. In many cases a larger aperture will be better in June or will be necessary in order to follow the variable during July and August.

Two Inches Aperture.—U Cephei, S and T Persei, R Lyncis, S Boötis, S Draconis, R Aurigæ, R T Cygni.

Three Inches Aperture.—S and T Ursæ Majoris, S and U Virginis, V Boötis, V Coronæ, S Cephei.

Four Inches Aperture.—R Ursæ Majoris, V and W Virginis.

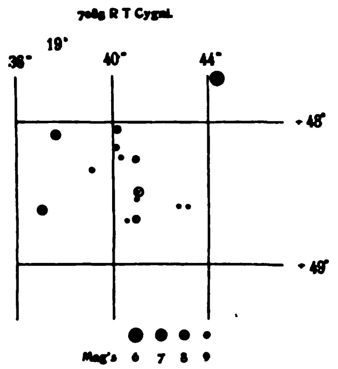
Five Inches Aperture.—R Draconis, U Boötis.

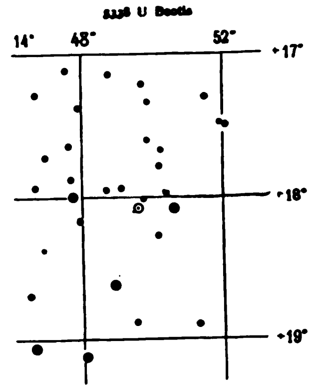
Six Inches Aperture.—W Leonis (?), R Comæ, R Camelopardalis, S Cygni.

REPORTS.

Mr. W. Dearden of Trinidad, Colo., has been watching 2815 U Geminorum, since its maximum in March, with his 9½-inch reflector. He finds it constant in light, about 4 steps fainter than the companion star *l* given in the May number.

The expected appearance of 3890 W Leonis has been watched for by Mr. Dearden and myself without success. My last observation was 1894, May 7, when the variable was not visible, and therefore was less than the 12th magnitude.





The following variables are charted this month:

No.	Star.	Place for 1900. R. A. h m s	Decl. ° ′	Redness	Magnitude. Max.	Min.	Period days.
5338	U Boötis	14 49 42	+ 18 6.0	2.7	9.1 — 9.3	12 — 13.6	173.8
7085	R T Cygni	19 40 50	+ 48 31.9	—	7	11	191

R T Cygni was discovered by Pickering in 1890. Its period is not yet well established. It will reach a maximum probably in June. It was about the 9th magnitude May 6. The 6th magnitude star in the upper right hand corner of the chart will aid in picking up the field which is 3½° north of the 3rd magnitude star δ Cygni.

U Boötis is placed 10° too far north on Proctor's Atlas, fourth edition.

The elements of 3890 W Leonis given in the May number page 401 should read:

1872 Feb. 12 + 394.3 E.

MARENGO, Ill., 1894, May 8.

The soul of man was made to wake the skies;
Delightful outlet of her prison *here!*
*   *   *   *

What involution! what extent! what swarms
Of World's that laugh at Earth! immensely great!
Immensely distant from each others spheres!

YOUNG'S NIGHT THOUGHTS.

PLANET NOTES FOR JULY AND AUGUST.

H C. WILSON.

Mercury, having been visible in the evening during the last days in June, will in July pass between us and the Sun, being hidden by the rays of the latter during the greater part of the month. He will be at inferior conjunction July 20 at 4^h 28^m P. M. central time. On Poole Bros. map in this number the apparent course of Mercury is shown for the next four months. He will be visible to the eye, however, only during the latter half of June in the evening and the first half of August in the morning.

Venus is slowly receding from us and moving around behind the Sun. Her disc will be 0.76 illuminated July 1 and 0.92 August 30. Venus will pass by Jupiter on the morning of July 20, the nearest approach of the two planets to each other occurring at about 2^h 30^m A. M. On the morning of July 28 at 6^h 13^m Venus will pass very close to the third magnitude star μ Geminorum, the difference of declination of the two bodies at the time of conjunction being only 3′. August 8 at 7^h 45^m A. M. Venus will pass 9′ to the south of another third magnitude star, δ Geminorum. Venus will be in conjunction with the Moon July 30 at 1^h 34^m A. M. and August 28 at 7^h 23^m P. M.

Mars will come into good position for observations after midnight by the first of August, and it is to be hoped that observers will begin early to study the markings on the surface of the planet. It is not necessary to have a great telescope, in order to see them to good advantage. In fact there are some good observers who believe that planetary details can be seen better with small than with large telescopes. We do not subscribe to this belief, but do say that the difference in favor of the large telescope is not so great as to entirely discourage the possessor of a good small one from attempting to add to our knowledge of the planetary markings.

Jupiter and *Neptune* are coming around as morning planets but will not be in good position for observation during the summer. As already noted, Jupiter will be in conjunction with Venus, 51′ north of the latter, on the morning of July 20. Neptune will be still closer to Venus, only 9′ north, July 11, 11^h 54^m P. M.

Saturn will be visible in the early evening but will be pretty low in the west by the time twilight is over. Saturn and the Moon will be in conjunction July 9 at 9^h 11^m P. M. and August 6, 7^h 30^m A. M.

Uranus is making the turn of the loop in his apparent course among the stars and will be almost stationary during July. In August he will move eastward toward the star α Libræ. Uranus will be in conjunction with the Moon July 11 and August 7.

Planet Tables for July and August.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits h m	Sets h m.
July 5......	8 23.4	+16 59	6 16 A. M.	1 28.2 P. M.	8 41 P. M.
15......	8 11.0	+15 25	5 30 "	12 36.5 "	7 43 "
25......	7 44.8	+16 30	4 18 "	11 31.2 A. M.	6 42 "
Aug. 5......	7 46.0	+18 53	3 27 "	10 49.2 "	6 11 "
15......	8 33.0	+19 04	3 33 "	10 56.7 "	6 20 "
25......	9 47.4	+15 04	4 27 "	11 31.5 "	6 36 "

