HORNER'S
EASY
ASTRONOMY

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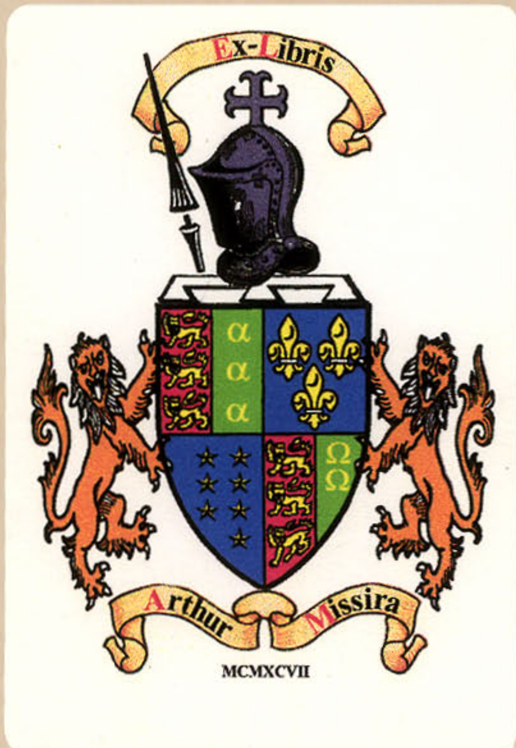
By

Donald W. Horner

F.R.A.S., F.R.Met.Soc., Etc.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HORNER'S EASY ASTRONOMY

FRONTISPIECE.

Constellations of the Northern Hemisphere, being Stars visible from Greenwich; or approximately latitude 51½° N.

Note.—Hold the Map so that the required date is facing you at the foot of it. Each date indicates the South Point on the horizon at 10 p.m.

[*Reproduced by permission from "The A.P.C. Guide to Astronomy," by H. Periam Hawkins.*]

HORNER'S
EASY ASTRONOMY

BY

DONALD W. HORNER, F.R.A.S., F.R.Met.Soc., etc.

Author of "Fireside Astronomy," "Astronomy for Amateurs," "Meteorology for All," "Helps for the Practical Meteorologist," etc., etc.

WITH AN INTRODUCTION

BY

W. F. DENNING, F.R.A.S., F.R.A S. (CANADA), ETC.

WITH MANY PLATES AND TEXT FIGURES

GLASGOW

JAMES BROWN & SON (GLASGOW) LTD., NAUTICAL PUBLISHERS

52 TO 58 DARNLEY STREET

1922

Who follow truth along her star-paved way.

Keble.

These are Thy glorious works, Parent of Good,
Almighty! Thine this universal frame,
Thus wondrous fair: Thyself how wondrous then!

Milton.

Lift up your eyes on high, and see Who hath created these, that bringeth out their host by number: He calleth them all by name; by the greatness of His might, and for that He is strong in power, not one is lacking.—*Isaiah* xi. 26 (*R.V.*).

INTRODUCTION.

NO apology is needed for offering another astronomical book to the public. Every new volume includes some special characteristics to recommend it, and of late years those who "consider the heavens" and study its glories as a very attractive and elevating hobby have greatly increased. Moreover, the advance of this science is so rapid that we need fresh descriptive works at short intervals so that readers may be kept abreast of present day knowledge.

Mr. Horner has designed his work to meet the particular requirements of seafaring men and they will find some of the information given well adapted for the purpose in view. In many seas delightful weather invites the astronomical observer to contemplate the firmament, for brilliantly starlit skies are the rule rather than the exception. Telescopic work of a critically exact or satisfactory nature may not be possible on board ships, but there are many suitable objects and phenomena which are grandly presented. The large expanse of sky commanded from the deck of a vessel enables a person to obtain a good knowledge of the constellations. By comparing a star atlas with the heavens the names and configurations of many of the brighter stars may be found and impressed on the memory. The stars are the nightly companions of the voyager, and familiarity with their features and grouping will cause him to regard them as friends accompanying him on his travels.

Difference in latitude will, it is true, introduce stars not seen before into the panorama of the sky, but these may be quickly learnt with a little application. An acquaintance with the sidereal firmament is both useful and entertaining in many respects. When a meteor, comet, or other object appears its place may be located and the direction of its motion observed and recorded. Moreover, the act of viewing the constellations and tracing the attractive difference of colour, magnitude, and distribution amongst the individual stars will always afford a pleasurable and instructive occupation. The student is not hampered by the smoke and artificial illumination of our large towns and has no obstruction from buildings and trees which are often the bane of land observers.

It is hardly necessary to give any details of the researches that may be successfully and entertainingly conducted by seamen.

The observations of comets, meteors, variable stars, and new stars, Auroræ Boreales, Zodiacal light, Eclipses, etc., offer strong inducements to the non-telescopic "watcher of the skies," and will bring many pleasant hours into the lives of those who appreciate celestial spectacles and make habitual efforts to witness them.

Lieut.-Colonel Tupman, R.M.A., made a fine and accurate series of observations of meteors while cruising in the Mediterranean in 1869-1871, and the remarkable trains of meteors which passed over Canada on 10th February, 1913, and had the longest luminous flight

(5500 miles) on record, was observed so well by seafarers that it was possible to trace its lengthy course and other features with a fulness and exactitude which would not otherwise have been possible.

Those who would relieve the monotony sometimes experienced on board ship will find welcome relief and agreeable variety by looking upward to the blue expanse of Heaven and perfecting their knowledge of the constellations. They may also seek to discover new stars, or other appearances which often come quickly and unexpectedly. An opera-glass or field-glass will be found a very useful aid to natural vision by giving a more brilliant and expanded view.

As an encouragement to, and guide for, amateurs both on sea and land this book will be found useful and will, it is hoped, lead young observers onward to more advanced instrumental work in celestial fields.

W. F. Denning.

PREFACE.

IN this little work, whilst it is quite suitable for all amateur novices in the "Queen of Sciences," I have endeavoured particularly to interest seamen in a Science which to them, owing to the nature of their calling, must seem very "dry" and unattractive.

But once we have glimpsed the Moon or one of the larger planets—such as Jupiter, with his retinue of satellites, or Saturn with his marvellous ring-system—through a 3-in. telescope we shall no longer deem the subject uninteresting.

In this book, also, I have tried to avoid giving elaborate illustrations of phenomena which are beyond the powers of a 3-in. or 4-in. object glass, as by so doing one only brings about the inevitable disappointment of a novice possessing an instrument of moderate aperture.

To the book itself I have added a Glossary of Astronomical and Nautical Terms in use every day, which I trust will be useful to young officers in the Merchant Service.

In compiling this treatise I have been ably assisted by many willing helpers, among whom I must mention Dr. A. C. D. Crommelin, F.R.A.S., and the Rev. Fredk. Ball, R.N., who kindly read the proofs; and Mr. W. F. Denning, F.R.A.S., who was so good as to write an Introduction to the work; and last, but not least, to Mrs. H. Periam Hawkins, who not only kindly allowed me to make extracts from her *A.B.C. Guide to Astronomy*, but also lent me many valuable illustration blocks.

The other illustrations have been lent by Messrs. Negretti & Zambra ; Messrs. Longmans, Green, & Co.; Messrs. Cassell & Co., Ltd., The Athenæum Press, and Mr. E. Walter Maunder, F.R.A.S., who also allowed me to quote from *Astronomy without a Telescope.*

Messrs. S.W. Partridge & Co. have kindly permitted me to make extracts from the twelfth edition of my old friend—the late Mr. W. T. Lynn's—*Celestial Motions*, and I hereby acknowledge the courtesy of all concerned, including Mr. J. D. Potter, of The Minories, London.

Any who may inadvertently be omitted from this list will understand that the apparent discourtesy was quite unintentional, and I sincerely hope that my readers will derive as much pleasure from the perusal of these pages as I have had in compiling them.

D. W. H.

December, 1922

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CHAPTER I.

THE EARTH.

STANDING on the surface of the Earth and gazing out into the star-spangled firmament, it is small wonder that the ancients fancied our small globe was the centre of the Universe, and that all other celestial bodies revolved round it. But since the days of Copernicus and Galilei we have come to learn that our Earth, far from occupying such an important position, is merely one of the smaller planets of the Solar System.

Most of the movements of the heavenly bodies are not real but apparent. The diurnal motions of the Sun and Moon from east to west are only apparent movements due to the fact that the Earth upon which the observer is standing is continually rotating in the opposite direction.

The real motion of the Moon, for instance, is from west to east, as will be readily noticed if we observe night after night her position among the fixed stars.

The form of the Earth is not quite round, but is what is known as an *oblate spheroid*, that is, it is slightly flattened at the poles, giving it the shape of an orange.

The polar diameter, that is, the axis from pole to pole, is about 7899 miles, whilst the equatorial diameter or thickness at the Equator is 27 miles more, being 7926.

The Earth rotates on its polar diameter, or axis, in the same direction as it revolves in its orbit round the Sun. This axis is inclined to the plane of the orbit at an angle 66° 33′, so that the plane of the Equator, to which the Earth's axis is perpendicular, makes an angle of about 23° 27′ with that of the ecliptic or Earth's path around the Sun.

The exact time in which our Earth rotates on its axis is 23h. 56m. 4.09s. of our time; this is called a *sidereal day*. What we call a *day* of 24 hours is a *solar day*, as the conveniences of life render it necessary to regulate our time by the Sun, and, in consequence of the Earth's annual motion round that body, the period of rotation between two successive similar positions relatively to him is a little longer than that between two which are similar relatively to the same point in the starry heavens, the latter interval constituting a sidereal day. The ordinary or solar day is in strictness of varying length, owing to the Earth's unequal motion in different parts of its orbit; but in practice a mean or average one for the whole year is adopted and called a *mean solar day*, and this is the unit of time in all other astronomical measurements of duration.

Of these mean solar days, then, the Earth occupies 365.25636 (equal to 365d. 6h. 9m. 9s.) in revolving round the Sun. But as the conveniences of life lead us to take for a day not the precise period of time in which the Earth rotates on its axis, so do they compel us to adopt for one year not the exact period of time in

which the Earth revolves in its orbit. For what makes the observance of the year necessary to us is the change produced by the variations in the seasons; and in consequence of a slow conical movement of the Earth's axis about its centre (occupying about 25,800 years to complete a whole round), which is called the *precession of the equinoxes*, from the effect it produces upon the equinoctial points, the tropical year, in which all the changes of the seasons are run through, is somewhat shorter than the sidereal year, or the actual duration of the Earth's revolution round the Sun. The length, in fact, of the tropical year (which is the year of ordinary speech) is 365.24220d. or 365d. 5h. 48m. 46s. It would be so extremely awkward to make a year consist of a number of days and a fraction of a day that the difficulty is got over by adopting in the calendar two kinds of years: one called a common year, which consists of 365 days, and an occasional one called a *bissextile*, or leap year, consisting of 366 days. By the old Julian reckoning, which erroneously supposed the year to contain 365¼ days exactly, every fourth year was reckoned as one of the latter, and each year which was divisible by four without remainder was considered to be a leap year, an extra day being added on in the month of February. But by the Gregorian reckoning (first introduced in 1582, but not adopted in England until 1752) a leap year is dropped at the end of each century, except those of which the century number is divisible by four without remainder; thus 1900 was not a leap year, but 2000 will be one. This is equivalent to considering a year to consist of 365.24250 days, differing by only the fraction 0.00030 of a day, or about 26s., from its true value, 365.24220 days; a small difference, which will not by accumulation amount to an entire day for more than 3000 years.*

It will be thus noticed that the globe upon which we dwell has three principal motions: (1) its rotation round its own axis; (2) its annual journey round the Sun; and (3) a slow conical motion of the axis, made in such a manner as to retain almost the same inclination to the plane of its orbit throughout.

The first of these movements causes what we know as day and night, the opposite hemisphere being alternately turned towards the Sun. The second brings about the seasons, owing to the fact that the ecliptic, or apparent path of the Sun through the Zodiac (this being the real path of the Earth around its primary), is inclined at an angle, as we have already said, of 23° 27′ to the Earth's Equator, this being termed the *obliquity of the ecliptic*. Were it not for this the days and nights would always be 12 hours in length all the year round and all the world over. Such a condition of affairs, however, only actually occurs at the Equator.

For instance, an observer in London, whose latitude is 51° 31′ N., on 21st June, the Sun being then 23° 27′ north of the Equator, would see our luminary at an apparent distance of 28° 4′ from the vertical; on 21st

*A more accurate plan would have been to drop a leap year at the end of each period of 128 years, so as to have only 31 instead of 32 leap years in that time, and 97 instead of 96 common years. For $365 \times 97 + 366 \times 31 = 35{,}405 + 11{,}346 = 46{,}751$ days. Divide this by 128, and we get 365·24219 days, almost exactly the true length of a tropical year.—[W. T. Lynn, in *Celestial Motions*, 12th edition, p. 5.] This would however be much less convenient, as it would be difficult to remember in which years the "leap day" was omitted. It would also make the use of astronomical tables more complicated.—D. W. H.

December, on the contrary, the Sun, being then 23° 27′ south of the Equator, would appear to our observer in London to be 15° 4′ above the horizon. Fig. 1 clearly shows what is meant.

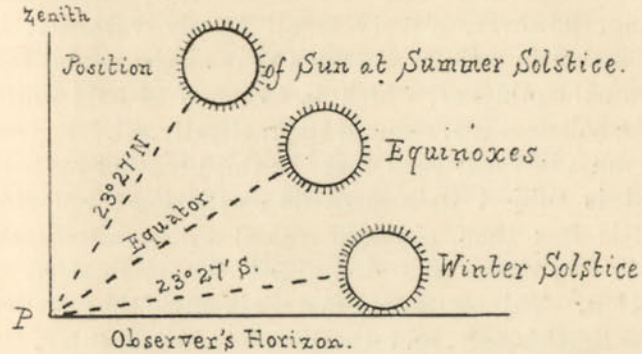


FIG. 1.—Showing the Apparent Altitude of the Sun at noon in various seasons.

If our observer were stationed in New York, whose latitude is only 40° 45′ N., then the Sun at the summer solstice would appear to be only 17° 18′ from the zenith. It is only within the Tropics that the Sun can appear vertical or directly overhead. The angular distance of the Sun from the celestial Equator is known astronomically as *apparent declination north* or *south*. For example, on 24th October the apparent declination of the Sun at noon is 11° 35′ south, and this means that an observer in the Northern Hemisphere would see the orb of day that amount below the celestial Equator, which is the prolongation of the plane of the terrestrial Equator. If he were in the Southern Hemisphere he would see it the same number of degrees above it.

The position taken up by the Sun on 21st June and

21st December, are known as the Solstices,* as on these dates the Sun is said to stand still in the Zodiac, before returning toward the Equator. Although the Sun has scarcely any motion in declination in its apparent path at the end of June and December, it never really stands still, having, however, a very small hourly variation in declination in comparison with that at the vernal and autumnal equinoxes† which is as much as 58″§ whilst at the solstices it is reduced to practically *nil*.

It must be mentioned that the third motion we have noted is subject to a periodic oscillation (occupying a little less than nineteen years) which alternately slightly increases and diminishes the inclination in question. This oscillatory motion is called the nutation of the Earth's axis, and was discovered by Bradley, the third Astronomer-Royal, in the year 1747. But the inclination is also subject to a very slow progressive diminution. This diminution is due to the change in the plane of the ecliptic arising from planetary action; two thousand years ago it amounted to 23° 42′; it is now about 23° 27′; 9000 years hence, according to Prof. Newcomb, it will be only 22° 35′, after which it will slowly increase again.

We must now explain the *equation of time*. By this we mean the difference between "solar time," or the time as shown by a properly located and adjusted sundial, and "mean time," or the time shown by a correctly regulated clock or watch.

* From the Latin :—*Sol*, the Sun ; and *Stare*, to stand.

† Latin, *æquus*, equal ; and *nox*, night.

§ ° degrees ; ′ minutes ; ″ seconds of arc. ; h, hours ; m, minutes ; s, seconds of time.

These two periods of time are only in actual agreement on four days in the year, viz., 16th April, 15th June, 2nd September and 25th December.

It will be seen on reference to any almanack that gives this information ("before" or "after clock") for each day, that the greatest correction for equation of time occurs in the beginning of November, when the "before clock" shown by the almanack amounts to over 16 minutes; that is to say, that the time shown by our clocks is 16 minutes behind that shown by a sundial at that time of year, and the next greatest, the "after clock" in the middle of February, which amounts to over 14 minutes, when the time shown by our clocks is that interval in advance of solar time. These figures are for the meridian of Greenwich; for other places correction for longitude is necessary.