Date.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			VENUS.		
July 5......	4 21.5	+19 39	2 01 A. M.	9 27.0 A. M.	4 53 A. M.
15......	5 11.0	+21 30	2 02 "	9 37.0 "	5 12 "
25......	6 01.9	+22 26	2 09 "	9 48.4 "	5 28 "
Aug. 5......	6 58.8	+22 17	2 23 "	10 02.0 "	5 41 "
15......	7 50.4	+21 02	2 41 "	10 14.1 "	5 47 "
25......	8 41.2	+18 47	3 04 "	10 25.5 "	5 47 "
			MARS.		
July 5......	0 35.0	+ 0 27	11 32 P. M.	5 37.2 A. M.	11 42 A. M.
15......	0 56.8	+ 2 34	11 06 "	5 19.5 "	11 33 "
25......	1 17.1	+ 4 28	10 40 "	5 00.6 "	11 21 "
Aug. 5......	1 37.2	+ 6 18	10 09 "	4 37.4 "	11 06 "
15......	1 52.8	+ 7 40	9 40 "	4 13.6 "	10 47 "
25......	2 05.1	+ 8 44	9 08 "	3 46.6 "	10 25 "
			JUPITER.		
July 5......	5 20.9	+22 43	2 45 A. M.	10 26.2 A. M.	6 07 P. M.
15......	5 30.4	+22 52	2 15 "	9 56.4 "	5 38 "
25......	5 39.5	+22 58	1 44 "	9 26.2 "	5 08 "
Aug. 5......	5 49.1	+23 02	1 10 "	8 52.4 "	4 35 "
15......	5 57.0	+23 04	12 38 "	8 21.1 "	4 04 "
25......	6 04.4	+23 04	12 06 "	7 49.2 "	3 32 "
			SATURN.		
July 5......	13 12.5	− 4 57	12 33 P. M.	6 16.5 P. M.	12 00midn
15......	13 13.6	− 5 07	11 55 A. M.	5 38.3 "	11 22 P. M.
25......	13 15.3	− 5 20	11 18 "	5 00.8 "	10 43 "
Aug. 5......	13 17.8	− 5 37	10 39 "	4 20.0 "	10 01 "
15......	13 20.5	− 5 57	10 04 "	3 43.4 "	9 23 "
25......	13 23.7	− 6 18	9 29 "	3 07.3 "	8 46 "
			URANUS.		
July 5......	14 36.2	−14 52	2 37 P. M.	7 40.0 P. M.	12 43 A. M.
15......	14 35.8	−14 51	1 57 "	7 00.4 "	12 04 "
25......	14 35.8	−14 51	1 18 "	6 21.1 "	11 24 P. M.
Aug. 5......	14 36.2	−14 54	12 35 "	5 38.4 "	10 41 "
15......	14 37.0	−14 58	11 57 A. M.	4 59.7 "	10 02 "
25......	14 38.0	−15 03	11 19 "	4 21.5 "	9 24 "
			NEPTUNE.		
July 5......	4 53.0	+21 06	2 26 A. M.	9 58.5 A. M.	5 31 P. M.
15......	4 54.4	+21 08	1 47 "	9 20.6 "	4 54 "
25......	4 55.6	+21 10	1 09 "	8 42.5 "	4 16 "
Aug. 5......	4 56.8	+21 11	12 27 "	8 00.5 "	3 34 "
15......	4 57.7	+21 12	11 49 P. M.	7 21.9 "	2 55 "
25......	4 58.4	+21 13	11 10 "	6 43.3 "	2 17 "
			THE SUN.		
July 5......	6 59.3	+22 45	4 21 A. M.	12 04.4 P. M.	7 48 P. M.
15......	7 40.1	+21 28	4 30 "	12 05.7 "	7 42 "
25......	8 20.0	+19 34	4 40 "	12 06.3 "	7 33 "
Aug. 5......	9 02.9	+16 51	4 52 "	12 05.8 "	7 20 "
15......	9 40.8	+13 55	5 04 "	12 04.2 "	7 04 "
25......	10 17.8	+10 36	5 15 "	12 01.9 "	6 49 "
			THE MOON.		
July 1......	5 04.7	+27 39	2 06 A. M.	10 25.8 A. M.	6 55 P. M.
3......	7 28.0	+26 49	4 15 "	12 40.9 P. M.	8 55 "
5......	9 38.7	+17 45	7 05 "	2 43.4 "	10 04 "
7......	11 28.3	+ 4 43	9 47 "	4 24.9 "	10 48 "
9......	13 06.9	− 8 26	12 13 P. M.	5 55.2 "	11 25 "
11......	14 45.3	−19 25	2 33 "	7. 25.6 "	12 08 A. M.
13......	16 30.9	−26 31	4 50 "	9 03.0 "	1 11 "
15......	18 22.2	−28 23	6 47 "	10 46.1 "	2 46 "
17......	20 10.8	−24 42	8 09 "	12 26.5 A. M.	4 50 "
19......	21 49.9	−16 32	9 02 "	1 57.5 "	7 04 "
21......	23 20.9	− 5 34	9 39 "	3 20.4 "	9 14 "

THE MOON.

Date.		R. A.	Decl.	Rises.	Transits.	Sets.
		h m	° ′	h m	h m	h m
July	23......	0 51.4	+ 6 36	10 13 P. M.	4 42.8 A. M.	11 27 A. M.
	25......	2 31.6	+18 15	10 53 "	6 14.8 "	1 53 P. M.
	27......	4 31.7	+26 40	11 55 "	8 06.9 "	4 30 "
	30......	6 51.2	+27 59	1 54 A. M.	10 18.0 "	6 49 "
Aug.	1......	9 06.7	+20 36	4 33 "	12 25.7 P. M.	8 01 "
	3......	11 03.8	+ 7 47	7 22 "	2 14.2 "	8 49 "
	5......	12 46.8	− 6 04	9 56 "	3 49.0 "	9 29 "
	7......	14 27.1	−17 54	12 22 P. M.	5 21.2 "	10 11 "
	9......	16 12.6	−25 52	2 42 "	6 58 6 "	11 10 "
	11......	18 03.8	−28 36	4 43 "	8 41.7 "	12 40 A. M.
	13......	19 53.5	−25 42	6 11 "	10 23.1 "	2 41 "
	15......	21 34.3	−18 04	7 07 "	11 55.9 "	4 54 "
	17......	23 06.8	− 7 09	7 46 "	1 20.2 A. M.	7 07 "
	19......	0 36.9	+ 4 52	8 20 "	2 42 2 "	9 19 "
	21......	2 13.8	+16 40	8 57 "	4 11.0 "	11 41 "
	23......	4 07.2	+25 40	9 52 "	5 56.3 "	2 13 P. M.
	25......	6 19.6	+28 36	11 29 "	8 00.3 "	4 29 "
	28......	8 34.9	+23 11	2 02 A. M.	10 07.4 "	5 57 "
	30......	10 35.3	+11 18	4 52 "	12 00 0 M.	6 50 "

Phases and Aspects of the Moon.

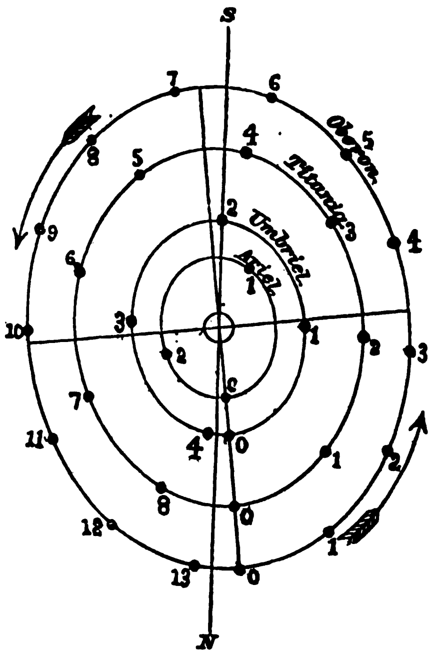
	Central Time.		
		d	h m
New Moon..	July	2	11 45 P. M.
Perigee..	"	3	7 40 A. M.
First Quarter..	"	9	4 15 P. M.
Apogee..	"	17	8 30 A. M.
Full Moon..	"	17	4 03 P. M.
Last Quarter..	"	25	3 07 P. M.
Perigee..	"	31	5 06 P. M.
New Moon..	Aug.	1	6 24 A. M.
First Quarter..	"	8	4 05 A. M.
Apogee..	"	13	1 30 P. M.
Full Moon..	"	16	7 17 A. M.
Last Quarter..	"	23	11 40 P. M.
Perigee..	"	29	12 36 A. M.
New Moon..	"	30	2 04 P. M.

Occultations Visible at Washington.

Date 1894		Star's Name.	Magnitude.	IMMERSION Washington M. T.	IMMERSION Angle f'm N p't.	EMERSION Washington M. T.	EMERSION Angle f't N p't.	Duration.
				h m	°	h m	°	h m
July	9	58 Virginis..............	7	10 29	100	11 30	312	1 01
	16	B. A. C. 6628..........	6	12 58	111	14 00	209	1 02
	18	χ Capricorni............	5½	14 58	67	16 14	227	1 16
	20	B. A. C. 7835..........	6	7 29	50	8 24	270	0 55
	23	B. A. C. 221............	6	11 34	15	12 20	279	0 46
	26	ζ Arietis..................	5	10 14	67	11 00	252	0 46
	26	B. A. C. 1055....	7	14 07	59	15 08	245	1 01
	27	χ Tauri....................	6	13 33	36	14 16	284	0 43
Aug.	13	ω Sagittarii............	5	8 42	30	9 47	300	1 05
	13	A Sagittarii............	5	10 44	61	12 12	252	1 28
	16	50 Aquarii..............	6	11 25	60	12 51	223	1 26
	18	20 Piscium..............	6	8 14	29	9 07	272	0 53
	26	47 Geminorum........	6	12 04	97	12 49	263	0 45

Elongations of the Satellites of Uranus.

[The diagram shows the apparent paths of the satellites of Uranus during the summer of 1894. The black dots with the numerals indicate the positions of the satellites at intervals of 1 day after each northern elongation The points marked 0 are those of northern elongation]



ARIEL.

		h	
July	2	10.7 P. M.	N
	5	11.2 A. M.	N
	7	11.7 P. M.	N
	10	12 2 P. M.	N
	13	12.7 A. M.	N
	15	1.2 P. M.	N
	18	1.6 A. M.	N
	20	2.1 P M.	N
	23	2.6 A. M.	N
	25	3.1 P. M.	N
	28	3.6 A. M.	N
	30	4.1 P. M.	N
Aug.	2	4.6 A. M.	N

UMBRIEL.

		h	
July	5	1.7 A. M.	N
	9	4.3 "	N
	13	7.8 "	N
	17	11.3 "	N
	21	2.8 P. M.	N
	25	6.3 "	N
	29	9 8 "	N
Aug.	3	1.2 A. M.	N

TITANIA.

		h	
July	2	6.7 P. M.	S
	7	3.2 A. M.	N
	11	11.7 "	S
	15	8.2 P. M.	N
	20	4.6 A. M.	S
	24	1.1 P. M.	N
	28	9.6 "	S
Aug.	2	6 1 A. M.	N

OBERON.

		h	
July	7	12.4 A. M.	N
	13	5.9 P. M.	S
	20	11.5 A. M.	N

OBERON, CONT.

		h	
July	27	5.0 A. M.	S
Aug.	3	10.6 P. M.	N

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

Alternate Minima.

		h
July	5	10 P. M.
	10	10 "
	15	9 "
	20	9 "
	25	9 "
	30	8 "
Aug.	4	8 "
	9	8 "
	14	7 "
	19	7 "
	24	7 "
	29	6 "

ALGOL.

Alternate Minima.

		h
July	4	2 P. M.
	10	8 A. M.
	16	2 A. M.
	21	7 P. M.
	27	1 "
Aug.	2	6 A. M.
	7	12 midn.
	13	6 P. M.
	19	11 A. M.
	25	5 "
	30	11 P. M.

λ TAURI.

Alternate Minima.

		h
July	2	4 A. M.
	10	2 "
	17	12 midn.
	25	9 P. M.
Aug.	2	7 "
	10	5 "
	18	2 "
	26	12 M.

δ LIBRÆ.

Alternate Minima.

		h
July	2	2 P. M.
	7	5 A. M.
	11	9 P. M.
	16	1 "
	21	4 A. M.
	25	8 P. M.
	30	12 M.
Aug.	4	4 A. M.
	8	7 P. M.
	13	11 A. M.
	18	3 "
	22	6 P. M.
	27	10 A. M.

U CORONÆ.

Alternate Minima.

July	2	9 P. M.
	9	7 "
	16	4 "
	23	2 "
	30	12 M.

U CORONÆ CONT.

(Alternate Minima.)

		h
Aug.	6	9 A. M.
	13	7 "
	20	5 "
	27	3 "

U OPHIUCHI.

(Every fourth Minimum)

July	1	4 P. M.
	5	1 A. M.
	8	9 P. M.
	11	6 "
	15	2 A. M.
	18	11 "
	21	7 P. M.
	25	4 A. M.
	28	12 M.
	31	9 P. M.
Aug.	4	6 A. M.
	7	2 P. M.
	10	11 "

U OPHIUCHI CONT.

(Every fourth minimum)

		h
Aug.	14	7 A. M.
	17	4 P. M.
	20	12 midn.
	24	9 A. M.
	27	5 P. M.
	31	2 A. M.

Y CYGNI.

(Every fourth minimum.)

July	6	11 A. M.
	12	10 "
	18	10 "
	24	10 "
	30	10 "
Aug.	5	10 "
	11	10 "
	17	9 "
	23	9 "
	29	9 "

Maxima and Minima of Variable Stars.

[From ephemerides by Dr. Loewy in the "Companion to the Observatory," and by Dr. Hartwig in the "Vierteljahrsschrift der Astronomische Gesellschaft".]

MAXIMA

July	1	X Capricorni
	2	R Corvi
	2	R Boötis
	2	R Persei
	2	R Geminorum
	3	U Cassiopeiæ
	3	S Scorpii
	4	R Aquarii
	4	U Boötis
	6	S Sagittarii
	10	R Comæ
	10	R Sculptoris
	18	R Sagittarii
	24	R[3] Libræ
	26	S Vulpeculæ
	27	R Leonis Minoris
	27	Y Virginis
	28	Z Scorpii
	29	R Delphini
	30	R Scorpii
	30	V Ceti
Aug.	1	U Monocerotis
	2	W Cygni
	3	S Herculis
	4	R Lyræ
	5	Z Virginis
	5	T Hydræ

MAXIMA

Aug.	7	R Vulpeculæ
	7	R Ceti
	7	Y Libræ
	8	R Ursæ Majoris
	8	R Pegasi
	9	S Ursæ Majoris
	10	R Carini
	11	U Geminorum
	11	R Virginis
	13	R Arietis
	13	R Lacertæ
	13	U. Libræ
	14	T Libræ
	14	S Ophiuchi
	15	R Scuti
	15	S Arietis
	16	S Cephei
	16	R Sagittæ
	17	T Ursæ Majoris
	17	R Pegasi
	18	U Ceti
	19	V Tauri
	25	T Cephei
	28	S Cygni
	29	W Scorpii
	30	L[2] Puppis
	30	U Aquarii
	30	V Ceti

MINIMA

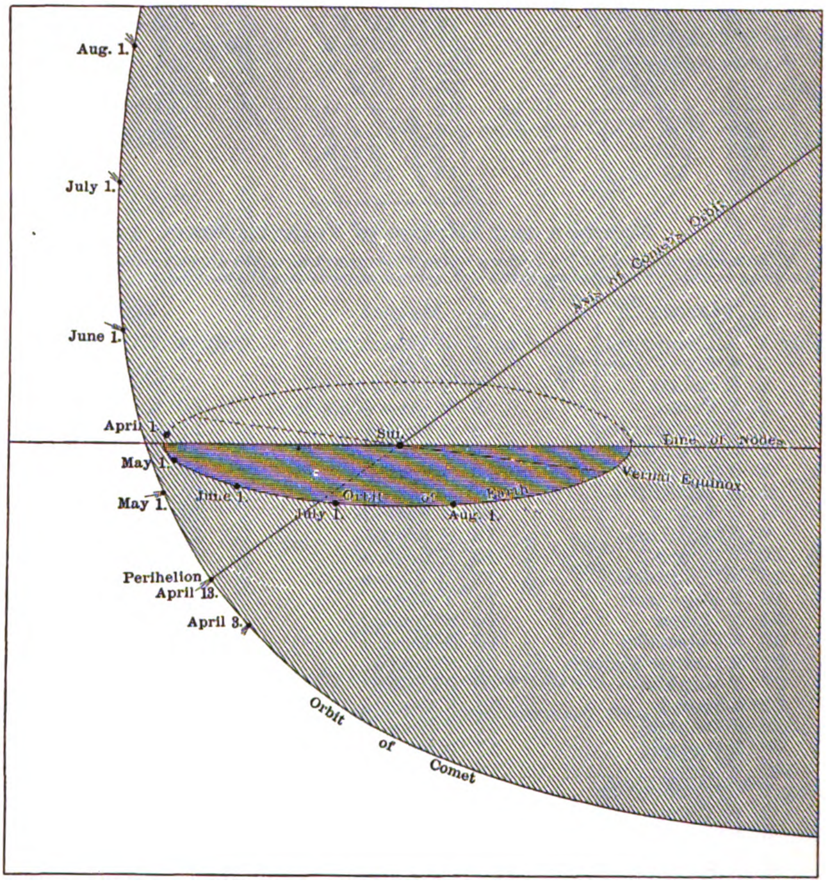
July	1	T Capricorni
	1	L[2] Puppis
	5	S Carini
	10	R Centauri
	11	R Scuti
	14	R Arietis
	14	U Monocerotis
	19	R Cancri
	20	R Lyræ
	25	S Ceti
	26	W Capricorni
	30	U Virginis
	30	V Cygni
	31	W Tauri
	31	R Sagittæ
Aug.	2	S Aquilæ
	5	X Boötis
	5	S Canis Minoris
	7	S Delphini
	16	T Herculis
	22	R Leporis
	29	U Monocerotis

COMET NOTES.