Were it not for the obliquity of the ecliptic, and the unequal velocity of the Earth in its orbit, the equation of time would not be necessary, as in that case the Sun would always come to the *meridian** exactly at noon, as on the four dates previously mentioned. But as this is not so, these two "variables," by acting either in conjunction or in opposition, cause the Sun to come to the meridian sometimes too early and at others too late in the day; hence arises the necessity for the equation of time to be applied to all readings of sundials. Some sundials have tables of the equation of time inscribed upon their dials as in fig. 2. The equation of time varies slightly from year to year ; but from our present point of view we need not go further into the matter.

* Latin, *medius*, middle ; *dies*, day ; meaning "mid-day," a line running from N. to S.

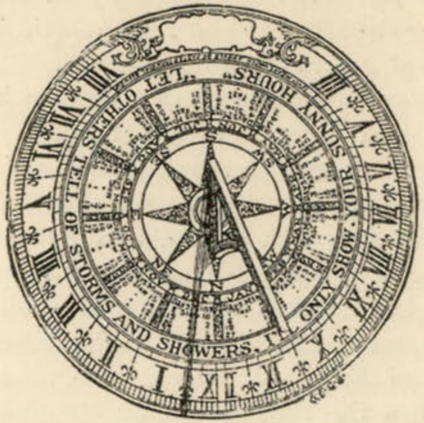


FIG. 2.—Sundial, with Equation of Time values.

Refraction and *parallax* will be treated of in a Glossary at the end of this book. We have already spoken of declination, which is the celestial equivalent of latitude; we now come to *right ascension*, which is the astronomer's *longitude*; but, whereas the terrestrial *latitude* and the celestial *declination* are reckoned in degrees, minutes and seconds of *arc* north or south of the Equator, the *right ascension* of a heavenly body, instead of being reckoned so many degrees, minutes and seconds of *arc* east or west of a given spot, as we use the meridian of Greenwich on the Earth when reckoning longitude, is usually given in hours, minutes, and seconds of *time* from the point of intersection of the Equator and ecliptic known as the "First Point of Aries." Owing, however, to the *precession* of the *equinoxes*, the (so-called) "First Point of Aries" is no longer situated in the constellation which gives

it its name. It is now about 2000 years since it left Aries, and is now situated in the constellation *Pisces*.*

The slow annual movement of fifty seconds of arc will, by the year 3132, carry this point into the zodiacal sign "Aquarius," but doubtless the advanced astronomers of that day will cease to give the "starting point" (if we may apply the phrase) of right ascension such an obvious misnomer.

* * * * * * * * *

In the latitude of Greenwich on 1st January day breaks at 6h. 2m. a.m., the Sun rising at 8h. 8m.; in a similar manner on the same date the Sun sets at 3h. 59m., and twilight ends at 6h. 5m. p.m. The interval between daybreak and sunrise, and sunset and twilight ending is occupied by an increasing and diminishing amount of diffused light known as *twilight* and begins and ends respectively when the Sun is 18° below the horizon. The moist atmosphere of an insular position like that of Great Britain may increase this amount to 20° or more, whilst it may be decreased to 16° or less by a dry air as in the deserts of Africa or in Central Asia. Duration of twilight also depends on latitude and varies from about 1h. 10m. at the Equator to more than two hours in latitude 50°. It may also be mentioned that there is no real night in the latitude of London from 26th May to 20th July, being either daylight or twilight.

A new factor has been introduced into *Whitaker's Almanack* called "civil twilight," which is defined as the time when the Sun's centre is less than $7\frac{1}{2}$° below the horizon.

* This point was in Taurus at the dawn of history.

To conclude this chapter upon the globe on which we live it is interesting to consider that its mean density is about $5\frac{1}{2}$ times that of water. This shows that a portion of the interior must be much more dense than the exterior. The area of the surface of the Earth is about 197,000,000 square miles, three-fourths of which is covered with water.

COMPARATIVE SIZES OF THE SUN & PRINCIPAL PLANETS.

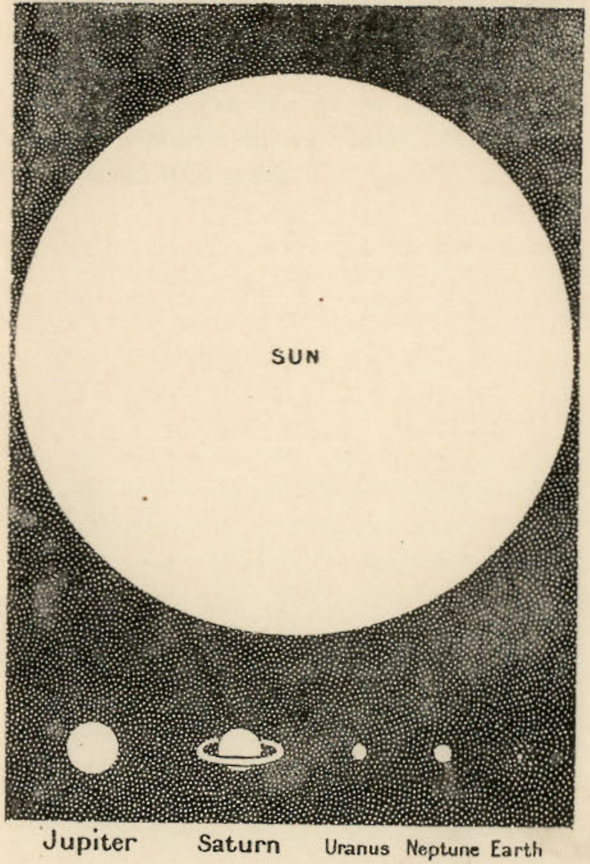


PLATE I.

Mercury, Venus, and Mars drawn to the same scale would be mere dots, being smaller than the Earth.

[Reproduced from "Celestial Motions," by W. T. Lynn, B.A., F.R.A.S., by permission of The Athenæum Press.]

[*To face page* 11.

CHAPTER II.

THE SUN.

THE Sun, the great centre of the Solar System, of which the Earth, as we have already said, is a small member, has a diameter of 866,200 miles, being about 109 times as great as the Earth's, the Sun's volume containing the Earth's about 1,306,300 times. The mean density amounts to only about 0.25 that of the Earth, which is shown by the comparative effects of their attractive forces, which indicate that the Sun's mass is only about 332,260 times as great as that of the Earth, which we note is only one quarter of the ratio of volume. (Plate I.)

With regard to the shape of the Sun, unlike that of the Earth, it is practically a perfect sphere.

To give some idea of the immense size of the Sun, the diameter which we have mentioned is almost equal to twice that of the elliptical path of the Moon round the Earth.

The mean distance of the Sun from the Earth calculated from measurements of his *parallax* is about 92,840,000* miles varying from about 91,400,000 in January to about 94,400,000 in July. The parallax employed was the one arrived at during the observations of the opposition of the minor planet Eros in 1900 and 1901 by Mr. A. R. Hinks, F.R.S. (see Glossary, *Eros*), when it was proved that the most consistent value was 8.806″, with a possible error of 0.02″. The Eros and

* These figures have entirely superseded those previously arrived at from observations of transits of Venus in 1874-1882.

other values have quite superseded the transit of Venus determinations formerly employed.

At more or less regular periods the Sun's disc shows black spots of various sizes, some being so large that the Earth could be dropped into and lost within the space they occupy. It is considered that these sun-spots show that our luminary is an incipient variable star, that in the course of millions of years his light and heat will be so affected by the formation of crust on his surface that life will no longer be possible on the Earth or any of his other planets.

It was through the motion of sunspots that it was first noticed that the solar orb had a slow rotation on his axis, the first to observe this being John, the son of David Fabricius, of East Friesland, in 1611.

A spot first appearing on the Sun's disc, if sufficiently long-lived, would appear in the same place again in about 27 days; allowing therefore for the simultaneous motion of the Earth around it, it is inferred that the Sun turns on his axis in about 25d. 7h. Spots near the Sun's Equator move rather more quickly than those further away from it; they are seldom seen at a greater distance from it than about 30° on either side, and these take 26½ days to go round. Fig. 3 gives a rough idea of some typical sunspots.

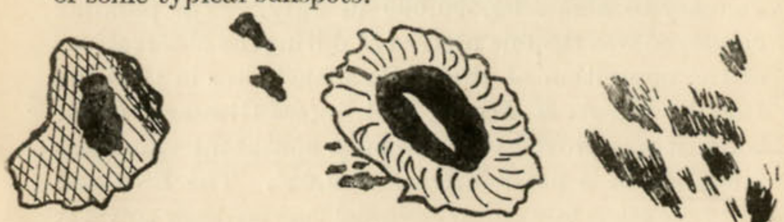


FIG. 3.—Some Typical Sunspots.

When we wish to take solar observations at a time when the Sun is high in the heavens it is better to use a solar diagonal eyepiece, or else the projection method. This last method is by far the simplest and best for the ordinary amateur astronomer, as there is no fear of damage to the sight and several people can observe sunspot and other phenomena at the same time ; it is also handy for observing eclipses (fig. 4). This photograph was taken in this way during the eclipse of the Sun of 28th May, 1900.*

FIG. 4.—Partial Eclipse of the Sun, May 28, 1900.

The means employed by the author to observe the Sun by projection are as follows:—Find a window facing the point at which the Sun will be situated at the time when we wish to make our observation. Having opened the window draw some thick curtains of dark

* Should we wish to make a careful study of solar phenomena we must of course use direct vision.—D. W. H.

material across it in such a way that they join in the centre of the window so that the object-glass end of the telescope can be thrust through in order that the only direct sunlight entering the room is that which comes through the telescope tube itself. An artist's easel is then placed with a large piece of white cardboard upon it in such a position that the rays of the Sun coming

Fig. 5.—Faculæ on the Sun's Limb, August 25, 1883, 9.40 p.m.

through the telescope fall directly upon its centre; then, if the instrument be properly focussed for the distance of the cardboard screen, the sunspots, faculæ (fig. 5) and prominences can be viewed with ease and comfort. If an ordinary eyepiece is employed, however, the telescope must be frequently moved to one

side, or in azimuth, as it is called, so as to get the Sun temporarily out of the field of view, or the glass of the eyepiece will be cracked with the heat.

A frequent mistake of amateur novices is to use too high power eyepieces when observing the Sun and Moon. The proper powers to use are ×50 for the former and ×80 for the latter.* It should be remembered that high powers do not *always* improve definition and considerably curtail the field of view.

Before leaving the subject of the Sun we must point out the origin of the present accepted theory of the Solar System.

Pythagoras, of Samos, was the first to hold that the Earth and the other planets circled around their common centre the Sun, and the doctrine was certainly taught by Aristarchus, of the same place, about two centuries later, the third before Christ. Unfortunately, however, this theory was rejected by the great writer, Claudius Ptolemy, of Pelusium, in Egypt, about A.D. 140, who believed that the Earth was fixed in the centre of the Universe, and that not only the Sun, Moon, and planets, but the stars as well, moved round once every 24 hours!

This (to us) extraordinary doctrine, known as the *Ptolemaic System*, continued to be credited till Copernicus reinstated the older theory, which became known to us as the *Copernican System*, or that theory of the Solar System which places the Sun in the centre. The book of Copernicus on the subject was not published until 1543, the year of his death.

* More advanced students can, of course, employ very much higher powers, and this is fully gone into in Appendix II.

Among other solar phenomena which must be mentioned are transits of Venus and Mercury and eclipses.

Of the first named it is only necessary to make passing mention, as although, as we have already seen, those of 1874 and 1882 were used for fixing the parallax of the Sun, which has been better determined by other methods; from an observational point of view their interest to the present generation is *nil*, as the phenomenon will not recur till 7th June, 2004.

It is a curious thing from the layman's point of view that the periods of the transits of Venus are so very uneven, being first 8 and then 122 years ; but the reason for this is that the planet first passes across one limb of the Sun, and at the end of the shorter period passes across the opposite limb, and then misses the solar disc for the longer period we have mentioned. This arises from 13 periods of Venus being approximately equal to 8 of the Earth.

With regard to transits of Mercury, the first time this planet was ever seen on the Sun's disc was by Gassendi at Paris on 7th November, 1631. Transits of Mercury are much more frequent than those of Venus. One occurred on 12th November, 1907, which the author observed through passing clouds, through a 4-inch telescope ; another taking place on 6th November, 1914. The next will occur on 7th May, 1924.

We now pass to one of the most interesting subjects for the amateur astronomer, but unfortunately they are not usually available for those who can only observe from their home stations.

In 1921, on 8th April, however, there was an annular

eclipse of the Sun in Scotland, the first visible in the British Isles since 1858, and on 29th June, 1927, the first total solar eclipse visible in England since 1724 will occur. We can only hope that fine weather will allow the latter to be observed.

Even the sailor, constantly travelling round the world, may be always in the wrong spot at the time of a total solar eclipse.

To give an idea of how eclipses of the Sun apparently wander about the globe, and the great difference in the duration of totality, we give herewith a short list of a few recent eclipses:—

Date.	Locality.	Duration of Totality.
1896 Aug. 9	Vadso, on Varanger Fjord, Norway	.... 1 min. 46½ sec
	Nova Zembla	.... About 2 min.
	Upper Lena, Siberia	.... 2 min. 42 sec.
1898 Jan. 22	India	.... About 2 min.
1900 May 28	U.S. America (Southern States)	About 1½ min.
	Portugal (Oporto)	.... About 3 min.
	Spain	.... About 2 min.
	Algiers	.... About 1 min.
1901 May 18	Mauritius	.... About 3 min.
	Sumatra (Island of Aoer Gedang)	.... 6 min. 21 sec.
	Sumatra (Sawah Leonto	.... 5 min. 47 sec.

A list of future solar eclipses visible in Great Britain is given in Appendix III.

The last total eclipse of the Sun in London was in 1715 and the last of these phenomena visible in Great Britain generally was in 1724.

The four largest solar eclipses of recent years visible in Great Britain were those of May, 1900, August, 1905, April, 1912 and April, 1921.

The reason why total eclipses of the Sun are so infrequent and affect such a small portion of the globe is well shown by the accompanying diagram (fig. 6). It

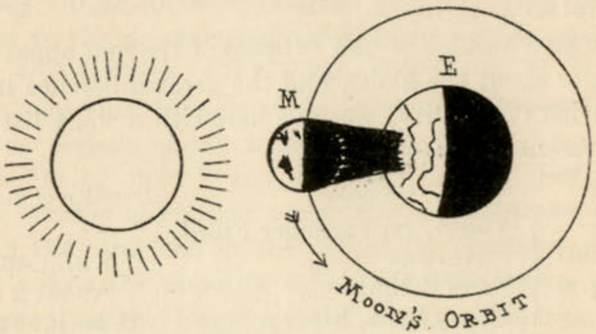


FIG. 6.—S = Sun. M = Moon. E = Earth.

will be seen that the small shadow of the Moon as it falls on the Earth's surface only covers an area of about 170 miles in breadth. In this position totality, or the time during which the Sun is entirely obscured, may last as long as $7\frac{2}{3}$ minutes. This is exceptional, however, as will be seen by the table just given where the longest actual duration was 6 min. 21 sec. in Sumatra, on 18th May, 1901. This long duration can only occur when the Sun and Moon are in or near one of their nodes* and the Moon is near perigee† and the Earth near aphelion,§

**Nodes*.—The points where the *plane* of the ecliptic cuts that of the Moon's orbit, or generally the intersection of any two planes. The First Point of Aries (mentioned previously) is also called the "Sun's ascending node." †Nearest the Earth. §Furthest from the Sun.

a correspondence of events which, however desirable from an astronomer's point of view, very seldom happens.

The chief interest in a solar eclipse until lately was the study of the construction of the corona, a luminous appendage surrounding the Sun, and only visible during the total phase.

More recently, however, the interest of the professional astronomer has turned towards the verification or otherwise of Einstein's theory of the bending by gravitation of a ray of light from a star near the Sun's limb. It will suffice to say here that the most recent Eclipse Expedition arrived at the conclusion from careful observations that the theory mentioned was substantially correct.

Before concluding our remarks on the Sun we would warn our readers never to study the face of the Sun, whether during an eclipse or at any other time, unless the eye is properly protected by a darkened glass. If we omit this precaution we render ourselves liable to permanent injury to the retina, which may even end in total blindness.

All good astronomical telescopes have a dark glass cap to screw on the eyepiece, but should we be using a hand telescope, or binoculars, a very easy and efficient method of darkening the eyepieces which the author has often employed is as follows:—

Half fill a saucer with water and place a small piece of camphor in the centre where it will float.

Then having unscrewed our eyepieces from their tubes we light the piece of camphor with a match and holding them at such a height that the smoke can thickly coat the inner side of the eyepiece without danger of the heat cracking the glass we continue the process until it looks a dead black. Then being careful not to wipe the smoky deposit from the glass we screw the eyepiece back into its tube and the instrument is ready for observation of the Sun.