Denning's Comet a 1894.—Our last observation of this comet was obtained on the night of May 3. It was then exceedingly faint, and will probably not be visible, even in the largest telescopes, in June.

Gale's Comet *b* 1894.—This comet which we reported last month as too far south for observation in our latitude has come rapidly north and is now almost out of view from the place of discovery. The orbit is almost perpendicular to that of the Earth, so that it is probably not a periodic comet, and the parabolic elements last received appear to represent the observations fairly well. Mr. Ellery, Government Astronomer, at Melbourne, Australia, has telegraphed the following elements:

$$\begin{aligned} T &= 1894 \text{ April } 13.75 \text{ Greenwich M. T.} \\ \omega &= 324^\circ\ 19' \\ \Omega &= 206\ \ 15 \\ i &= \ \ 87\ \ 15 \\ q &= 0.9849 \end{aligned} \quad \left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} 1894.0$$



From these elements we have calculated the ephemeris, given in another place, and have indicated the course of the comet on Poole Bros.' map for June. During the next three months it will move northeast through Leo, Leo Minor and Ursa Major into Canes Venatici. It is growing rapidly fainter and will doubtless be invisible before it has completed the course indicated on the map.

The accompanying cut shows the orbit of the comet in relation to that of the Earth. It will be seen that the comet was near perihelion when discovered, that it was rapidly approaching the Earth, that it passed the point nearest to the latter about May 1, and that now it is rapidly receding.

The comet was first seen in northern latitudes by Mr. Douglass at Lowell Observatory, Flagstaff, Arizona, April 26. At Northfield cloudy weather prevented observations until May 3, when the comet was visible to the naked eye as a hazy star of the fifth magnitude. No tail was visible to the naked eye or with an opera glass, but with the 16-inch telescope the tail could be traced 20′ or 30′ from the nucleus. A photograph taken with our 6-inch Brashear camera on May 5 with an exposure of one hour shows very faint traces of a tail extending to the edge of the plate, a little over 6°. Unfortunately the 2½-inch camera happened to be provided with a poor plate and showed the merest trace of a tail in the same time.

Mr. Barnard at Lick Observatory was more fortunate and succeeded in getting a very beautiful picture of the comet with an exposure of two hours and twenty minutes on the night of May 3. He reports a second successful photograph, the copy of which has not reached us at this writing.

This comet was observed by Mr. Douglas at the Lowell Observatory, Arizona, on April 26th, 15^h G. M. T., in R. A. 6^h 50^m, and Decl. 33° 32′ south. He described it as of 5th magnitude brightness; circular, with a central nucleus, and a diameter approximately four minutes of arc, and a narrow tail eight minutes long. On Apıil 28th he found it of the fourth magnitude, and from these and subsequent observations its positions showed it to be gaining somewhat on its ephemeris.

Ephemeris of Gale's Comet, *b* 1894.

Greenwich Midn.		R. A. h	m	Decl. °	′	log *r*.	log Δ	Br.
June	1	11	02.3	+38	39	0.1086	9.9869	0.48
	3		07.9	39	21			
	5		13.3	39	57			
	7		18.4	40	28			
	9		23.3	40	56	0.1366	0.0694	0.29
	11		28.0	41	20			
	13		32.5	41	41			
	15		36.9	41	59			
	17		41.1	42	14	0.1642	0.1369	0.19
	19		45.3	42	27			
	21		49.4	42	39			
	23		53.4	42	49			
	25	11	57.3	42	57	0.1912	0.1935	0.13
	27	12	01.1	43	04			
	29		04.8		10			
July	1		08.5		15			
	3		12.1		19	0.2172	0.2415	0.09
	5		15.8		22			
	7		19.4		24			
	9		23.1		25			
	11		26.7		25	0.2418	0.2825	0.07
	13		30.3		24			
	15		33.8		23			
	17		37.3		22			
	19		40.8		20	0.2684	0.3181	0.05
	21		44.4		18			
	23		47.9		16			
	25		51.4		13			

Greenwich Midn.		R. A.	Decl.	log r.	log Δ	Br.
		h m	° ′			
July	27	54.9	10	0.2882	0.3497	0.04
	29	12 58.4	06			
	31	13 01.9	+43 02			

Gale's Comet in an Inch-and-a-half Glass.—The ephemeris of Comet *b*, 1894, (Gale) gave its place in the sky and this was laid down upon Klein's Star Atlas. The comet's position was found to be in a continuation of the line joining *o* and *ξ* Leonis, *ξ* being almost equally distant from *o* and the comet. About half past eight on the evening of May ninth a small, home-made inch-and-a-half telescope was directed toward that portion of the sky and a nebulous object was seen about where the comet was expected. A diagram of the object and two neighboring stars was made, and at the end of forty-five minutes the object had changed its position in regard to the stars, thus proving that it was the comet. The sky was clear and the star discs were sharply defined. Although the Moon was four days old and shining brightly about thirty degrees from the comet, yet the latter was faintly visible to the naked eye. In the telescope the nucleus appeared as a somewhat elongated condensation just below the center. The coma was circular in general outline, the edges shading off indistinctly into the surrounding sky. No tail was visible.

On May twelfth another observation was taken. In the increased moonlight the comet was smaller and the nucleus not so definite. From the diagrams made on these two evenings the motion was estimated as about seven degrees for the three days. Two days later the comet was again seen. On this evening the sky was hazy although the moonlight was bright. The comet appeared smaller and fainter.

FLORA E. HARPHAM.

Smith College Observatory, Northampton, Mass.

Gale's Comet.—Professor E. E. Barnard has just sent us two fine large positives of Gale's comet taken respectively May 3 and 5. The exposures were over two hours. The long train is beautifully shown in each picture. That of the 3d shows a curious bend near the end, while that of the 5th gives a plain division of the tail for nearly its whole length. These pictures and article about them by Mr. Barnard will appear in the June number of *Astronomy and Astro-Physics*.

Tempel's Periodic Comet.—This comet was found very near the predicted place on the morning of May 9 by Mr. Finlay an astronomer at the Cape of Good Hope. The observed position of the comet was as follows:

May 8.6628 Gr. M. T.; R. A. $23^h\ 45^m\ 21^s.1$; Decl. $-4°\ 51'\ 18''$. This gives as the corrections to Mr. Schulhof's ephemeris $+47^s$ in R. A. and $-1'.9$ in Decl; remarkably small corrections considering the fact that the comet has not been observed since 1878. The comet is described as circular, less than 1′ in diameter, 11 magnitude or fainter, with some central condensation and no tail. It is now at its greatest theoretical brightness but in a quite unfavorable position for observation in the northern hemisphere, owing to the morning twilight in which it must be observed.

PRACTICAL SUGGESTIONS.

44. Mr. Parkhurst says R. Leonis passed minimum Jan. 8, and its maximum is due June. 1; but Klein gives its period as 313 days, and Chandler as 312 days. I would be thankful for any light you may give on the subject. D. P.

Answer: Referring the question to Mr. Chandler we are favored by the following reply:—"By the elements of my catalogue,* the minimum took place 1894 Jan. 8 and the maximum will occur 1894, June 1. See the Ephemeris *Astronomical Journal*, 308, pp. 172, 173."

It may be of service to indicate how any desired epoch of maximum or minimum of any star can be derived from the elements of the catalogue

I take this star as an example. The elements of 3493 R. Leonis in the catalogue are:

M — m = 144 days.
M = 1757 April 21 (= 2362902 0) + 312.90 E + 25 sin (2 : 75 E + 318°)
Put E = 160
Then add to the principal epoch, or.........2362902.0
The quantity 312.90 × 160, or.........50064.0
Also 25.0 sin 38°, 25.0 × (+ 0.616), or.........+ 15.4
(Since 2 : 75 × E = 2 : 75 × 160 = 440° = 80°)
(and 80° + 318° = 398° = 38°; and since 38° = 0.616)
Then maximum, or M is 1894 June 1.4 =.........2412981.4
and since M — m =.........144.0

The minimum will be m = 1894, Jan. 8.4 = 2412837.4

The conversions for Julian calendar dates can be made by the little table given in the introduction to the catalogue before referred to.

45. Do variable stars change gradually from maximum to minimum or is it suddenly between the extremes? D. P.

Answer: Stellar lustre, in general, is affected by endless gradations of change. Long and short period fluctuations are in many cases well known. Secular variations are suspected. There is no known case of a very sudden change from one extreme to another. But in short period changes there are often fluctuations of light when the star is either in a waxing or a waning phase. Miss A. M. Clerke's book, *The Systems of the Stars*, will give much information about the variable stars.

46. I find that the rising and setting of the heavenly bodies as given in POPULAR ASTRONOMY differ from the times given in the Conneticut Almanac in some cases and in others do not. Please explain. C. D. H.

Answer: I think I can explain the discrepancies which you have noticed between our tables of rising and setting and those of the "Connecticut Almanac." The "Almanac" tables have evidently been computed for the longitude and latitude of New Haven. At least, I calculated the times of rising for the three cases which you cite on that assumption and get a constant difference of 8^m which is the reduction from local to standard time at New Haven. Your latitude and that of New Haven are about the same, 41° 18′, while ours is 44° 28′. Bodies on the equator will rise and set at practically the same *local* time at both places but bodies north of the equator rise earlier and set later at Northfield, while those south of the equator rise later and set earlier. The farther from the equator the bodies are the greater the difference. I have a table from which I take the following corrections to reduce local times of rising and setting at Northfield to those at Guilford:

Decl. of Planet	Corr. to Time of Rising	Corr. to Time of Setting
°	m	m
0	0.0	0.0
+ 5	+ 2.2	− 2.2
+ 10	+ 4.1	− 4.1
+ 15	+ 6 6	− 6.6
+ 20	+ 9 2	− 9.2
+ 25	+ 12.3	− 12.3

For south declination change the signs.

As near as I can determine, Guilford is about 1 minute of time east of New Haven so that the reduction from local to standard time, will be — 9ᵐ. The reductions, then, in the three cases cited will be:

	Sun, May 5	Venus, May 15	Mars, May 15
	h m	h m	h m
Local time of rising in Lat. 44° 28′	4 44 A. M.	2 51 A. M.	1 36 A. M.
Reduction to Latitude 41 18	+ 7 "	+ 1 "	− 5 "
Local time of rising in Lat. 41° 18′	4 51 A. M.	2 52 A. M.	1 31 A. M.
Reduction to Standard Time, Guilford	− 9 "	− 9 "	− 9 "
Standard time of rising, Guilford	4 42 A. M.	2 43 A. M.	1 22 A. M.

In computing the times of rising of the planets we have not attempted to be very exact and have taken no account of their motions, but the times are probably all within 1 or 2 minutes. H. C. W.

47. L. H. Ling of Chicago reports the discovery of a new comet in the constellation of Hydra. Is not this Gale's comet?

Answer: It is undoubtedly.

48. The fine photographic view of the Pleiades in the May number of *Astronomy and Astro-Physics* (also plate No. 24) recalls a legend which I have nowhere read and have heard somewhere else than in Chicago, that at the time of our Savior's birth the brightest and best star in the constellation of Virgo had its position in the lap of the Virgin, and that (so runs the legend) when the time shall arrive for the second coming of our Lord, that the same shall take its position as a crown upon the Virgin's head. The idea is very pretty and poetical, and I write to ask whether it receives any color of truth from the annals of astronomical science? H. M. H.

49. I now have a very good Brashear grating and am much interested in spectroscopy. The reversal of the C line in the umbra of the large spot now visible (Feb. 23) is easily seen. I have also secured some fairly good photographs of the Sun showing the large group of spots now visible with a "photoheliograph" of my own make. I am using a 3-inch Jena glass visual objective (by Brashear) and enlarging lens at focus and secure photographs about 2½-inches in diameter. What kind of plates should I use to decrease or avoid halation altogether?

Answer: The best results are obtained at Goodsell Observatory in photography by the use of the Seed non-halation plates. Other companies also make non-halation plates.

50. In "The Natural Genesis" I find the following quotation: When Herodotus was in Egypt, the Egyptians had as now known, observed at least five Sothic cycles of 1,461 years. The priests informed the Greek enquirer that time had been reckoned by them for so long that the Sun had twice risen where it then set, and twice set where it then arose. This can only be realized as a fact in nature by means of two cycles of precession, or a period of 51,736 years." The time of Herodotus was 484 B. C. and later.

What I wish to ask, is whether or not it is positively known that the Earth changes its inclination in relation to the stars simultaneously with the change of the inclination of its axis which causes the precession of the equinoxes. Or does the axis change its relative position to the Earth as well as to its orbit?

H. D. C.

Answer: The statement preceding this query contains several points which we have not space to allude to now. It may be done latter. We have been accustomed to put the final query in a little different language although the meaning is the same. Does the line we call the terrestrial equator and the points we call the poles of the axis of the Earth change, or are they fixed in position on the Earth's surface? The opinion that the axis within the globe is not in an absolutely fixed position with reference to points on the Earth's surface is, I think, gaining ground though it can hardly be said to be generally accepted as a doctrine of the terrestrial sphere. An article will soon be published setting out the nature of this question, its mode of study and the results so far reached.

51. At what hour should one look for a star, whose position is known in right ascension and declination? We will take for instance Capella whose R. A. is $5^h\ 8^m$ and Decl. 45° 52′ (Webb 1880). Supposing that a person had an equatorial and had set his R. A. and Decl. circles as above, at what hour should he expect to find Capella?

Answer: The declination circle should be set as suggested whenever the star is to be observed, but this is not true of the right ascension circle (or more properly the hour circle). The setting for this circle at any given time is the difference between the star's right ascension and the sidereal time. If the sidereal time is less than the right ascension the star is past the meridian, if greater it has not yet reached the meridian. It is very desirable that the observer should have a sidereal clock or chronometer to aid in determining this setting; if such a timepiece is lacking it is not difficult to obtain sidereal time from mean time when certain necessary data are given. The following table gives the difference between mean time and sidereal time at noon for each fifth day of June, sidereal time being the faster.

Date	Sid Time of mean Noon. h	m	s	Date	Sid. Time of mean Noon. h	m	s
June 5	4	56	36.54	June 20	5	55	44.92
10	5	16	19.33	25	6	15	27.71
15	5	36	2.13	30	6	35	10.51

From this table it is evident that sidereal time gains $3^m\ 56^s.56$ per day and $9^s.86$ per hour on mean time. It is thus possible to calculate the difference between mean time and sidereal time for any hour of any day. To obtain sidereal time add this difference to *local* mean time.

52. Kindly give the name of the best history of astronomy which is earlier than than that written by Miss Clerke. E. H. MC L.

Answer: History of Physical Astronomy from the earliest ages to the middle of the 19th century by Robert Grant, F. R. A. S. This book was written in 1852 and published by Robert Baldwin, Paternoster Row, London. It can be imported by any bookseller.

53. Can you refer me to any authority where I may find the proper catalogue number of the nine named Pleiades? R. H. A.

Answer: We take the following designations of the Pleiades stars from Bessel's list in "Abhandlungen von F. W. Bessel," by Engelmann, Leipzig, 1876, and from Heis' "Catalogues; Atlas Coelestis."

We have no means at hand of determining when Atlas and Pleione were added to the ancient group.