The advantage of this method is that, whilst the eyepiece is effectually obscured, there is no dirt to wipe off on face or hands as the smoked surface is inside the tube.

The same object can be achieved for naked-eye observation by smoking two ordinary pieces of glass about 6 inches square and then placing the two smoked surfaces together, binding round the edges with music-tape.

If we examine the Sun through a spectroscope we find the spectrum to be as in the accompanying diagram (fig. 7). We see a number of dark lines crossing the

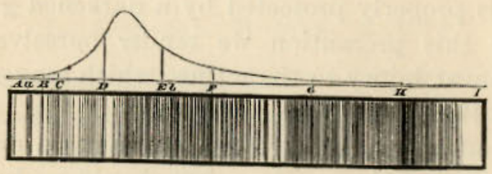


FIG. 7.—The Solar Spectrum.

solar spectrum parallel to the upright slit of the spectroscope. These lines are called Fraunhofer's lines.

The peculiarity of these lines is that each dark line in the solar spectrum has been found to correspond with a bright line in the spectrum of various coloured flames. Thus a certain dark line in the yellow portion of the solar spectrum coincides with the yellow line in the

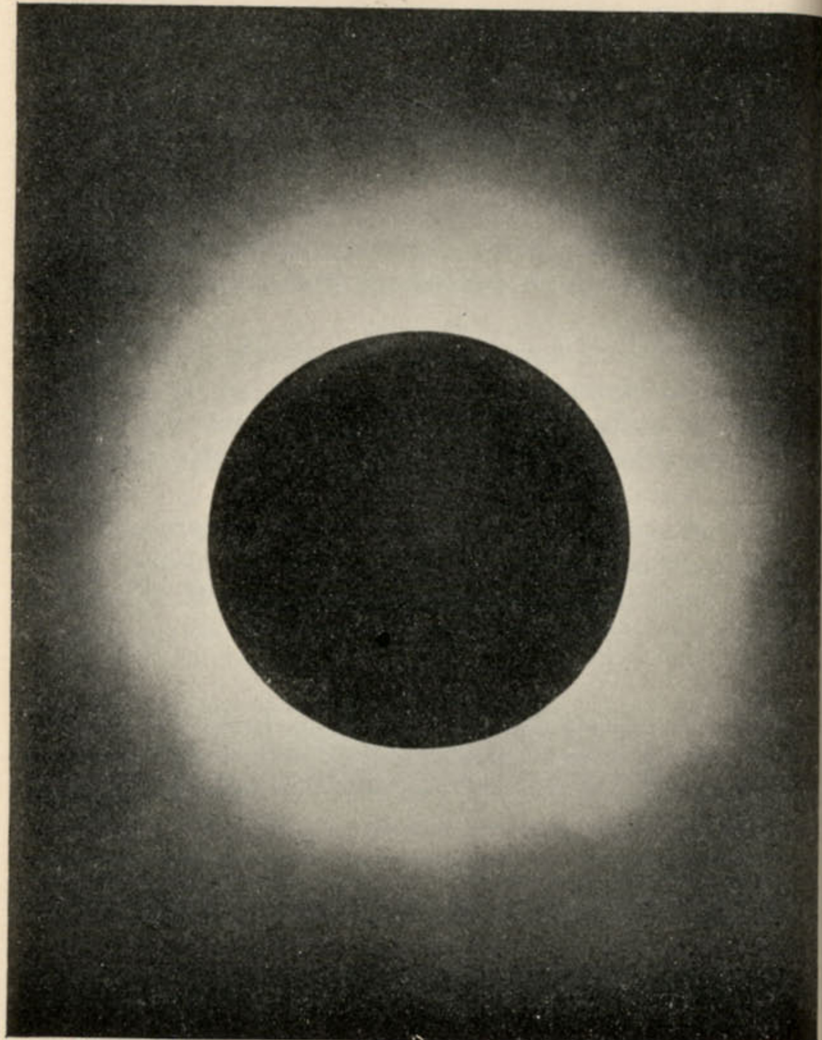


PLATE II.—Total Solar Eclipse of August 30th, 1905, showing the Corona.
[*Photo by Father Cortie, S.J., Stonyhurst Observatory.*

[*To face page* 21.

spectrum obtained from the burning salted wick of a spirit lamp.

It is from the spectroscopic examination of the Sun that the theory of the chemical properties of the orb of day has been arrived at, for we can artificially produce similar effects in the laboratory, and by comparison with observations of the Sun itself deduce results from similar phenomena and so find out the composition of the Sun. The meaning of these dark lines was discovered by two German philosophers, Kirchhoff and Bunsen.

Before leaving the subject of the Sun we must further describe the corona seen to surround the solar orb during total eclipses. It is a halo of white light of which some of the streamers (plate II.) extend to several millions of miles from the body of the Sun himself. These streamers are closely connected with the prominences, enormous flames of glowing hydrogen enveloping the Sun and rising to great heights at tremendous velocities, sometimes extending 300,000 miles above the solar surface.

The shape and size of the corona alters according to the sunspot period, being different at maximum or minimum. It would appear to be composed of gases, partly self-luminous and partly reflecting the light of the Sun. The coronium line, showing a gas only known in the corona, was discovered spectroscopically by Prof. Young in 1869, but the nature of coronium is still unknown.

CHAPTER III.

THE MOON.

IT is well known that our Earth is accompanied in her annual journey round the Sun by a satellite which we call the Moon.

Owing to the proximity of the orb of night more is known about her than of any other celestial body. When we compare her distance with that of the Sun it seems relatively insignificant, being only about 238,000 miles, which is her mean distance from us ; when in *apogee* she is 253,000 miles distant; in *perigee* she approaches the Earth to within 222,000 miles.

Although to an observer on our globe she appears such an apparently large object in the sky, her disc having a diameter of over half a degree of arc, being equal to that of the Sun, yet in reality she is one of the smallest members of the solar system, her diameter being only 2160 miles, or about three-elevenths that of the Earth.

It will be remembered that in speaking of the Sun we mentioned that his distance had been arrived at by observations of his parallax, which was only 8.80″, the Moon's parallax is as much as 57′ 3″, which gives the much less distance already referred to.

The most casual observer will have noticed that from time to time the apparent path of the Moon is higher

PLATE III.

Full Moon, showing "Lady in the Moon."

(In this picture we see the Moon with the South Pole at the bottom ; that is, as it appears through a pair of binoculars, or "look-out" telescope. Fig. 8 shows her as observed through an astronomical telescope, *i.e.*, *inverted*.)

[*To face page* 23.

or lower than that of the Sun at midsummer or mid-winter respectively; this is caused from the fact that its plane is inclined to that of the ecliptic, or Earth's orbit, by a mean value of 5° 8′ 40″, and she may wander as far as 5° 17′.

On account of the fact that our satellite turns on her axis in exactly the same time as she takes to revolve around us, we only see one side of the Moon. If we look at this through a 3-in. astronomical telescope we can see the markings on the lunar surface as shown in the illustration (fig. 8).

FIG. 8.—The Moon as seen through an Astronomical or Inverting Telescope.

The bright spot near the top of the picture with rays running therefrom, giving the Moon the appearance of a somewhat shrivelled orange, is the crater known as Tycho (fig. 9). Halfway down is another bright

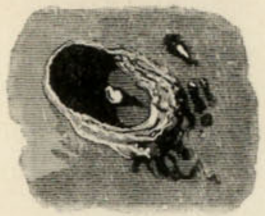


FIG. 9.—Tycho. Age of Moon 9¼ days.

formation known as Copernicus (fig. 10), but as this is not a treatise on Selenography it is unnecessary to enter further into the details of the lunar landscape.

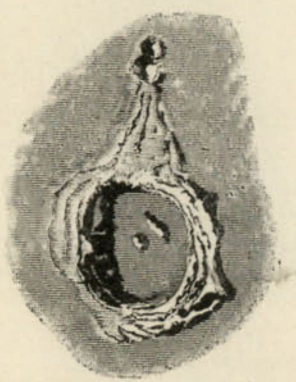


FIG. 10.—Copernicus. Age of Moon 10¼ days.

Suffice it to say that the bright spots are mountain ranges or volcanoes, whilst the dark patches, although they bear the names of "seas," are in reality arid deserts, there being practically no water on the lunar surface.

In proportion to the size of the globe the mountains of the Moon are very much higher than those of the Earth. Mont Blanc, in the lunar Alps, is about 12,000 feet high whilst some of the peaks in the Apennines rise to more than 18,000 ft., one in the Caucasus attaining an elevation of 19,000 ft. above the plain. When we consider the small diameter of the Moon the heights of these mountains are very great. It must, however, be remembered that if terrestrial mountains were measured from the sea bottom they would be much higher.

We have already said that owing to the Moon turning on her axis in the same time as she revolves round the Earth we only see one side of our satellite, except for a small portion due to *librations*, therefore there has been some speculation as to what the invisible hemisphere may be like. It is probable that it is similar to the portion of the Moon with which we are familiar, as both sides of our satellite experience the same conditions for alternate periods of 14.765 days, that is to say, each hemisphere enjoys about a fortnight of continual sunshine, and then for a like period is plunged into total darkness and intense cold.

It must not be supposed that during the lunar day which, as we have seen, is roughly 15 of our days in length, that the heat engendered at the Moon's surface is very great. On the contrary, during the long night temperature is thought to fall very near to the absolute zero, consequently the solar rays are only able to raise the temperature at the Moon's surface to between 30° and 40° F.

These figures have been arrived at from most refined observations made by Mr. Langley with his bolometer.*

It must be understood that the Moon receives the whole of her light from the Sun; in other words she is a huge mirror reflecting back the solar rays in a diluted form. This is what causes what are called *Phases or Changes of the Moon*. The accompanying diagram (fig. 11) will show the cause of the phases of the Moon

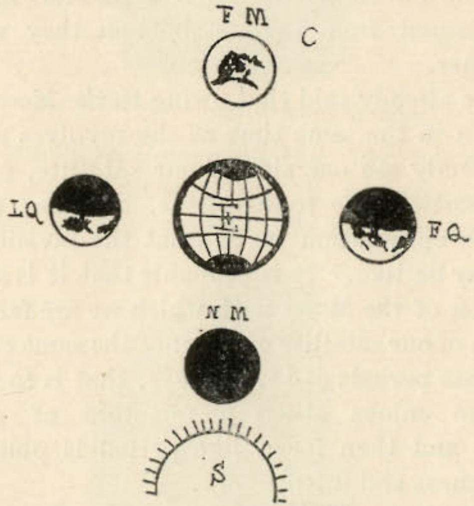


FIG. 11.—Showing the cause of the Phases of the Moon.

better than any written description. If we look at the Moon some time between new and first quarter, when she is visible in the daytime, we shall notice that she is illuminated on the western limb or right hand side; if

* Some astronomers contend, however, that the lunar rocks attain a much higher temperature than this, averring that under a high Sun they would reach a temperature near that of the boiling point of water (212° F.).

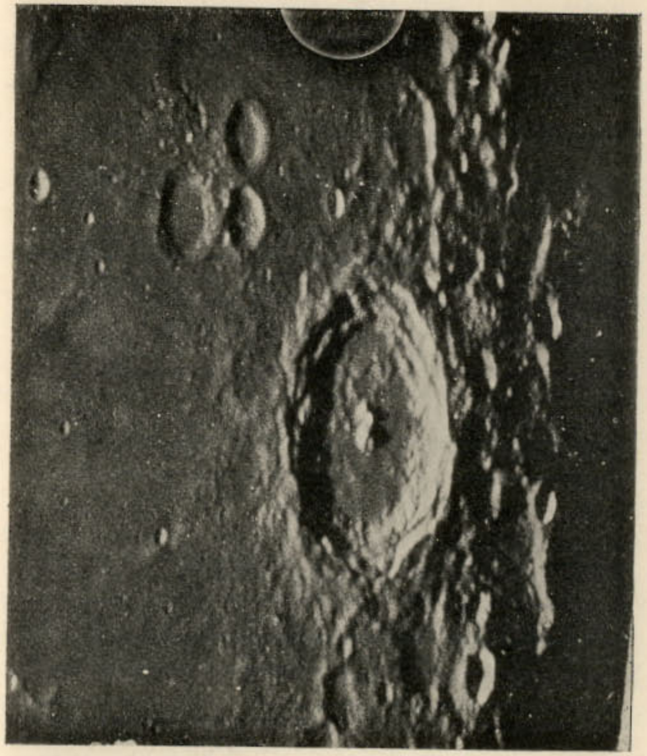


PLATE IV.—The Lunar Crater Langranus. (Waning Moon.)

[*Photo by M. Puisseux, Paris Observatory.*]

[*See page* 25.

on the contrary we observe her between full and last quarter in the morning, we shall see her eastern limb or left hand side illuminated. If we carefully consider the cause of this appearance of the Moon at different periods of a lunation it is quite obvious that in the first case mentioned the Sun is situated or the right hand or illuminated side of the Moon, whilst in the second case he is on the left hand aside, which is then the illuminated portion, thus conclusively showing that the Moon receives the whole of her light from the Sun. Unfortunately her *albedo*, or light-reflecting power, is very low, were it as high as that of Venus, when the Moon was full we should enjoy a night landscape under a light about five times as bright as that now received.*

As things are, the actual amount of light received by us from the full Moon is about $\frac{1}{500000}$ that which we receive from the Sun.

Some attempts have been made to find whether the Moon radiated sufficient heat to affect us on the Earth, but the amount, though perceptible in refined instruments, is very small.

Owing to the Moon's proximity to the Earth an exact knowledge of her apparent motion among the stars was at one time of immense practical utility in navigation, as it enabled the mariner to find his longitude at sea. There used to be difficulty in this problem, however, which has exercised the labours of many distinguished mathematicians; it arises from the perturbations to which the Moon's elliptic motion round the Earth is subjected through the gravitating action of the Sun

* The low *albedo* of the Moon is primarily due to her lack of atmosphere and therefore of cloud.

and even of some of the planets.* This difficulty has now been fully surmounted by mathematicians.

The "*Harvest Moon*" is distinguished by the fact that she rises for several evenings in succession just after "full"† soon after sunset in September, and was so named from its usefulness in giving additional light for the ingathering of the harvest. This "Full Moon" happens most advantageously when the angle of the ecliptic (or Moon's orbit nearly) and the horizon, at moonrise, make the least angle, being when the *sign*‡ Aries rises and Libra sets. On the contrary, when Libra rises and Aries sets the angle of the ecliptic (or Moon's orbit nearly) and the horizon is the greatest. So it will be seen that the September "Full Moon" gives the most prolonged amount of light and the March one the shortest.

When the "Harvest Moon" at rising happens to be at the beginning of Aries, and near her nodes, the angle that the Moon's orbit then makes with the horizon will be least, or nearly so; and therefore her depression below the horizon for one day's motion or more will be least also, when she will rise soon after sunset for some days. This always happens about the autumnal equinox, when the intervals of her rising on two successive evenings may be as small as twenty minutes.§

* Lunar distances have now fallen into disusage among navigators.

† The proper astronomical term for "Full Moon" is "Moon in *opposition*" (*i.e.*, directly opposite the Sun). "New" is called *conjunction*.

‡ Constellations of Pisces and Virgo respectively. The Full Moon nearest to the autumnal equinox is the "Harvest Moon," so that this year (1922) it is in October.

§ In high latitudes she may actually rise *earlier* on the following evening.

We now come to lunar eclipses.

It must be clearly comprehended that the cause of an eclipse of the Moon is the *Earth's* shadow, and is quite distinct in origin from the Moon's *phases*. It seems necessary to mention this, as many persons may be met with who appear to hopelessly confuse the two phenomena. Now it has already been pointed out that she receives the *whole* of her light from the Sun, simply acting as a large mirror* and reflecting the solar rays back to the Earth. Therefore it will readily be comprehended that if an opaque body, such as the Earth, happens to come directly between the Sun and the Moon, then necessarily the solar rays will, for a time, be shut off from the Moon, and thus she will present a dark face to us until our globe has sufficiently fallen behind her in her orbit to leave her basking once more in the ardent rays of the orb of day.

The Earth, being so much larger than the Moon, is capable of cutting off sunlight from the lunar disc for a space of about 1¾ hours, which, in comparison with the duration of totality in a solar eclipse, is sufficiently striking, and affords ample proof of the relative volume of each orb and converts theory into fact. Although, as we have seen, the *total phase* of a lunar eclipse may last not quite two hours, yet from beginning to end the phenomenon endures for an even more extended period, sometimes prolonged to over three hours, whilst from first to last "contact" with the *penumbra* an interval of more than six hours may elapse. Why the Moon

* It must not be supposed that by this simile we mean to imply regular reflection; we merely give it to show that the Moon has no light of her own; only reflected sunlight.

seldom, if ever, completely disappears during an eclipse is due to sunlight refracted by the Earth's atmosphere.