Bessel's Letter.	Name.	Flamsteed's No.	Heis' No.	Bayer's Letter.
η	Alcyone	25	31	η
b	Electra	17	24	...
c	Maia	20	27	...
d	Merope	23	28	...
e	Taygeta	19	26	*g*
f	Atlas	27	36	...
g	Celœna	16	23	...
h	Pleione	28	35	...
k	Asterope	21	...	...
l	.....	22	...	

54. I desire a book that will tell me how to construct and to use a small telescope. Please give information. W. C. P.

Answer: We do not know of any one book that will furnish the information asked. In regard to the care and use of telescopes a book called The Amateur Telescopist's Hand-book by Frank M. Gibson and published by Messrs. Longmans, Green & Co., 15 East Sixteenth St., New York City is just out and would give some of the information wanted. A brief notice of the book was given in our last issue.

GENERAL NOTES.

Attention is called particularly to the publisher's notices at the end of this number.

We are not satisfied with the illustration that we have been able to give so far. It has been good in kind generally, but we want to give more of it. We can and will do this if our subscription list for the coming year is much increased.

Note for Beginners about Motion in the Sky.—In the celestial sphere there is north and south but not east and west, only direction of motion. The bodies which we watch in the dome of the sky are moving in curves, and the direction of their motion must be that of one of the two screw motions, either with the hands of a clock or against them. Thus, if in northern latitudes we follow the stars of the big dipper, they seem sometimes to be going toward the east point and sometimes toward the west point of the horizon, but the circular or screw motion remains always unchanged in direction

If we face the south and place in imagination near the Sun, Moon and planets a clock dial with the "XII" that is the zero up toward the zenith, we find that the Sun and the Moon are moving against the hands of the dial. The planets when advancing, move in the same direction, but when retrograding they go with the hands. Since astronomers are agreed in calling the apparent annual motion of the Sun among the stars an eastward motion, we may conclude that in the northern hemisphere counter clock-wise motion is eastward motion and clock-wise motion westward.

The Earth, as well as other bodies of the solar system, may be projected upon the celestial sphere. If we think of the Earth and the Sun as projected at the same time, both these bodies move eastward among the stars, even though at a given instant they are going in opposite directions in regard to the west point of our horizon. These two motions are of course opposite as regards right and left but they are both eastward throughout the year, since the screw motion in both curves iscontinuously counter clock-wise. MARY E. BYRD.

Suspected Variable near ν Scorpii.—Mr. W. E. Sperra of Randolph, Ohio, has been observing since January a star in the field with ν Scorpii which seems to vary. It can be identified if the following stars are charted:

Star.	Co-ordinates from ν		Mag.
	m	′	
var	−1.8	+2	
a	−1.4	−38	8.5
b	−2.1	−7	9.5
d	−3 5	−5	6 5
e	−2 8	−17	9.8
f	−3 4	−19	9 7
g	−1.7	+7	10.0

It seems to vary with a short period between 8.5 and 9.3 magnitude. It is in good position for evening observation, and will bear watching.

J. A. PARKHURST.

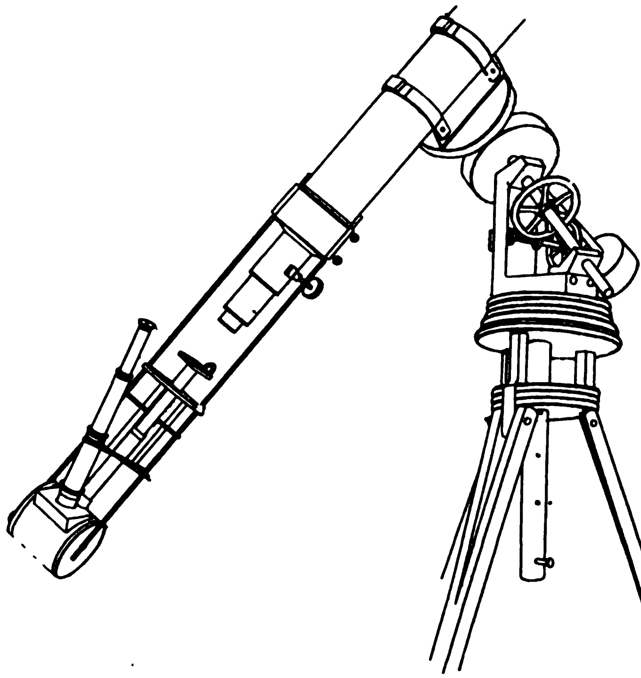
Professor Glassenapp's Double-Star Measures in 1892.—The measures of double-stars made by Professor S. Glasenapp at Abastuman in 1892 have just appeared in a handsomely printed volume issued from the press of the Imperial Academy of Sciences of St. Petersburg. The observations include about six hundred pairs, principally from the Dorpat catalogue, each star being observed as a rule on two nights. The other pairs measured are from the OΣ and β catalogues. The measures are excellent, and the stars judiciously selected considering the aperture of the equatorial.

It is to be regretted that this work could not have been continued, as the atmospheric conditions were found to be very favorable both as to the steadiness of the air, and the number of working nights. The elevation is some three hundred feet higher than Mt. Hamilton, and in point of latitude is much more favorably placed for observing south of the equator than any of the other Russian Observatories. From the amount of work done in the comparatively short time the Observatory was in active operation, it is evident that Professor Glasenapp made good use of his opportunities. Visitors to the Russian exhibit at the World's Fair will recall the beautiful photographs contributed by Professor Glasenapp of the picturesque Mountain Observatory at Abastuman. S. W. B.

Double Star Measures Near H 3950.—The faint pair of stars, near H 3950, referred to by Mr. Sprague in the May number of *Astronomy and Astro-Physics*, (p 417) was first noted in the low-power sweeps at Madison (*Pub.*

Washburn Observatory Vol. II), and subsequently measured by Comstock in his review of those stars (Vol. VI). It is much too wide in distance and too faint in magnitudes to be of any interest as a real double star. S. W. B.

Small Telescope with Spectroscope.—In a note on "Observations of Sun-spot Spectra" published in the February, 1892, number of *Astronomy and Astro-Physics*, the attention of amateurs was called to the valuable contributions which they can make to Astro-Physics with simple apparatus and at a moderate outlay. Some time ago I obtained from Mr. J. A. Brashear of Allegheny, Penn., an excellent 2-inch Rowland diffraction grating of 14438 lines to the inch, and the following description of its mounting and the completed instrument may be of service to some other amateur with moderate means.



The illustration, taken from a photograph by myself, represents the eye-end of the telescope tube with spectroscopic attachment and spectroscope in position, the telescope is mounted equatorially with slow motion in R. A.; the object glass is 3-inches aperture made of Jena glass; the tube is of polished brass and has near the eye end a revolving ring or collar 2 inches in length and about ¼ inch thick containing apertures into which the brass rods of the spectroscope are inserted, also the necessary adjusting screws for clamping the rods and collar to the tube; thus the spectroscope may be rotated around the optical axis of the tube and clamped tightly in any position. This tube with its attachment was designed and manufactured by Mr. J. A. Brashear, (as was also the object glass), who is one of the finest opticians and instrument makers in the country. The grating box I had turned from a piece of very hard wood; it is 4¼ inches long and 3¾ inches diameter on the outside, and 3¼ inches internal measure (this large size was necessary on account of the 2 inch grating; a smaller grating would be better on the same size telescope); the ends are removable and to one of them the grating mounted on a T piece is affixed; the grating or prism may be rotated on its axis by means of a small brass button connected by a couple of gear wheels. Two brass rods 21 inches long and five-sixteenths inch diameter are securely fastened by screws to the end pieces of the grating box, the distance between the rods being about 4 inches. The collimator and observing telescope are each about 10 inches long with object glasses of one inch aperture (smaller ones would answer just as well and would be preferable being lighter, but these were used as I had them on hand) these are inserted into holes accurately bored in the grating box, so that the angle between them is about 28 degrees. A small frame-work of hard wood fastened to the brass rods serves to hold the collimator in place, also the observing telescope which is secured to it by means of a brass support.

The entire instrument is very quickly and easily attached to the telescope, by simply inserting the rods into the apertures in the collar the proper distance and clamping; the finer adjustments to the focus, etc., are made by rack-and-pinion movement to the collimator tube. When all the necessary adjustments are made, the Sun's image brought accurately to focus on the slit plate and the collimator and observing telescope moved until the lines are clear and sharp,—the chromosphere lines, reversals in and near large sun-spots, and the various prominences are very readily seen; for viewing the prominences the great C line in the second order is generally used, the images in the F line being not as distinct.

Solar spectroscopy is indeed a most interesting and fascinating study and it is hoped the above short sketch of the instrument put together at moderate expense may be of use to some other amateur desiring to obtain a knowledge of the new astronomy. DAVID E. HADDEN.

ALTA, Iowa, May 9th, 1894.

Auroræ, Sun-Spots and Earth Currents.—I now have more complete information respecting the outbreak previously mentioned on Feb. 22, 23 and 25, and in regard to those of April 12-14 and March 30th, etc. The following are some of the points that may be of interest:

There were some premonitions of an aurora on Feb. 21st, sporadic displays being reported from various localities in this country and Europe. Magnetic perturbations and disturbance of the telegraph lines by Earth currents began to be felt on this date. On Feb. 22d the aurora became bright near the Pacific coast of North America extending unusually far south in California, Arizona and New Mexico, and Earth currents affected the telegraph lines to a noticeable extent west of Chicago exclusively. Mr. Finn of the Western Union Company says that he can find "no record whatever of the presence of Earth currents east of Chicago on Feb. 22d." On Feb. 23d, however, both Earth currents and aurora appear to have been strongest near the Atlantic coast although generally felt on the North American continent. On Feb. 24th, there was nothing special noted either in regard to aurora or Earth currents as far as reports are at hand. But on Feb. 25th there was very strong disturbance of the telegraph circuit extending northeastward from New York City, a distance of about six hundred miles, at 3:30 A. M. and between 8:30 and 9:30 A. M. Reports now at hand from Ekatrainenburg in the Ural mountains, and from Irkutsk, Siberia, in the northern hemisphere and from Australia and Tasmania in the southern hemisphere show that there was a splendid aurora which seems to have been at its maximum at the very time on Feb. 25th at which the Earth currents above mentioned were strongest. It will be extremely interesting when the Greenland observations come to hand to learn whether there was concentration of the auroral effect in the direction of the meridian of Asia and Australia, it being possible to determine this only by the aid of reports from localities where observations were not hindered by daylight throughout the entire twenty-four hours. The relation of the geographical distribution of Earth currents to the corresponding distribution of the aurora, and the concentration of the aurora particularly, at certain longitudes and latitudes is a subject that deserves careful study. A notable instance of a similar localization in longitude to that above described appears in the case of the aurora of April 12-14, the Earth currents accompanying which, however, did not disturb the telegraph lines in such manner that their distribution could be traced without much greater care than it was possible to exercise at the time. The aurora itself, however, was a conspicuous display on the North American continent on the night of April 12th, only very faint and evanescent auroral glows being seen on April 13th and 14th on this side of the Atlantic. In Europe, on the other hand, the display did not become conspicuous until the night of April 14th when it was very widely seen.

It will be observed that both in February and April there was a progression eastward of the maximum phase on successive nights. It is possible that this may have been merely fortuitous, it is a point however worth keeping in mind for the purpose of obtaining further evidence.

The great magnetic storm aud aurora of March 30th appears to have been more evenly continuous and more uniformly diffused in longitude, its most striking peculiarity being its forming a belt whose center was in unusually low latitude both in this country and Europe. The recurrence of this aurora at the usual 27¼ day interval on April 25th as seen at Lyons was marked by the rare phenomenon of the appearance of streaks resembling ordinary auroral streamers in shape and arrangement, but looking like shadows across the diffused luminous background of the aurora. There were no streamers of the usual kind at the time, so that it could not have been the effect of contrast of dark spaces intervening between such streamers. I have read descriptions of something of the sort as having been seen in the Arctic regions, but have never met with it before.

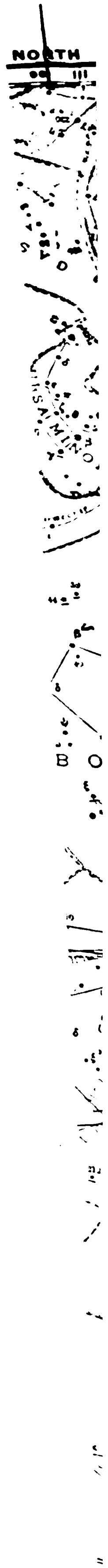
As appears from the above descriptions an effort is being made to compare the records of Earth currents affecting the telegraph lines with the distribution of the aurora. Through the courtesy of Gen. Eckert president of the Western Union Company, the matter has been referred to their electrical engineer, A. S. Brown, and such measures as are likely to be most practicable are being taken in order to secure the requisite memoranda for such purposes of comparison. The results already obtained, which are merely hinted at rather than fully described, are such as to stimulate a very decided interest. M. A. VEEDER.

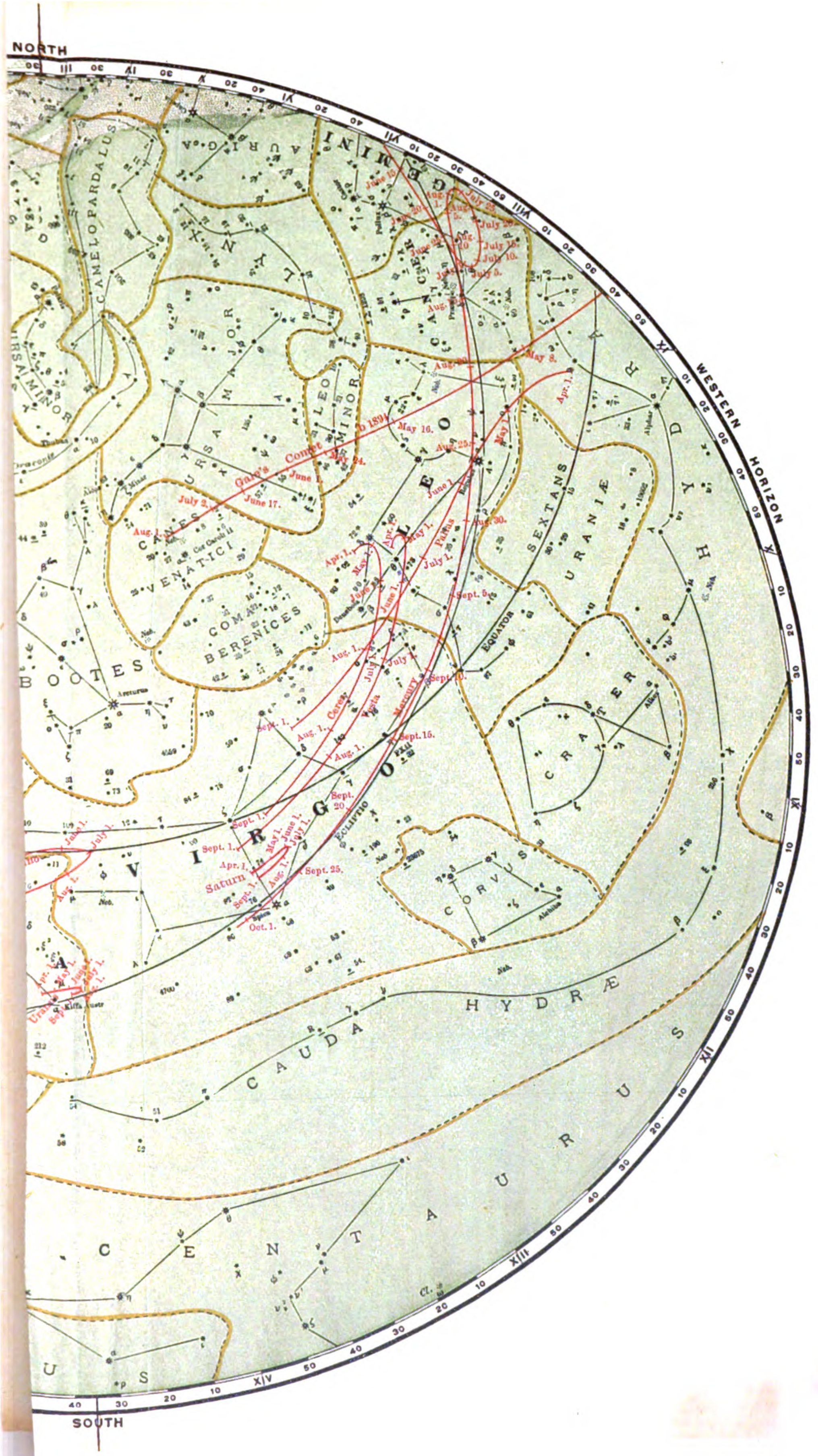
BOOK NOTICE.