The reason the Moon is not eclipsed at every opposition, as would appear at first sight inevitable, owing to the relative sizes of the Earth and her satellite, arises from the inclination of the Moon's orbit with respect to the ecliptic (or Sun's apparent path). It may possibly have struck some observant reader that in 1913 in summer the "Full Moon" appeared relatively lower in the southern sky than did the Sun in December, and *per contra*, the Sun in June never seemed to attain such an altitude at midday, as the winter "Full Moon" at the time of "southing" at midnight. In 1922 this state of things will be reversed, and the extreme apparent declination attained by the Moon will be but 18° north or south of the Equator as compared with 28° in 1895 and 1913. This is caused by the Moon's orbit being inclined to that of the Earth, so that our satellite is sometimes apparently raised about 5° *above*, and at others depressed about 5° *below* the ecliptic, or apparent path of the Sun. This is the chief cause of the irregularity of not only lunar but also solar eclipses, as the Moon, owing to her irregular path in the heavens, not only escapes the Earth's shadow more often than not, but also misses coming between us and the Sun for similar reasons. It is only, therefore, when the Moon comes into *opposition* (*i.e.*, is "Full"), when she is within 12° of one of her nodes*, or point where her apparent path cuts the ecliptic, that a lunar eclipse (either total or partial) can take place. If the Moon is at a greater distance

**Nodus*, a knot.

from the point mentioned than 12°, she passes outside the zone of the shadow of the Earth, and no eclipse can occur.† Fig. 12 clearly shows the cause of a total eclipse of the Moon.

Other phenomena of special interest to observers are

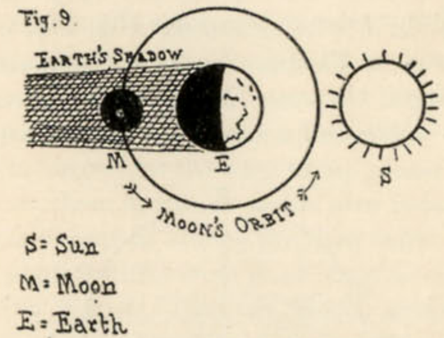


FIG. 12.—Showing the cause of Eclipses of tne Moon.

FIG. 13.—Occultation of λ Geminorum, March 6, 1884, power 80.

† Every time the Sun passes either of the Moon's nodes, that is about every six months, there *must* be one eclipse and *may* be three, in which case two are solar and one lunar.

occultations, because, even to the unaided eye, one of a 1st or 2nd magnitude star, or, better still, of a planet, though this is unfortunately of rare occurrence, is a sight worthy a little trouble to observe, whilst, with the assistance of the humble opera-glass, observations of some scientific value can be made by possessors of a reliable chronometer or regulator (fig. 13).

The points of disappearance and reappearance are reckoned from the true N. point and vertex, and counted in degrees of a circle as shown in fig. 14. If

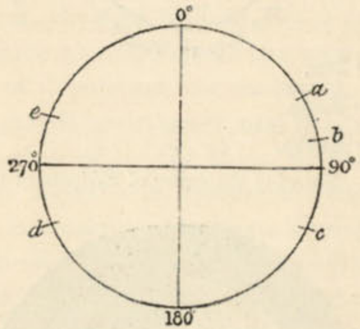


FIG. 14.—Diagram showing angles for observing Occultations.

the angle from N.P. is given as 60° the star or planet would disappear at *a*; if 79° at *b*; 116° at *c*, and so on. Reappearance taking place at 245° from N.P. the star would emerge at *d*; or if 292° at *e*.

CHAPTER IV.

THE PLANETS.

IT is the habit with those uninitiated in astronomical matters to speak of all celestial objects, except, of course, the Sun and Moon, as "stars." It will not be necessary to inform the nautical readers of this book that this is quite incorrect, as the very name *planet* means a "wanderer," as these members of our own Solar System apparently wander about among the *fixed stars*.

Again the planets differ from fixed stars from the fact that whilst the planets, like our Moon, shine by the reflected light of the Sun, the stars are suns in themselves, shining by their own light and many of them possibly carrying systems of planets with them similar to ours.

The planets of the Solar System with which we are now dealing to all intents and purposes apparently revolve around the Earth in the plane of the ecliptic, in other words from the point of view of an observer on our globe they never seem to move many degrees away from the Sun's apparent path in the celestial vault.

The path of the planets being roughly that of the Sun, within a limit of 5° on either side, they appear to vary in altitude from time to time as does the orb of day.

The planets, however, have a *real* motion in addition to the apparent one just described, which latter motion is caused by the rotation of the Earth on its axis. Owing to their real motions they do not go through their changes in height with the same regularity as the Sun, but on some occasions will remain high or low in our skies for a long period.

As we have already said, these bodies, like our satellite the Moon, are merely a number of "mirrors"* reflecting the light of the Sun, which they do in greater or less proportion according to their size, distance, and *albedo*. This last is perhaps the most important factor in deciding the brightness of a planet, because although Jupiter is very much further away from us than Venus, he may at some oppositions appear as large and bright as the latter planet.

Of course Jupiter is much larger than Venus, his diameter being about 88,500 miles; Venus being only 7,700 miles in diameter or rather smaller than our Earth. But at the same time it is chiefly the large albedo, or light-reflecting power, of Jupiter that causes him to shine on some occasions as such a resplendent object in our winter skies.† The best determinations of the albedo of Venus make it almost as high as Jupiter's. In this connection it should be mentioned that if a planet come into *opposition* in winter it will be high in the sky, and if in summer on the contrary it will be low. The reason for this is the same which accounts for the full Moon attaining a great altitude in the winter months and a low one in summer; that is, the Sun is low on the former occasion, and high on the latter, being in exact opposition to the Moon or planets as the case may be, hence the name.

* This simile has been objected to as suggesting a too regular degree of reflection, but it will best convey what is meant to the lay mind.

† The high albedo of Jupiter and Venus is due to their thickly clouded atmospheres; it is practically the same for the two planets.

It may seem curious to the reader who may be entirely uninitiated in astronomy that after having so carefully explained the meaning of *opposition* the first two planets with which we have to deal never come into opposition at all!

The first of these is Mercury, which never leaves the neighbourhood of the Sun by more than 28° 14′ east or west, which is called his *greatest elongation*. When Mercury is said to be at greatest elongation east he is an "evening star" according to the almanacks. These evening apparitions are best observed in February and March, the morning apparitions, or elongation west, are an autumn phenomenon.

FIG. 15.—Mercury, 15th Sept., 1885, power 160.

On these rare occasions when this elusive planet escapes sufficiently far from the solar rays, he may be seen for about five evenings or mornings in succession at about an hour after sunset, or the same interval before sunrise, as a pale pink "star" close to where the Sun has just set or is about to rise.

With the aid of a 3-in. telescope we can easily discern the fact that this little planet has phases like our Moon (fig. 15), but although he can appear crescent-shaped or gibbous, he can never appear full as he is unable to come into opposition with the Sun.

Mercury's year, or the time occupied in going round the Sun, is 88 days long, the planet's day, or period of axial rotation, is a matter for doubt, one theory being that he revolves on his axis in exactly the same period as he takes to go round his primary; another theory being that he revolves on his axis in about 24 hours.

This planet is at best a very difficult object for the amateur, as at its most favourable elongation it only shows a disc of 13″ diameter.

The poet John Milton gives us the following exact description of Venus, the next planet on our list:—

. . . "Hesperus that led
The starry host rode brightest."

That this is a fact one has only to recall apparitions of this planet when at greatest brilliancy she adorns the morning or evening sky.

Venus, also called Hesperus, Aphrodite, and Lucifer, like Mercury, can never come into opposition with the Sun; in other words, she never appears on the meridian at midnight; however, her elongation east or west is much greater than Mercury's, being as much as 45°, which enables Venus to appear at comparatively great altitudes above the horizon before sunrise or after sunset.

Like Mercury, with a 3-in. telescope Venus shows all the phases of the Moon except that of full (fig. 16).

To take her appearance as an "evening star", or as she appears at greatest elongation east, we must accompany her in imagination from the time when being in superior conjunction (that is, on the opposite

side of the Sun to that occupied by the Earth) the planet gradually draws away to the eastward, and night after night becomes a more brilliant object in the evening sky. This journey away from the Sun takes 218 days; after this Venus travels almost directly towards us for a period of 35 days, and, being nearest the Earth, is at greatest brilliancy, and will then even throw a faint shadow on a piece of white paper.

So quickly does she renew her journey towards the Sun that 36 days later Venus is completely lost in the solar rays. Now, however, the planet is in inferior conjunction with our central luminary, passing on the side nearest the Earth.

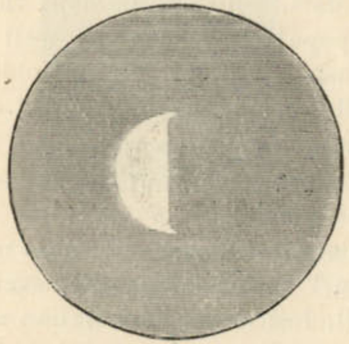


FIG. 16.—Venus, power 160.

The sidereal period of Venus, or to put it another way her "year," amounts to 225 of our days. The rotation period has been put at 23h. 21m., but there is some doubt as to its accuracy, owing to the illusory nature of the markings on the planet from which it was calculated. The cloudy surface of the planet renders exact knowledge impossible.*

The distance of the planet from the Sun is about 66 millions of miles, and her diameter is about 200 miles less than that of the Earth; indeed she may be taken as being almost the same size.†

The comparative size of the principal planets and of the Sun are well shown in plate I. (p. 11).

Had we not already treated of the Earth, it would, as a planet of the Solar System, come next in our catalogue, as it is the third in order of distance from the Sun; but as we have previously mentioned our own globe in its relative greater importance to ourselves as that upon which we live and have our being, we will pass on to the "red planet" Mars, which is perhaps that which has caused more popular interest, as well as scientific controversy, than any other celestial object.

This is chiefly owing to the "canals" discovered by the Italian astronomer Schiaparelli in 1877.

Many and various have been the explanations as to the cause of these canals.

In the first place it is objected by what may be termed the "opposition," that Schiaparelli never called them "canals" at all, but *canale*, an Italian word meaning "channels"; others have contended that these markings are an optical illusion. In any case giving the phenomena the English name canals has largely been the cause of Mars being considered the only other planet of our system inhabited by human beings similar to

* Some astronomers favour the theory that, like the Moon and probably Mercury, Venus turns on her axis in the same time as she takes to go round the Sun.

† Venus has been called "The Earth's Twin Sister" for this reason.

ourselves; for it was natural to assume that if there were canals on Mars, which we know as artificial man-made waterways on the Earth, then there must be men to make the canals on Mars!

Prof. Lowell, observing with a 24-in. telescope at Flagstaff, Arizona, showed the canals very distinctly in his drawings, and suggests that they are artificial waterways conveying water from the melting polar snow-caps to the arid regions near the Equator. M. Antoniadi, observing near Paris, did not show the canals with such definite detail. Dr. Crommelin commenting upon these observations* states that both observers are certainly in good faith, and it is very

FIG. 17.—Mars, power 204.

difficult to judge which is correct. Even photographs of these markings do not agree, and Prof. Pickering considers that the lines are caused by volcanic action, where the crust has been fractured as on the Moon.

Fig. 17 gives a good general view of Mars as seen with a 3-in. telescope using a power of 204. The chief marking is that commonly known as the "wine glass," which is well shown in the engraving.

Mars is best observed telescopically at time of opposition which takes place once in a little over two

* *The Star World*, by A. C. D. Crommelin, F.R.A.S., p. 101.

years, but not every opposition is a favourable one, those occurring in August being the best, whilst those taking place in February are the least satisfactory.*

During recent years the most remarkable oppositions were those of August in 1877, and in the same month in 1892, 1907 and 1909.

In 1877 Prof. Asaph Hall, of Washington, U.S.A., discovered that Mars is attended by two very small satellites, or moons, to which he afterwards gave the names of Phobos and Deimos respectively. The one nearest to Mars, which is Phobos, is the brighter of the two, and is probably slightly larger, but even then it is not more than 30 or 40 miles in diameter. This little moon goes round Mars in about 7h. 39m., or less than one-third of the time taken by the planet himself to turn on his axis: the outer satellite takes about 30h. 18m. to go round his primary. The distance of Phobos from Mars is so small that it is less than the radius of the Earth, namely 4000 miles, whilst Deimos is approximately 15,000 miles distant.

"A year" on Mars is equivalent to 687 days, his "day" being almost of equal length to our own, that is 24h. 37m. 23s.

At time of the most favourable opposition Mars presents a disc of about 25″ apparent diameter, and that is the time when we should try the powers of our telescope upon his interesting topography.

It was noticed by astronomers that between Mars and Jupiter there was an apparently unaccountable gap in the generally regular progress of the orbits of the planets of the Solar System.

* See note at end of chapter.

It was suspected therefore that there might be a planet or planets in the space between Mars and Jupiter, and consequently six astronomers formed an association for research for the missing bodies, with the result that very soon the little planets now known as the asteroids, planetoids, or minor planets, were brought to light.

The first discovery was made on 1st January, 1801, and this asteroid was called Ceres* and since then they have continued to be discovered in such large numbers that they now number about 1100.

These objects are scarcely within the scope of a treatise of this kind, for only five of these little planets are of interest to the owner of a small telescope; these are Ceres, Pallas, Juno, Vesta, and Eros when nearest the Earth. The brightest of these is Vesta, which is sometimes even visible to the naked eye as a sixth magnitude star; the other four are about the seventh magnitude and may be classed as telescopic objects, though of course these, as well as the planets, may be well observed with a good pair of binoculars; indeed on board ship it is doubtful whether the binoculars would not be preferable to a telescope.

A gyroscopic mounting is necessary when using a telescope at sea, except, of course, the small telescope of a sextant and the ordinary "look-out" telescope.

To return to the minor planets; the largest of these bodies does not exceed about 400 miles in diameter.

The discovery of these minute planets is now made entirely by photographic methods. A plate is exposed for a long period on a certain portion of the sky, the equatorial mounting of the camera following exactly the

* Ceres was discovered independently of this search.

slow motions of fixed stars; on development the stars make their presence known by points of light on the plate, the planetoids showing as streaks owing to their own proper motion. On examining the plates, if a new streak is found, which has not been noted previously, then it is considered that a new asteroid has been discovered.

The most important body of this kind discovered in recent years is "Eros," found by Prof. Witt at Berlin

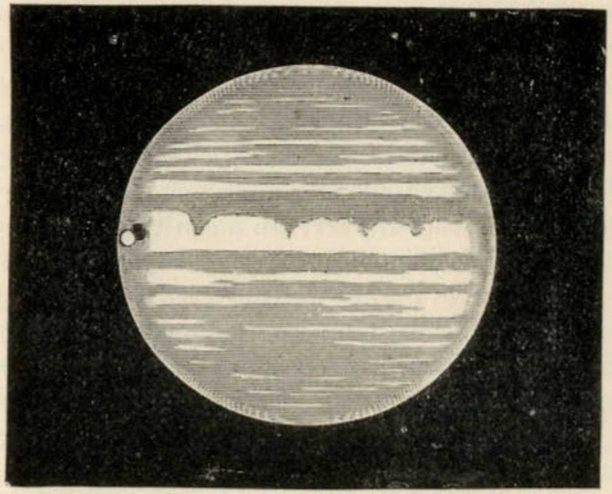


FIG. 18.—Jupiter, with a Satellite in Transit, power 150.

in 1898, and which at certain intervals approaches the Earth much more nearly than does Venus or Mars. It is somewhat remarkable, considering the powerful telescopes employed, and the almost ubiquitous use of the photographic camera, that this small planet was not discovered earlier; possibly it may have been

glimpsed, but not observed sufficiently for recognition as a planet. Perhaps, too, it may vary in its light.

We now come to the giant planet of the solar system—Jupiter—his diameter being 88,439 miles, so that roughly the Earth's diameter would go into that of the planet about ten times (fig. 18).

Jupiter is one of the most interesting planets for the amateur telescopist, or for the user of a good pair of binoculars, or even for the observer possessing an ordinary opera or field-glass. The reason for this is that this planet possesses four comparatively large satellites, or moons, whose mutations around and about Jupiter form an endless variety of interesting phenomena for the observer (fig. 19).

FIG. 19.—Jupiter, and his Four Principal Satellites.

The discovery of these moons was the immediate result of the invention of the telescope by Galileo in the early part of the seventeenth century.

The late Mr. W. T. Lynn, in his frequent letters to *The Observatory* magazine, drew attention to the fact that in all probability one Simon Mayr independently discovered these satellites very soon after Galileo; in any case Mayr gave them their names, which are—Io, Europa, Ganymede, and Callisto. Although these little moons bear such high sounding names, their cognomens are entirely ignored by professional astronomers, to whom they are known simply as "Satellites I, II, III, and IV." They are numbered in order of distance from their primary. No. III. is the largest, Nos. I. and II. being smaller than our Moon. No. I, probably owing to his close proximity to Jupiter, is quite different in shape to his fellows.

In *Whitaker's Almanack* is given each month the configurations of Jupiter's satellites, which is very useful to Jovian observers.

In 1892 Prof. Barnard, of Lick Observatory, California, discovered a fifth satellite to Jupiter, but as this and all more recent discoveries, bringing the number up to nine at the present time, are far beyond the reach of the optical aid we are now considering, we will not discuss them further.

Although the satellites were not discovered until comparatively recent times, yet Jupiter himself was known to the Chinese and Chaldeans, appearing on a chart made about the year 600 B.C., which contained as many as 1460 stars precisely mapped thereon, and which is believed to be still preserved in the National Library in Paris to this day.

Of Jupiter little can be said with absolute precision, it being held as most probable that, like the Sun, the solid body of the planet is hidden beneath a thick atmospheric envelope, *self-luminous* in the case of the Sun, but, in the case of the planet under discussion merely luminous by virtue of its great capacity for reflecting the solar rays, which is said to be many times that of the surface of our Moon. The theory that Jupiter is not a self-luminous body receives support from observations of his satellites as they pass through their

various phenomena, the eclipse of one of these "moons" being so complete as to lead to the opinion of their receiving *all* their light from the *Sun*, and *none* from the "parent planet".

We may mention here that on 21st August, 1867, *all* Jupiter's satellites were invisible at the same time—an extremely rare occurrence, indeed.*

Jupiter's "year," or, more correctly, his sidereal period, is equal to nearly twelve of our years, and it is this interval which divides the periods of favourable position of the planet for observation in either hemisphere of our globe. An occasion of this sort last occurred in 1918, the next being in 1930, these dates being for the Northern Hemisphere; south of the Equator the next most favourable opposition will be in 1924.

We do not mean to imply by this that Jupiter can only be observed satisfactorily at these distant periods, as is the case with Mars and his period of about two years, for by consulting the various almanacks and ephemerides numerous occasions present themselves for good observations of this planet, the Jovian markings and satellites being a constant source of interest to the amateur astronomer.

Jupiter's "day" is very much shorter than ours, as he turns on his axis in 9h. 55m.† This is the more re-

* The late Mr. Whitmell, F.R.A.S., related in the "Journal" of the B.A.A., vol. ix., pp. 376-8, that he calculated that there would be another occasion on which Jupiter would be "moonless," viz., 22nd March, 1874. He afterwards noted ("Journal" B.A.A., vol. x., p. 223) that Prof. Todd, in the U.S., saw this planet apparently moonless for nearly two hours on that date.—D. W. H.

‡ Equatorial markings on the Jovian surface go round in 9h. 50m.; in temperate zones they take 9h. 55m.—D. W. H.

markable when we take into consideration his enormous size, and seems only compatible with the gaseous condition of a large part of his body.

Owing to the large size and rapid rotation of the planet, Jupiter's figure is very elliptical, that is to say, that directly we observe him with even a moderate sized telescope we notice that he is very much flattened at the poles. This polar compression amounts to about $\frac{1}{17}$, that of the Earth being only $\frac{1}{289}$.

The apparent diameter of the planet as seen in a telescope varies from 30″ to 50″, his mean distance from the Sun being 483 millions of miles.

The speed of Jupiter in his orbit, or annual path round the Sun, is 29,200 miles per hour.

Reverting once more to the satellite phenomena, an eclipse of one of Jupiter's "moons" is similar in principle to one of our own Moon; in other words just as our Moon is eclipsed when she passes into the Earth's shadow, so is a satellite eclipsed when it passes into the shadow of Jupiter. Owing to the smallness of the inclination of their orbits I, II, and III are eclipsed every time they go round Jupiter, but "four" escapes eclipse fairly frequently, this being due to his greater distance from his primary.

In the same way an occultation of a satellite is similar to that of a star or planet by our Moon. The satellite gradually disappears behind Jupiter in the same way as, but less instantaneously, than a star, or, more infrequently, a planet, is hidden by the Moon.

As we have said, these eclipse and occultation phenomena form the chief interest in Jovian observation, though they are rivalled in the idea of some astronomers

by the surface marking on the planet itself (fig. 18 *ante*).

At one time the chief feature was the Great Red Spot to which attention was first called by an American astronomer in 1878 and which, although since remaining visible, has fluctuated greatly in brightness.

There are permanent belts known as the South and North Equatorial Belts among which spots and streaks appear from time to time, but in the author's opinion Jovian topography is rather beyond the powers of a 3-in. telescope; even a 4-in. will not bring up much detail and it will be noticed that observers writing to the press of the beauty of these markings mention the fact that these rare feasts of astronomical observation are only for those possessing a telescope of 6 inches aperture and over.*

The albedo of Jupiter is very large, it being calculated that he reflects back to us considerably more than half the light that he receives from the Sun.

Astronomers have taken valuable photographs of this important member of our system.

We now come in our imaginary journey outwards from the Sun to the planet Saturn, which until the discovery of Uranus by Sir William Herschel in 1781, was considered to be the outermost planet of the Solar System.

The peculiarity of Saturn is that he is the only one among all the planets which possesses a ring, or more correctly, a system of concentric rings surrounding him within the orbits of all his satellites.

Directly a telescope of even moderate aperture is

* See Mr. F. Burnerd's letter in *The English Mechanic and World of Science*, No. 2870, p. 110, letter 95, 26th March, 1920.

turned upon this planet the first thing that strikes the observer's eye, is the ring system except on those rare occasions when it is turned with its edge towards us. This period of Saturn's ring system amounts to about fifteen years, during one portion of which the ring closes up till the edge only is turned towards us, and becomes practically invisible from the Earth, and during the other portion opens out again till it attains its greatest visible breadth. Our picture (fig. 20) gives a good idea of the ring system when fairly well open.

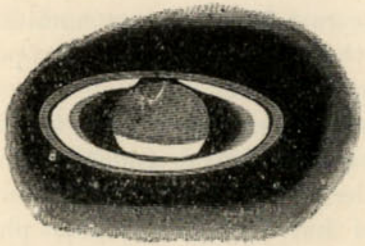


FIG. 20.—Saturn and his Rings, power 204.

Saturn's ring was a great puzzle to the astronomers of the middle ages. When first discovered by Galileo in the seventeenth century he did not recognise the fact that it was an *annulus* surrounding the planet, but deemed it to be attached bodies adhering to Saturn somewhat in the nature of "handles" making, in fact, *tria juncta in uno*. So perplexed did the Florentine astronomer become at his inability to discover the true cause of Saturn's apparent appendage, that he relinquished observation of this planet for some time, and it was not until after his death in 1642 that the real character of

the rings was explained, when Huyghens, in 1656, brought his improved telescope to bear on the subject.

Even then, though Huyghens was able to demonstrate that it was actually a ring of some sort which surrounded Saturn, yet he was no nearer than his predecessor in discovering of what the ring was composed. At that time some considered it to be solid, like the wooden horizon of a school-room globe, others supposed that it was a mass of liquid held in suspension by some means which they were unable to explain.

It was not until 1715 that the real composition of the Saturnian ring system was demonstrated, when Jacques Cassini expressed the view in a paper read before the French Academy that the ring consists of an innumerable multitude of very small satellites, so arranged as to present at a distance the appearance of a thin flat ring with several narrow divisions in its breadth. In 1857 the late Prof. Clerk Maxwell proved theoretically that this is the only possible constitution of Saturn's ring system.

It is interesting to recall that Huyghens' first announced the discovery of Saturn's ring by means of a Latin anagram which was afterwards interpreted to contain the following sentence, *Annulo cingitur tenui plano, nusquam cohærente, ad eclipticum inclinato*, which means—"It is surrounded by a thin plane ring, nowhere adhering to it, and inclined to the ecliptic."

In 1676 Cassini, in France, found a division in the ring; the inner ring being perceptibly brighter than the outer. Since then other smaller divisions have been noted, the most remarkable of these being the dusky or crepe ring inside the two bright rings. This was discovered by the Bonds of Cambridge, U.S.A., in 1850. It is presumed that the crepe ring is caused by the tiny moons of which it is composed being much more sparsely arranged than in the case of those forming the bright rings; that is to say, satellites composing the ring thin out, so to speak, at the edges, as a similar dusky appearance has been noticed outside the outer ring.

The outer diameter of the exterior ring is about 173,000 miles; whilst its inner diameter is about 149,000 miles; the outer diameter of the interior bright ring is about 146,000, its inner diameter being about 111,000 miles. Each particle is revolving round Saturn with its proper period.

Not being satisfied with these myriads of tiny satellites, Saturn is also attended by nine larger moons which are named in order of distance from their primary —Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus, and Phoebe. The first, second, seventh, and ninth, are only to be observed in very large telescopes so that only five satellites are within the scope of a 4-in. telescope.

The largest of these moons is Titan; it was discovered by the same astronomer who first pointed out the true nature of the ring system, namely, Huyghens, the discovery being made on 25th March, 1655.

Iapetus was discovered by Giovanni Domenico Cassini in 1671, who also found Rhea in 1672 and Tethys and Dione in 1684. In the autumn of 1789, just after having completed his great 40-feet reflecting telescope, Sir William Herschel found the two innermost satellites—Mimas and Enceladus. Hyperion had

the honour of being discovered independently by Bond in America and by Lassell in England, in 1848.

As the largest of these moons is only about 2600 miles in diameter, or rather larger than our Moon, it will be seen that although Saturn has such a large number of moons they are none of them of a very great size.

Saturn's equatorial diameter is 75,000 miles, his mass being about 75 times that of the Earth, so that with the exception of Jupiter the ringed planet is larger than any other member of our planetary system.

The sidereal period, or "year," of Saturn is nearly thirty of our years, although he is travelling around the Sun at the immense speed of 21,560 miles per hour, his distance from that luminary being 886 millions of miles.

In connection with the telescopic observation of Saturn and the other planets the author would advise the amateur novice never to look at more elaborate drawings than those given in this book before going to observe the actual object with a 3 or 4-in. telescope.

From experience with a 4-in. instrument the author knows that one can really see what is given in these pages, the drawings here given being actually made at a 3-in. telescope.*

He does not mean by this to cast any doubt upon the splendid drawings made by such masters of astronomical art as Mr. Scriven Bolton, M. E. M. Antoniadi, and others, as such wonderful pictures can be seen with telescopes of 6 inches aperture and over.

In speaking in a previous chapter on suitable powers

* By the late Capt. Wm. Noble, F.R.A.S., who was a most enthusiastic and painstaking *amateur* astronomer.—D. W. H.

of eyepieces for the observation of the Sun, Moon, and planets we recommended the general use of low powers, these being the best for the novice with a refracting telescope with an alt-azimuth stand, as a relatively low power gives a wide field of view and obviates the continual readjustment of the rackwork which is so irritating to the beginner.

When, however, the observer has become accustomed to the adjustments, focussing screw, etc., and has become adept at changing the eyepieces without disarranging the whole apparatus, then, and only then, should he begin to experiment with the higher powers, up to ×204 for Jupiter and Saturn, and up to ×250 if we essay to observe the outer planets Uranus and Neptune, which we shall now proceed to describe. (See Appendix II.)

FIG. 21.—Uranus, power 250.

Uranus* was discovered by Sir William Herschel in 1781 (fig. 21). Its diameter is about 31,000 miles, and its time of rotation on its axis, ("or day") is $10\frac{3}{4}$ hours.

It was something in the nature of a lucky chance that Herschel became the acknowledged discoverer of this planet, as, after the fact had been announced, it was found that this planet had been previously observed by several other astronomers; but these, taking it for

*This planet was named by Herschel the "Georgium Sidus" in honour of George III., and was afterwards called Herschel; hence its sign.

granted that the object was merely a fixed star, passed it over and thus lost for themselves the credit of having made one of the most brilliant discoveries of the age. Especially was this so in the case of a French astronomer named Le Monnier. He had not only made casual observations of this object, but had actually taken the pains to calculate the relative positions thereof at different periods, and yet, so careless was he by nature, that his deductions were merely pencilled on old scraps of paper, which he mislaid forthwith and thus rendered his computations useless.

This little story certainly holds a moral for all beginners in scientific work; it is futile to make the most elaborate calculations or observations if we will not take the trouble to "pigeon-hole" them, so to speak, in such a manner that we can find them at the exact moment when we really want them.

Uranus is attended in his long journey round the Sun, which occupies 84 years, by four small satellites named Ariel, Umbriel, Titania, and Oberon, each only about 600 miles in diameter.

Six years after the discovery of the planet itself, two of these tiny moons were discovered by Herschel, and later on two more were found by Lassell. The sizes were deduced from the amount of light they give.

The motions of these satellites are interesting, as are also those of both Uranus and Neptune themselves for they all rotate *backwards*, as do also the outer satellites of Jupiter and Saturn. It is conjectured that the cause of this is that the solar tides, which cause the direct motion of the inner planets, are weak in the case of the outer ones, hence their retrograde motions.

In speaking of our next planet—Neptune—our discourse must of necessity be historical rather than observational, as in a 3-in telescope, with a power of 250, he resembles an eighth-magnitude star, and is far beyond the optical means we are now considering.

The history of Neptune's discovery is, however, worth briefly relating.

Calculations with regard to the orbits of Uranus showed perturbations in his movements suggesting that there must be another planet still further away from the Sun, yet being a member of the Solar System. Adams in England, and Le Verrier in France, worked out the position of the supposed planet. Having arrived at their conclusions almost simultaneously, Le Verrier informed Galle of the probable region in which to look for the object, and in 1846 Neptune was discovered.

It is curious to note that whilst, through the carelessness of a Frenchman the discovery of Uranus fell to an Englishman, the discovery of Neptune fell to a Frenchman and a German owing to the ill-luck of Adams and Prof. Challis, of Cambridge, England. The latter received the former's calculations in time to make the discovery before Galle had already announced his find and had actually observed the object, but failed to recognise its planetary character. The diameter of Neptune is 33,000 miles and distance from the Sun 2700 millions of miles.

Note on Mars.

The opposition of Mars on 23rd August, 1924, will be absolutely the most favourable one in the 200 years

1800-1999. It so happens on this occasion that the planet will be nearest the Earth on the same day, his distance from us being then only 34,650,000 miles, his angular diameter being 25.1″: compared with his brightness at the opposition of April, 1920, taken as 31, his brilliancy in 1924 will be represented by 100, giving a stellar magnitude of—2.7 or—2.8 at that opposition.

CHAPTER V.

THE CONSTELLATIONS.

The North Circumpolar Stars.

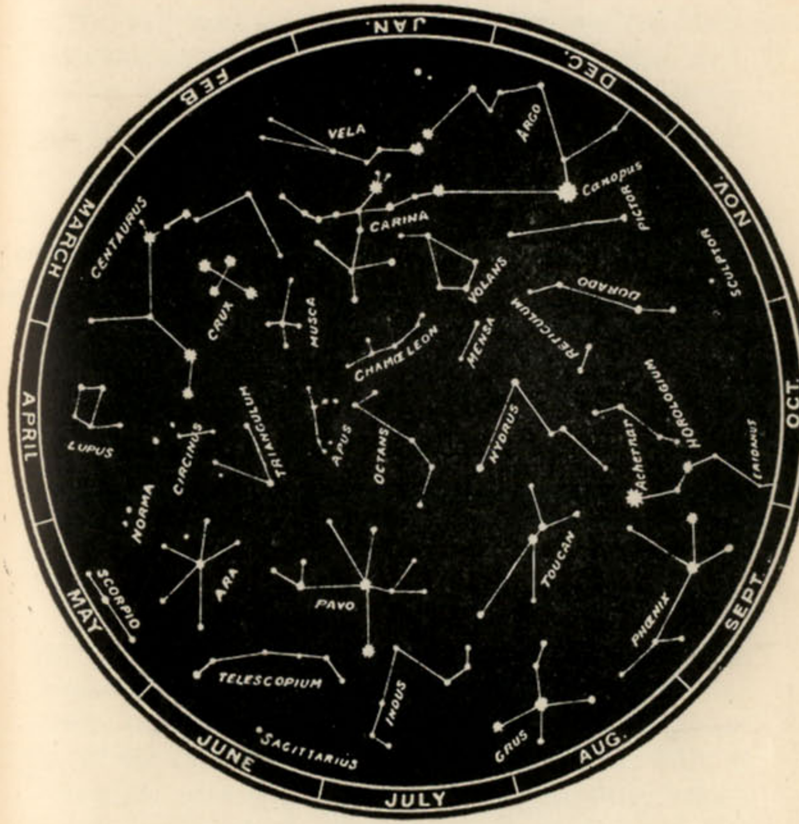
IN previous chapters we have had occasion to allude to the *fixed stars*. In contradistinction to the planets or wanderers in the celestial sphere, these stars may be termed the astronomer's guide-posts in the otherwise indefinite maze of brilliant points of light which the heavens present to us.