Elementary Meteorology by William Morris Davis, Professor of Physical Geography in Harvard College. Messrs. Ginn & Company, Boston, Publishers, 1894, pp. 355.

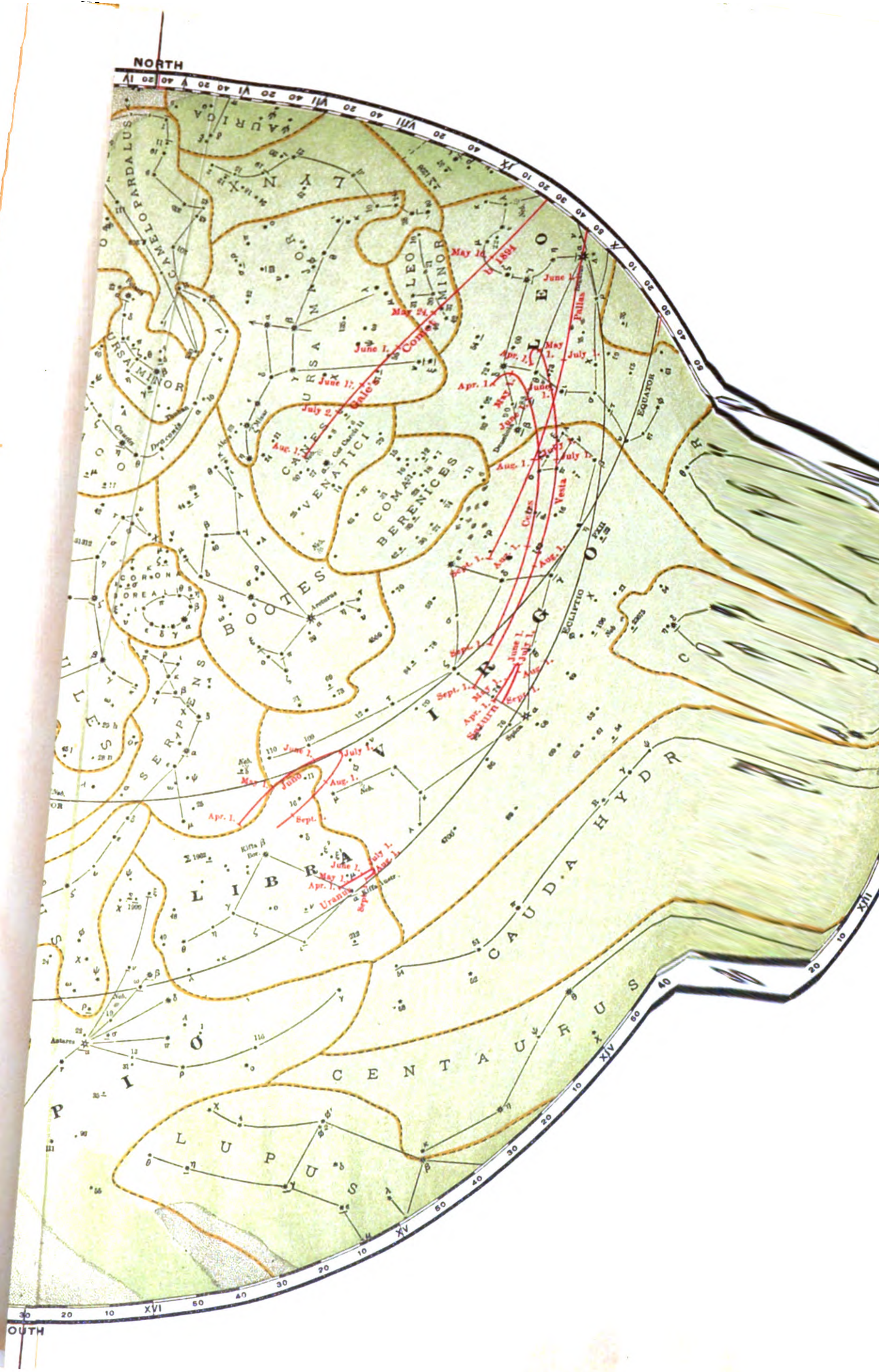
Mr. Davis has written a timely and a much-needed book on the subject of Meteorology. The earlier work by Professor Loomis and the recent and scholarly study by the late Professor William Ferrel in some branches of meteorology have awakened interest in this science and in some degree, prepared the way for a more complete treatise on the elementary principles of the branch like the work now before us. The table of contents is given in fourteen chapters, each of which is broken into subject paragraphs numbered and titled in heavy-faced letters and figures, making the text a useful one for class work, and equally convenient for popular reading. An idea of the scope of the book is obtained readily from the titles of its chapters, as follows: The general relations of the atmosphere; extent and arrangement of the atmosphere about the Earth; the control of atmospheric temperatures by the Sun; the colors of the sky; the measurement and distribution of atmospheric temperatures; the pressure and circulation of the atmosphere; the general classification of the winds; the moisture of the atmosphere; dew, frost and clouds; cyclonic storms and winds; local storms; causes and distribution of rainfall; weather and climate. Many of the chapters are illustrated either by cuts of instruments used in observation, or to show graphic results pertaining to some features of the science that may be best presented in that way.

Professor Davis has worked out his subject matter in an admirable way. It seems to us that this would also be an excellent reference book for any one whose duty it is to teach the elements of physical geography for it will put into the instructor's hands a great many facts that would aid in explaining much hat the ordinary text-book does not give.




NORTH
WESTERN HORIZON
SOUTH
GEMINI
AURIGA
CAMELOPARDALUS
LYNX
URSA MINOR
URSA MAJOR
LEO MINOR
CANCER
LEO
SEXTANS
URANIÆ
HYDRA
CANES VENATICI
COMA BERENICES
BOOTES
Arcturus
VIRGO
Spica
CRATER
CORVUS
HYDRÆ
CAUDA
CENTAURUS
EQUATOR
ECLIPTIC
Gale's Comet b 1894
Saturn
Mercury
Ceres
Vesta
Pallas
Regulus
Alphard
Cor Caroli
Pollux
Castor
Uranus
Kiffa Austr.


NORTH
PARDALUS
URSA



NORTH
AURIGA
LYNX
CAMELOPARDALUS
URSA MINOR
URSA MAJOR
LEO MINOR
LEO
CANES VENATICI
COMA BERENICES
BOOTES
CORONA BOREALIS
SERPENS
VIRGO
LIBRA
CAUDA HYDR
CENTAURUS
LUPUS
ECLIPTIC
EQUATOR
Arcturus
Antares
Spica
Saturn
Uranus
Juno
Vesta
Ceres
Pallas
Gale's Comet
OUTH

GENERAL INDEX TO VOLUME I.

This book is a preservation facsimile.
It is made in compliance with copyright law
and produced on acid-free archival
60# book weight paper
which meets the requirements of
ANSI/NISO Z39.48-1992 (permanence of paper)

Preservation facsimile printing and binding
by
Acme Bookbinding
Charlestown, Massachusetts

2006