The chief guides to the student of the heavens are the constellations, which are the arrangement of the stars in groups in order to indicate the different parts of the sky and to identify the individual stars.

The older constellations of the Zodiac are supposed to have been designed nearly 5000 years ago by a people observing in latitude 40° N., which would give a geographical position at about the head of the valley of the Euphrates.

Perhaps the most useful stars are those that circulate round the north or south poles (see plates V. and VI.).

There is one thing a sailor can congratulate himself upon : he need never, like the landsman, make the complaint of Carlyle, who said: "Why did not somebody teach me the constellations, and make me at home in the starry heavens, which are always overhead and which I don't half know to this day?"



CONSTELLATIONS SURROUNDING THE SOUTH POLE.

Invisible from Greenwich.

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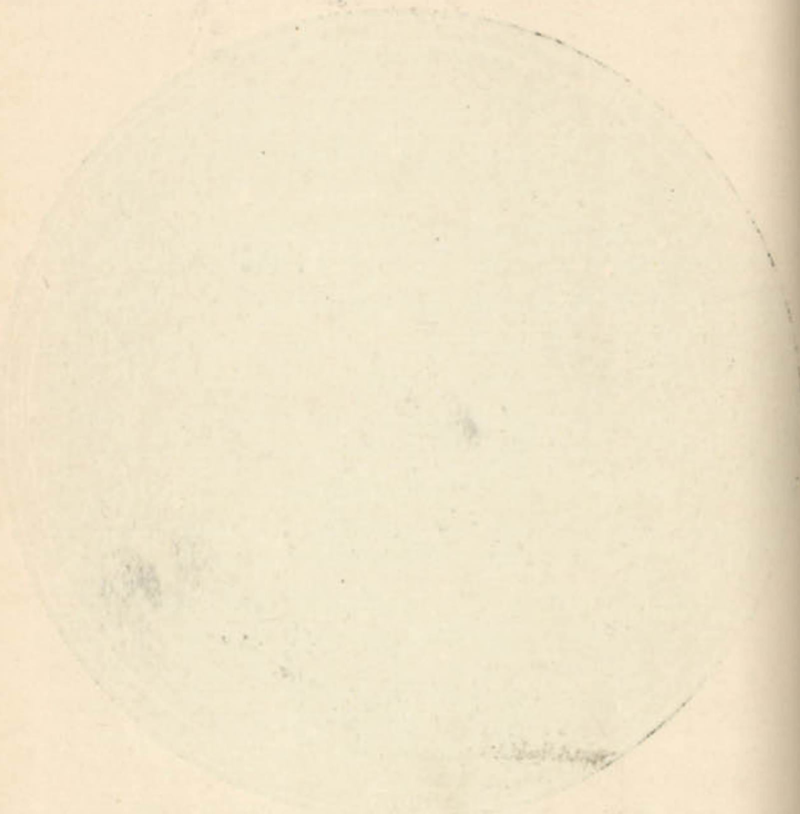


The observation of the starry firmament is part of the seaman's calling.

We will take as our starting point the "northern circumpolar stars," and begin by describing that well-known constellation Ursa Major (the Great Bear), otherwise known as the Plough or Dipper* (fig. 22). In

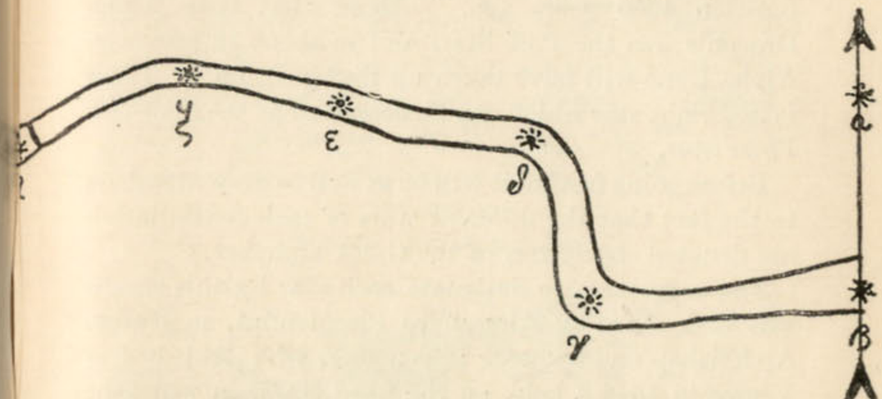


FIG. 22.—Great Bear, or Plough, showing the "Pointers." The head of the arrow points to Polaris.

the diagram the arrow passes through the two stars Alpha and Beta, known as the pointers, as a line drawn through them from the latter to the former, that is, in the direction of the point of the arrow, will, if extended, pass nearly through the Pole Star, which is practically at the Northern Pole of the celestial vault.

The Pole Star itself (Polaris, or Alpha Ursæ Minoris) is in the constellation of Ursa Minor (the Little Bear), in fact, it is the last star in the tail of the supposed animal, and is the brightest star in close proximity to

* In the United States.

the celestial North Pole. At the present time it is between 1° and $1\frac{1}{8}$° distant from the Pole, but in about 100 years it will be only half a degree away from it.

It is curious to reflect that the Pole Star of to-day by which we set so much store as a guide was not in that position 4000 years ago. About that time Alpha Draconis was the Pole Star, and in about 12,000 years Alpha Lyræ will have taken up that position. There is no bright star which can be described as the Southern Polar Star.

Before going further it will be as well to draw attention to the fact that the different stars of each constellation are denoted by letters of the Greek alphabet.*

The suggestion to designate each star by this means was first made by Alessandro Piccolomini, an Italian Archbishop and amateur astronomer, who published at Venice in 1548 a book on the fixed stars, in which he gave some rough diagrams of constellations, with Roman letters affixed to the most conspicuous stars. The idea was not adopted, however, until Bayer, a lawyer of Augsburg, published in 1603 his well-known series of maps of the constellations in which each star was marked by one of the letters of the Greek alphabet, which method remains in use to the present day. If there are so many stars in a constellation that the letters of the Greek alphabet are exhausted, then Roman letters are employed. When this means of designating the fixed stars is used in the text of a book the name of the Greek or Roman letter is prefixed to the Latin name of the constellation in the genitive case ; thus Sirius,

* The letters of the Greek Alphabet will be found in Appendix IV.

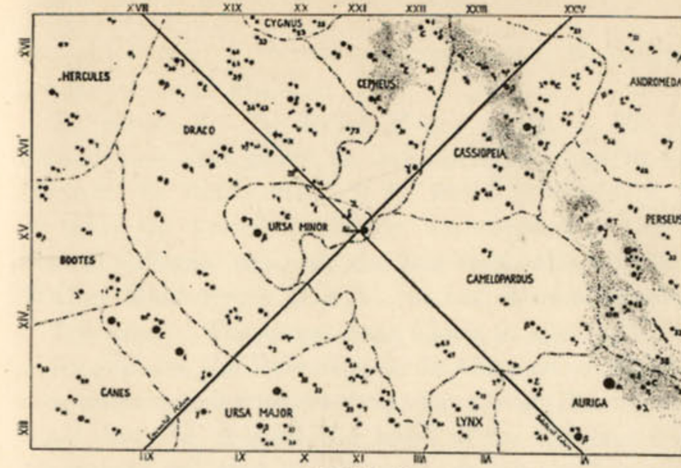


PLATE V.

Northern Circumpolar Stars.

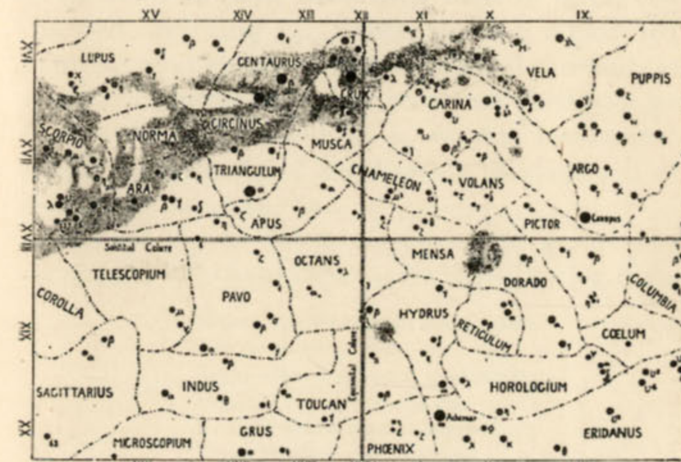


PLATE VI.

Southern Circumpolar Stars.

(Both the above maps are reproduced by permission from "Astronomy without a Telescope.")

[To face page 58.

the chief star of the Great Dog, would be written—Alpha (α) Canis Majoris.

To return to the Great Bear, which is the most conspicuous star group in our northern skies in Great Britain, we shall notice, if we watch it carefully, that it takes up varied positions with regard to the Pole Star at different seasons, and has been called by Mr. E. Walter Maunder, F.R.A.S., in his *Astronomy without a Telescope*, "The Great Star Clock in the North," for if we suppose the Pole Star to be the axis on which the constellation slowly revolves, the Great Bear becomes what may be termed the hand of an immense clock. He points out that an observer, watching through the hours of a winter's night, will see the Plough, low down in the north at first, raise itself little by little towards the east, reaching the zenith about 5 o'clock in the morning, and at daybreak be moving downwards in the west. Therefore it will be seen that these star groups have a diurnal as well as a seasonal movement, the results respectively of the Earth's rotation and of her revolution round the Sun.

Perhaps a good way to memorise the groups of stars around the Pole would be to learn the following rhyme.

Where yonder radiant hosts adorn
The northern evening sky,
Seven stars a splendid glorious train
First fix the wandering eye.
To deck great Ursa's shaggy form
Those brilliant orbs combine,
And where the first and second point
There see Polaris shine.

If we imagine a line drawn from the star in the Great Bear's tail nearest the root (Epsilon Ursæ Majoris) right across the North Pole we find on the other side of the Pole Star, and amidst the Milky Way, five stars in the shape of a W, these are the principal stars of Cassiopeia, the "Lady in her Chair."

Leaving Cassiopeia and following the line of the galaxy towards the west we see several stars marking out the Milky Way and curving towards the bright yellowish star in the north-west. These stars are the largest members of the constellation Perseus and the bright star already referred to is Capella, being Alpha of the constellation Auriga.

Beta Aurigæ, or Menkalinan, is a bluish-white star of the second magnitude, and if we draw a line from this star through Polaris and extend it rather further from the Pole Star on the opposite side to Menkalinan, we come to Vega, the chief star in the group of the Lyre. This is a brilliant steel-blue star and rivals Capella in brightness.

As has been said these stars form a clock in the northern heavens to anyone who will take the trouble to follow their movements.

The chief stars in this natural timepiece are the Plough, or Great Bear, Cassiopeia on the opposite side of Polaris, and Capella and Vega to right and left of them. In Scotland and the North of England these stars are always visible, but in Southern England Vega disappears for a short time below the horizon when due north.

As Mr. Maunder truly remarks*:—"To watch these northern constellations as they follow each other in regular ceaseless procession round the Pole, is one of the

* *Astronomy Without a Telescope*, by E. Walter Maunder, F.R.A.S.

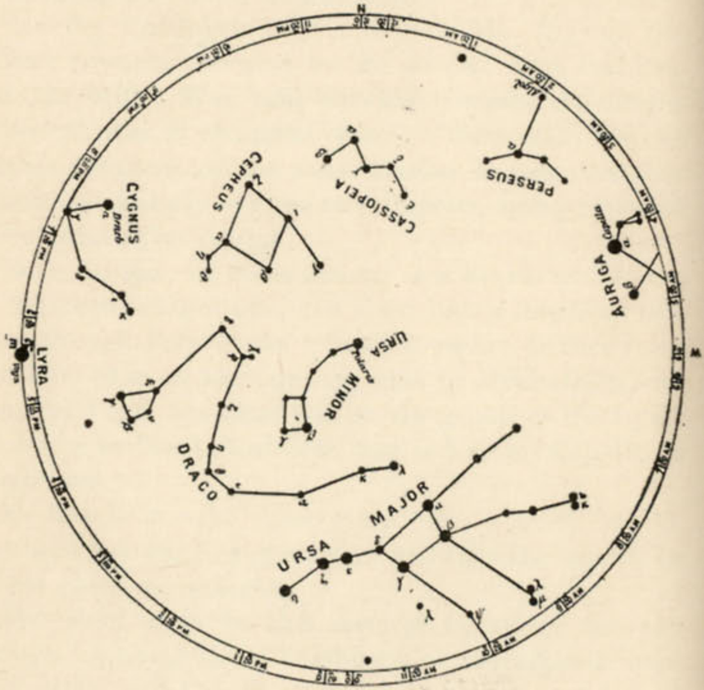


PLATE Va.

The Great Star Clock in the Northern Sky. (The Great Bear.)

[*Reproduced by permission from "Astronomy without a Telescope," by E. Walter Maunder, F.R.A.S.*]

[*To face page* 61.

most impressive spectacles to a mind capable of realising the actual significance of what is seen. We are spectators of the movement of one of Nature's machines, the vastness of the scale of which and the absolutely perfect smoothness and regularity of whose working so utterly dwarf the mightiest work accomplished by man. The sense of this ceaseless motion and of its perfect regularity sank deep into the minds of the earliest observers, and had much to do with the sacred, or at least semi-sacred, character, which attached to the study of astronomy in those ages. But beyond this, there was the actual practical value of the movements of this great celestial clock."

This we have previously described and these appearances and the accompanying star map of the chief northern circumpolar stars (plate Va.) are for midnight on 1st April in each year, or 10 p.m. 1st May and so on, remembering that for every month later in the year the stars will take up the same position two hours earlier or four minutes earlier on each successive day.

The Winter Stars of the Southern Sky.

Having described the appearance of the northern sky as seen from the latitudes of Great Britain, at various seasons of the year, we will now turn southwards, and imagining that it is 1st January at about 10.30 p.m. we shall, on a clear frosty night, behold a sight which cannot be surpassed at any other season or in any other part of the globe.

In the centre of the picture Orion will be seen just about to cross the meridian.

This constellation in itself forms a striking object, the figure of the giant hunter being outlined with seven bright stars standing out with great distinctness. On the north-east is Alpha, or Betelgeuse, meaning a shoulder of the giant; this star is of an orange hue. It has been the subject of discussion in the *English Mechanic and World of Science* and elsewhere as to whether its light varies, and it is fairly well established that its light does undergo considerable modifications, though it hardly comes into the category of regular variable stars.

The opposite or south-western corner of this star group is occupied by Beta, or Rigel, which constitutes the foot of the hunter and is the most brilliant star in the constellation.

The south-eastern quadrant is filled by Kappa, now known as Saiph, the sword, the name which once belonged to Iota.

What makes the star group now under discussion more striking than any other is the Belt, formed by three stars in close juxtaposition, in the middle of the constellation; and on clear nights close by can be seen without any optical aid the Great Nebula, which is one of the most beautiful objects in the heavens.

Even the much vaunted Southern Cross does not in any way equal in brilliancy this splendid constellation. The star in the north-western corner is Gamma, or Bellatrix, the female warrior.

As will be seen from the star map forming the frontispiece, Orion is closely associated with other constellations with many brilliant members. Just below him, for instance, is Canis Major, the Great Dog, with its bright first magnitude star Sirius, the Dog Star. This star is

the brightest, though not the largest, of the fixed stars of both hemispheres. It is thirty times as bright as the Sun, but only twice its mass.

Sirius is about 49 billion miles distant from the Earth, his parallax being about 0.37″, his light taking about $8\frac{1}{4}$ years to reach us. Whilst the Sun with the whole of his system is moving towards Vega, he is leaving behind the region of the Dog Star. It will be perhaps more correct to say that the Sun is *attempting* to get away from Sirius, as the latter travels faster than our luminary and is *overtaking* it at the rate of 5 miles a second.

Arcturus (Alpha Boötis) is also moving towards us, as it is approaching us at the rate of about 5 miles a second. His light, which is about 1300 times as bright as that of our Sun, takes about $33\frac{1}{2}$ years to reach us. His lateral velocity is large being some $83\frac{1}{3}$ miles per second.

The means employed to find in which direction a star may be moving is the use of the spectroscope, by which it is possible to observe whether the spectral lines of the star are shifted from those in a terrestrial spectrum. If they move towards the *violet* end, the star under observation is *approaching* us; if towards the red, it is *receding* from us. Measures can in this way be made with a great nicety, an accuracy of about $\frac{1}{10}$ of a mile per second being possible.

Finding the rate of approach or otherwise of stars by this method is a most valuable one and has been employed to elucidate problems of the Solar System as well as of the stars.

But to return to Sirius, this mighty sun is attended by a companion star with half its mass but less than

$\frac{1}{10,000}$ of its light, and it has been found that these twin suns revolve around one another in exactly 50 years.

The reason why the days from 3rd July to 11th August are called "Dog Days" is that at one time the Dog Star during that period rose with the Sun, but owing to the precession of the equinoxes these dates are now not absolutely correct.

The next bright star in the region of which we are treating is Procyon, or the Lesser Dog.

The name Sirius is usually taken as bearing its Greek meaning of sparkling, burning, or scorching; the name Procyon simply meaning "before the dog," that is to say Procyon was the precursor of the Dog Star, as, although not crossing the meridian earlier, rises before him and so heralds his coming.

In his *Fireside Astronomy* (p. 102) the author remarks " . . . there is nothing more disappointing and disillusioning than to read about 'bears,' 'lions,' 'dogs,' etc., as the names of the constellations and then to try to recognise them by such outlines in the sky." Mr. Maunder, in his work already quoted, confirms this, as he says "Procyon and its companion form yet another proof that the constellation names were not given in consequence of forms suggested by the actual groupings of the stars. Certainly there is nothing to suggest a dog in the presence of two fairly bright stars some five degrees apart."

There is another constellation of modern design, without any large stars, between the two dogs and following Orion, which is called Monoceros, or the Unicorn. The chief interest in this region is the number of double stars, star clusters and nebulæ suitable for the amateur

with a 3 or 4-inch telescope, and there is even one star (S. Monocerotis), which is variable within a range of half a magnitude, with a period of about 3¼ days; this makes a suitable object for binoculars or even an opera-glass.

Farther on we find the well-known star cluster of the Pleiades, which name is probably derived from the Greek *Pleiones*, meaning "many."* The individual stars of the Pleiades are named after the seven daughters of Atlas and Pleione. Aeschylus has it that they were placed in heaven owing to their filial sorrow at their father being turned into a mountain, and having to carry the weight of the firmament. Many and varied are the names which have been given to this star group, one of the most familiar being the "Hen and Chickens." In a marginal note to the book of Job in his translation of the Bible, Miles Coverdale calls them "the Cloc Henne with her chickens." Modern astronomers have completed the group by naming the pair of stars at the eastern end of the group after the parents of the seven daughters, calling them Atlas and Pleione.

> Near Perseus' knee, the Pleiades, next are rolled
> Like seven pure brilliants set in ring of gold;
> Though each one small, their splendour all combine
> To form one gem, and gloriously they shine.
> Their number seven, though some men fondly say
> And poets feign that one has passed away.
> Alcyone—Celæno—Merope—
> Electra—Taygeta and Sterope—
> With Maia—honoured sisterhood—by Jove!
> To rule the seasons placed in heaven above
> Men mark them rising with the solar ray,
> The harbinger of summer's brighter day.

* *Astronomy without a Telescope*, by E. W. Maunder.

Men mark them rising with Sol's setting light
Forerunners of the winter's gloomy night.
They guide the ploughman to the mellow land;
The sower casts his seed at their command.

This star cluster is part of the Zodiacal constellation Taurus (the Bull), of which Aldebaran is the brightest star. The cluster appears on the eastern horizon in September and is on the meridian at midnight in November. Originally the rising of these stars with the Sun was supposed to indicate a safe time for navigation.

On a photographic plate taken by the Brothers Henry at the Paris Observatory in 1888, no less than 2326 stars were counted, although only six can be easily seen with the unaided vision.*

Another cluster of stars in Taurus is the Hyades. They are shaped like a V and are named thus because the ancient astronomers believed that rain was indicated when this cluster rose with the Sun.

We have now briefly outlined all the principal constellations of the winter sky in northern latitudes.

The Summer Stars of the Southern Sky.

We have already spoken of Arcturus, the Alpha of the constellation Boötes, which is one of the principal stars in the summer southern skies. This star has a most rapid movement, having a velocity of 83⅓ miles per second, the average velocity of stars being only 20 miles per second.

This star is one of the easiest to recognise in the whole sky; starting from the Pole Star and drawing a line through the star in the tip of the Great Bear's tail we

* The Pleiades as represented on pre-historic stones were composed of ten stars instead of seven. *Vide English Mechanic*, No. 2971, p. 72.

are led straight to Arcturus, which with Denebola of Leo and Spica of Virgo mark out an almost equilateral triangle.

Arcturus means the "Watcher of the Bear," as Boötes, the Herdsman is supposed to be guarding his flocks from the close proximity of the Bear.

It is curious to find that some confusion seemed to have arisen in the minds of the ancients between Boötes and Orion, as by means of excluding Arcturus from the former constellation they made it a ghost-like and distorted representation of the latter.*

The first magnitude star Arcturus is found almost midway between the Herdsman's two legs which are marked by the stars Eta and Theta, the Belt stars, three in number, as in Orion, are represented by Rho, Sigma, and Epsilon, the last named being the brightest. Gamma and Delta mark the shoulders, and Beta denotes the head.

While Boötes, with Arcturus, is approaching the western quadrant of the sky in early summer, Vega, the chief star of the Lyre, is at the zenith in our latitudes at midnight.

If we draw a line from Gamma Boötes, through Theta Coronæ we come to Beta in the constellation of the Kneeler. The modern name of this star group is Hercules.

We next come to the constellation of the Lyre. Although Lyra is not a large constellation it is conspicuous through the brilliancy of its Alpha star—Vega—which is superior to both Arcturus and Capella.

* See *Astronomy without a Telescope*, by E. Walter Maunder, F.R.A.S., p. 52.

An interesting point in Lyra is that Beta, Gamma, and Delta are all easy double-stars for the binoculars, the companions to Beta and Gamma being Mu and Lambda respectively. Beta is particularly interesting, being a short-period variable; the period is 12d. 22h., during which time it passes through 2 minima and 2 maxima; the minima are of unequal brightness. Its magnitude being never less than $4\frac{1}{2}$, it can easily be perceived with the naked eye. This constellation also contains the interesting ring nebula illustrated in plate VII.

When we mentally compare the constellations of the southern heavens in the summer with those we observed in the winter the comparison goes very much in favour of those of winter; for although we may have the bright first-magnitude stars, Capella, Arcturus, Vega, and, lower down in the South, Spica, in the constellation of the Virgin, there is no cluster of stars to equal the Pleiades, nor is there any constellation to come up to Orion.

Working downwards from the region of Hercules, Corona, and Boötes, we pass through Ophiuchus and Serpens, and, crossing the Equator, through Virgo, and Libra, we find Spica almost on the ecliptic.

It is perhaps hardly necessary to point out to readers versed in Nautical Astronomy that the Sun in the course of his apparent journey along the ecliptic passes through the constellations bearing the names of the various signs of the Zodiac, and that is why the constellations of Sagittarius, Capricornus, etc., seem low down in the south to us when in northern latitudes; Cancer, Leo, etc., seemingly being equally high up;

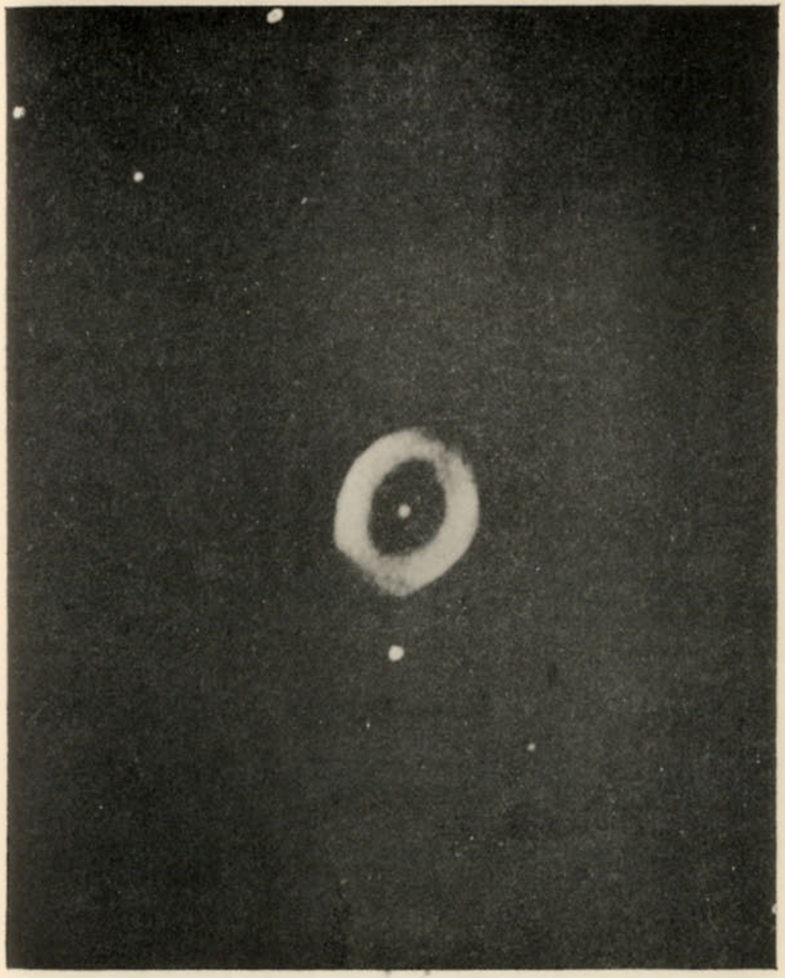


PLATE VII.—Ring Nebula in Lyra.

[*Photo by Dr. W. E. Wilson.*]

[*To face page* 68.

for in December the Sun occupies what is known as the Tropic of Capricorn, whilst in June it is in the Tropic of Cancer.

The Southern Circumpolar Stars.

Although the stars of the South Polar Regions can, of course, never be seen from our high northern latitudes here in England, it is necessary to mention them here, for the sailorman goes all over the world, his astronomy, like his life, being cosmopolitan. They will appreciate the gradual change in the starry firmament as the "line" is approached and passed, and also the fact that when at last the Equator has been left behind, and we are fairly launched into the Southern Hemisphere, even the Sun and Moon take on a different aspect, rising in the east and setting in the west certainly, but going round by the north instead of the south, the "southing" becoming an apparent, if not actual, misnomer. The face of the Moon even seems different to that to which we are accustomed, her face being no longer the one we know as such, for we see her "standing on her head," if we may use the phrase ! But in our present chapter we are more directly concerned with the fixed stars surrounding the South Pole of the heavens.

There is no bright star at or near the position of the South Pole equivalent to the Pole Star of the Northern Hemisphere, the southern region of the Pole being practically devoid of any but faint stars.

The star groups in the immediate vicinity of the South Pole are Chameleon, Mensa, Hydrus, Octans, and Apus.

In some parts of Australia and in New Zealand as well as at the Cape of Good Hope, the Southern Cross is a circumpolar constellation, being always above the horizon. On 28th March, at midnight, it is vertical over the South Pole.

As we have before had occasion to remark, the much praised Southern Cross is but a small constellation, and does not possess one star of the first magnitude; but what causes its fame is the fact that within it, closely grouped together, are three stars just above the second magnitude, and six more between the second and fifth magnitude; also its two chief stars Alpha and Beta Crucis are very important to navigators.

The finest constellation is the Centaur, which is the next group of stars to Crux, the first named having ten stars over the third magnitude. This constellation also contains the nearest star to the Solar System, and which is known as Alpha Centauri. This star shows a parallax of 0.75″, giving a distance of about 25 billions of miles, or about 4¼ light-years.

The finest individual star near the Southern Pole is Canopus, which almost equals Sirius in brilliancy; this star belongs to the constellation Argo, being near the bottom corner of that group. Its actual brightness is many thousand times that of our Sun.

The maps (frontispiece and plates V. and Va., and VI.) show the grouping of the stars we have just been discussing.

PLATE VIII.—Spiral Nebula. M. 100, Comæ Berenicis.

[*Photo by Dr. Isaac Roberts, Starfield Observatory.*]

[*See page 69.*

CHAPTER VI.

COMETS AND METEORS.

COMETS may be divided into two classes, viz., those having *closed* or elliptical orbits and those whose orbits are hyperbolic or parabolic.

Astronomers have computed "periods" for many of the first-named objects which have proved in the event extremely correct. Among short-period comets of this description (*i.e.*, those which come within a reasonable distance of the Earth at intervals of 3 to 13 years) is Encke's (period $3\frac{1}{3}$ years), which duly appeared as predicted in the spring of 1918, and this comet has been seen at every return since 1822. It belongs to the Jupiter family of these wandering objects.

Tuttle's is the fellow comet of the Saturn group.

Halley's, another of the relatively short-period comets, appeared in 1835, and there were great expectations of its next visit in 1910; certainly it arrived, but its appearance was very disappointing in comparison with its previous apparitions.* Its defalcations in the Northern Hemisphere, however, were made up for by the unexpected arrival of what was known as the "Great Daylight Comet," which appeared in January of that year; but even this one, like all comets of recent

* This was in the N. Hemisphere and was due to the strong twilight. In the tropics and S. Hemisphere it was a very fine object.

years, with the sole exception of that of 1882, appeared as a far more striking object to observers south of the Equator than to those in more northern latitudes.

In the olden times comets were not only a great puzzle to the early astronomers, but were also a frequent source of terror and dismay to the populace. It is possible that when the prophet Jeremiah exhorted the Israelites not to be "dismayed at the signs of heaven," (Jeremiah x. 2), he was referring to the appearance of a comet.

It was always thought that should the Earth collide with even the tail of a comet complete disaster would ensue. That this idea is quite erroneous is shown by the fact that in 1861 the Earth did actually pass through the tail of the great comet of that year, and nothing worse happened than a peculiar gloom which overspread the landscape some time before sunset, notwithstanding the fact that the sky at the time was free from clouds, the disc of the Sun being perfectly seen through the murky atmosphere. The Earth also passed through Halley's Comet's tail in 1910, and we suffered no ill effects.

We have already said that comets are of two classes, and it is only those of the first named class, that is, those having closed or elliptical orbits, that we should ever see again even though we lived for thousands of years. Those having parabolic orbits go away into space and never return. It has recently been thought, however, that no cometary orbit is an actual parabola, but is in fact an enormously elongated ellipse. If this is so they will, of course, return after a very great lapse of time, if not suffering disintegration meanwhile.

In the author's opinion the theory of an elongated ellipse fits in best with the order of the Universe.

Comets' tails have been the subject of much discussion, but the generally accepted theory is that the repulsive force exerted by the Sun drives a light gas existing in the *nucleus*, or head, of the comet itself away from it, and colour is given to this assertion from the fact that a comet's tail invariably flows away from the Sun. This gas has been assumed to be hydrogen. The spectroscope shows the spectra of a compound of carbon and hydrogen, such as cynogen.

It has been surmised that the origin of comets must have been some catastrophe in the history of our own Sun, when as a dark star it collided with some other sun, causing an explosion, blowing fragments into space, which in time returned to the centre from which they started, revolving around it in greater or less elliptical orbits.

Another theory is that they are small condensations from the outer portions of the nebula from which the Solar System is supposed to have been evolved according to the generally accepted theory of the Nebular Hypothesis.*

It is supposed that the heads, or *nuclei*, of comets are swarms of meteors, and this brings us to our next subject, but before going on we would draw attention to fig. 23, showing some ancient and modern comets. It is not generally known that the comet depicted on the Bayeux Tapestry is an early appearance of Halley's in 1066.

* The Nebular Hypothesis of the origin of the Solar System is not now so generally accepted as it once was. (See Glossary, *Nebular Hypothesis*.)

Meteors are dark bodies moving in entirely independent paths in space, until finally meeting a resisting medium such as our atmosphere, a greater or less number of them, rushing with enormous velocity (44 miles per second in the case of the Leonids), are caused by friction to be superheated to the point of incandescence: thus, whilst being rendered visible to

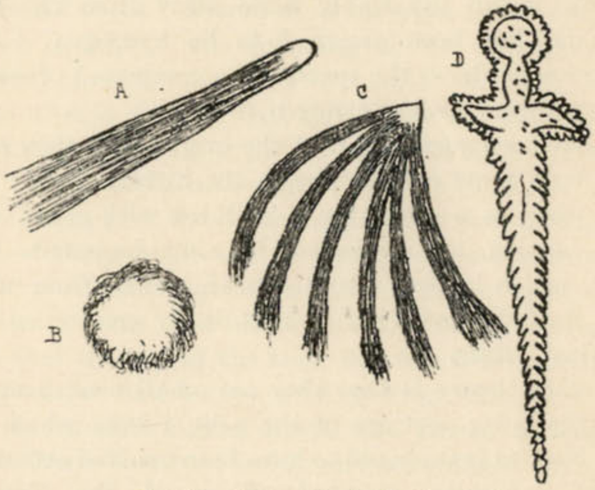


FIG. 23.—Some remarkable Comets.*

(A—Halley's. B—Encke's. C—Six-tailed comet of 1744. D—Representation of comet by an ancient artist.)

us as streaks of light, they are consumed and reach the surface of the Earth in the form of ashes, known as "meteoric dust." It will be seen from this that if there was not an atmosphere surrounding the Earth the meteors could not be consumed by friction with it, but would drop in *solid* form upon the surface of our globe, which would be very uncomfortable, as we

* From an old print.

should suffer from a more or less continuous shower of stones !

Of course, there are some meteors too vast to be consumed during their short passages through the Earth's atmosphere, and these reach the ground in solid form. Many small specimens may be seen in museums labelled "Meteoric Stones," "Meteorites," or "Aërolites." The largest known specimen was that discovered by the late Commander Peary, in Greenland, which weighed *several tons.*

CHAPTER VII.

TELESCOPES AND BINOCULARS.

BEFORE concluding this treatise on astronomy it will be as well to give a brief description of the construction and uses of the telescope and the double vision telescope, generally known under the various names of binoculars, field-glasses, opera-glasses, etc.

The ordinary refracting telescope, usually called an astronomical telescope (fig. 24), consists of two convex lenses, an object-glass, of as great focal length and low magnifying power as the size of the telescope will allow, and the eye-piece of small focal length and high magnifying power. For distinctly viewing a distant object, the two lenses are arranged at distances equal to the sum of their focal lengths, and an inverted image of the object looked at is seen in the eye-piece.

In the original telescopes of Galileo and other pioneers the object-glass was a single lens, but a fringe of colours always appeared around the object viewed. In the eighteenth century, however, experiments were made with a compound object-glass, the outer piece being made convex of crown glass and the inner concave, and of flint glass. In this way in modern telescopes chromatic aberration, as it is called, has been largely overcome.*

* See Glossary, *Achromatic Lens.*

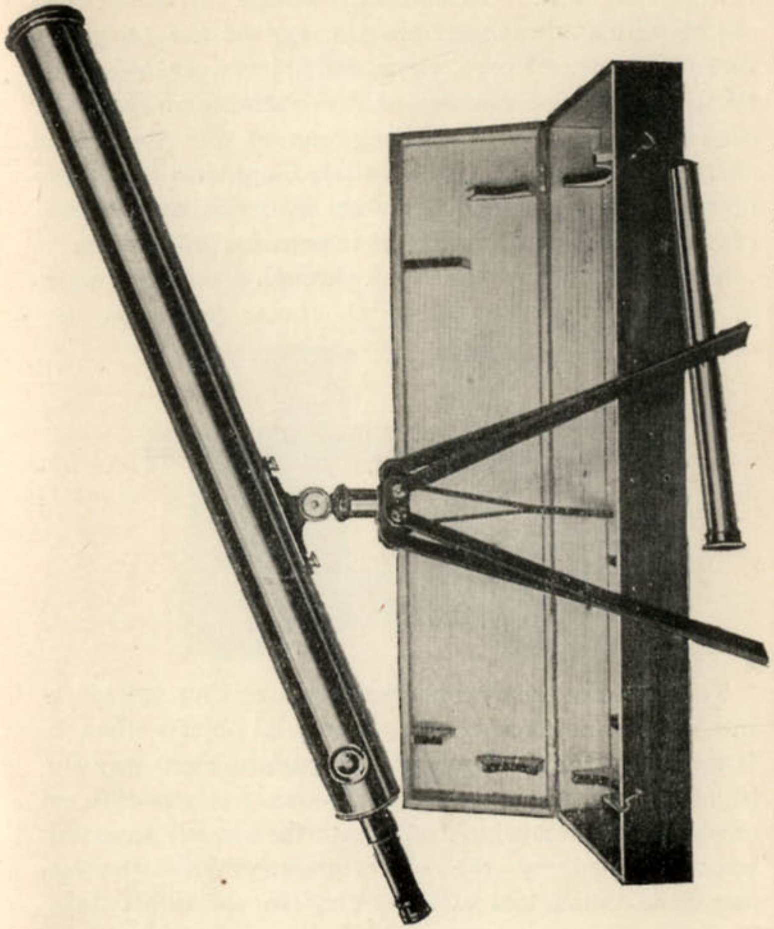


FIG. 24.—Astronomical Telescope on pillar and claw stand, with garden tripod.

In fig. 8 (*ante*) we see a picture of the full Moon as seen through astronomical telescopes, the South Pole being at the top. In this view of the full Moon the object which always strikes the eye of the observer first is the crater Tycho, the round object near the top of the picture with streamers or rays running away in all directions from it, reminding one of the top of a shrivelled orange. About a little more than half-way down on the right-hand side are two similar systems of rays, these being the craters Copernicus and Kepler.

Should we look at the Moon through a powerful pair of binoculars we should see the lunar landscape the other way up.

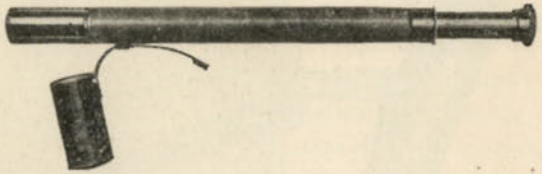


FIG. 25.—Officer of the Watch Telescope.

To transform the astronomical, or inverting, telescope into one suitable for viewing terrestrial objects when it is necessary that they should appear the right way up (fig. 25), we use a telescope having a terrestrial or erecting eye-piece which re-inverts the already inverted image formed by the object-glass. This process causes so much loss of light that in the olden days seamen used to employ portable astronomical telescopes for seeing objects at night and these instruments were therefore known as "night-glasses." The necessity

for this has now, however, been obviated by the use of binocular glasses of great light-gathering power (fig. 26). Some of these double telescopes, as we may call them, can be adjusted to give powers from 4¼ to 9½ diameters. The advantage of the binocular over the single vision telescope is that it does not appear to magnify the haze which may intervene between the observer and the object it is desired to observe; the author recalls observing an object nearly 20 miles away on a very hazy afternoon with a binocular with perfect clarity although to the unaided eye it was practically invisible.

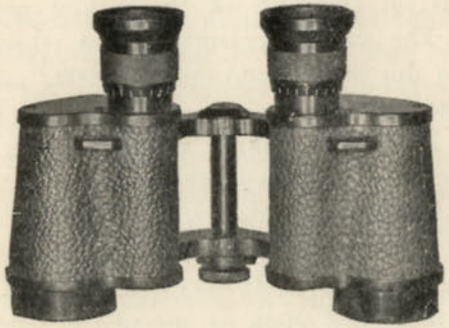


FIG. 26.—Binoculars.

As we have before had occasion to remark, these instruments are very useful for astronomical observations made at sea, as they are easily portable and there is no stand to bother about.

Of course if we are in a position to take observations on land, and can afford the expense of an observatory with a revolving roof, then it is worth our while in the first place to have our telescope, whether refracting or reflecting, mounted equatorially, as in this way we can follow a celestial object, when once found, with one motion of the hand only, instead of the double movement of the alt-azimuth apparatus.

If we can add a clockwork movement to our equatorially adjusted telescope, we have what may be termed *l'astronomie de luxe* ! But unfortunately very few of us can indulge our hobby to such an extent !

. . . .

We will finish this treatise by mentioning what may be termed some of the humours of Astronomy.

The apparitions which mainly cause comical misconceptions on the part of the public are those of comets. The author remembers that when Perrine's Comet was due in the autumn of 1902, and popular interest had been aroused in such matters, he noticed two farm labourers walking to the station, and one said to the other: "They say, Jack, that this comet will be visible *fine* in October." "What's the good of that, Bill?" answered his companion, "All the visitors 'll be gone by then !" It was evident from this that a comet was looked upon as one of the "sights" of a popular resort !

But the most humorous event in connection with a comet appearing in recent years was the extraordinary misconception with regard to the name of the discoverer of the Great Daylight Comet of 1910.

This comet, as is well known, was first seen in the Southern Hemisphere, and when its discovery was telephoned the receiver of the message mistook the word "great" for "Drake," thinking that a "Mr. Drake" was responsible for the discovery, and so this

celestial wanderer obtained the name of "Drake's Comet" ! For a long time this "Mr. Drake" remained a mystery, as it could not be understood why he did not come forward to claim his "prize," so to speak, and his great modesty was remarked upon. When it was found that the gentleman was non-existent a new name had to be found for the comet, and it was generally known popularly thereafter as the "Great Daylight Comet," but to astronomers it is known to this day merely as "Comet 1910*a*."

Passing from comets to planets, we come to the curious conception existing among the general public as to the speed at which celestial objects travel through space. At a well-known seaside resort a man was giving "penny peeps" at Jupiter and his satellites through a 3-in. telescope, and among others to avail themselves of the privilege of making a closer aquaintance with the giant orb was a lady, who found that the planet moved out of the telescopic field so rapidly that she had difficulty in getting her "money's worth." So, turning suddenly to the gentleman who accompanied her, she asked him at about what rate Jupiter travelled. "Oh," he said, in an off-hand manner, "at about 250 miles an hour" ! Comment is needless !

The difficulty of popularising astronomy, whilst still keeping to the facts, has been experienced by many writers, and the trouble of elucidating its mysteries and inculcating them into the youthful mind is well shown by the following amusing story culled from the leaves of "An Oxford Note-Book" (*Observatory*, vol. xix., p. 69).

A London assistant schoolmistress received orders to give tuition in Astronomy to some nine-year-old children. According to instruction she explained to her class the uses and purposes of the *Zodiac*. Resuming her lesson some time afterwards she asked, "What is the Zodiac?" "There aren't none now, ma'am," replied a little girl, "it's bust up." "What's burst up?" said the teacher, in great surprise. "The sody-'urk," answered the girl, "where they make the sody-water, and father's been thrown out of work!" Subsequent investigation showed that a soda-water manufactory in the neighbourhood had been closed through the bursting of a steam-pipe, and in this calamity the pupil had seen the destruction of the Zodiac! After this the teacher thought it useless to continue explanations of Astronomy!

Another note from the same source (see *Obs.*, vol. xxiv., p. 472) is of more encouraging nature. Mazzini, on being asked what he would have taught in schools, replied, "One thing at any rate in all—Astronomy. A man learns nothing if he hasn't learnt to wonder, and Astronomy, better than any other Science, teaches him something of the mystery and grandeur of the Universe. Now a man who feels this will soon feel something of his own greatness and mystery, and then for the first time he is a man." And it must be remembered that Mazzini was not an astronomer, but merely an Italian patriot with somewhat advanced ideas.

We cannot do better to conclude our little work on the "Queen of Sciences" than quote these very fine verses by Mrs. H. Periam Hawkins, the well-known amateur astronomer.

THE VOICES OF THE STARS.

Listen to the quiet voices
 In the stillness of the night,
When the dome of purple darkness
 Sparkles with its gems of light.
Look upon those starry spaces,
 Read the hidden secrets there;
Beauty infinite surrounds you,
 Mystic music fills the air.

Listen to the earth's soft breathing
 As you lie upon her breast,
While she bears you through the ether,
 Closely to her bosom pressed.
Lo! above, around, beneath you,
 Hang the wondrous lamps of God,
Each a sun of shining splendour,
 Quenched or lighted at His nod.

By a mighty Power directed,
 Each moves on its silent way,
All unerring, all fulfilling
 Their divinely ordered day.
Perfect wisdom, perfect order
 Reign throughout the mighty vast,
Each gigantic power of Nature
 To the throne of God held fast.

Listen to the quiet voices
 They will speak if you will hear
They will tell you that the finite
 To the Infinite is near
Do you crave, in hours of darkness,
 More than human sympathy?
Lift your eyes! the stars are shining!
 Where they are, Love, too, must be.

THE END.

GLOSSARY OF ASTRONOMICAL AND NAUTICAL TERMS.

GLOSSARY OF ASTRONOMICAL AND NAUTICAL TERMS.

Achromatic Lens.—A compound object-glass for a refracting telescope formed of a convex lens of crown glass in conjunction with a concave lens of flint glass, producing a practically colourless image of the object under observation. (See Chapter VII., p. 76).

Aërolites.—Meteoric stones reaching the Earth. (See Chapter VI., p. 75).

Albedo.—The fraction of incident light which a heavenly body (the Moon, planets, etc.) is capable of reflecting.

Algol.—Beta Persei; variable star in Perseus. Every 2d. 20h. 48m. it varies in magnitude, being first 2.3, then falls in 4½ hours to 3.5, at which it remains for 20 minutes, recovering its normal light in another 4½ hours. Its variability is caused by a less bright companion star revolving round the bright one in such a way as alternately to show and cut off its light, like the revolving flash-light in a lighthouse. The companion star is as bright as our Sun.

Altazimuth.—An instrument employed to find the altitude and azimuth of a celestial object. (Fig. 1.)

Altitude.—The arc of a vertical circle intercepted between the centre of the object and the horizon.

Amplitude.—The arc of the horizon intercepted between the east or west point and the centre of the body at rising or setting.

Angle of Position.—The angle made by the meridian and the great circle passing through any two places on the Earth; or the angle made by two great circles passing through any heavenly body.

Annular Eclipse of the Sun.—One in which the apparent diameter of the Moon is less than that of the Sun, and the apparent disc, being smaller than that of the Sun, leaves an *annulus*, or ring of light, at what otherwise would be total phase. The Moon must be less than 90° away from apogee at the time of an annular eclipse.

Ant-Apex.—The point in the universe from which the Sun is moving in the neighbourhood of Sirius.*

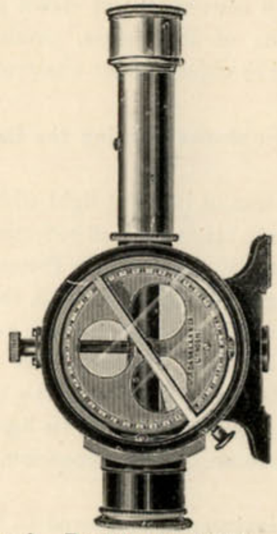


FIG. 1.—Pocket Altazimuth.

Aperture.—The diameter of a telescope's object-glass. A telescope is spoken of as having a 3 or 4-in. aperture, *i.e.*, object-glass, or o.g.

Apogee.—Most distant from the Earth. The point in the *real* orbit of the Moon, or *apparent* orbit of the Sun, round the Earth, at which either is at its greatest distance from it.

* The apex of the Sun's way, *i.e.*, whither it is moving with all its planets, is within a a few degrees of Vega (Lyræ).

Apparent Solar Day.—The interval between the Sun's passing the meridian one day, and re-passing it the next.

Apparent Time.—The time shown by sundial.

Apsis, Apsides.—Point, or points, of greatest and least distance of a heavenly body from its primary. Line connecting these points is termed the "Line of the apsides."

Arc.—Any portion of the circumference of a circle. Degrees, minutes and seconds of arc are shown thus:—° ′ ″

Asteroids.—Small planets (minor planets or planetoids) occupying space between Mars and Jupiter. (*q. v.*, Chap. IV., p. 41.)

Astrolabe.—Instrument at one time used for measuring the altitude of stars at sea. It was also used in observatories on land.

Augmentation of the Moon's Semi-diameter.—The increase in the Moon's semi-diameter in consequence of her being nearer the observer when high in the sky than when close to the horizon.

Axis.—A line from Pole to Pole on which the Earth, or other body, turns. The turning of the Earth on her axis from west to east gives us the phenomenon of day and night.

Azimuth.—The arc of the horizon intercepted between the north and south point, and the circle of altitude passing through the place of the body.

Azimuth Clock.—An instrument devised by a naval lieutenant to give automatically the azimuth of a celestial body.

Baily's Beads.—Phenomenon seen during a total or annular solar eclipse several seconds before the beginning of totality or annularity, and similarly after the end of totality or annularity. A series of bright points, like beads, appearing on the edge of the Moon's disc, due to the Sun shining through the lunar valleys.

Base Line.—A line used in calculating parallax for the determination of the distance of heavenly bodies. For this line the radius of Earth is used for Sun, Moon, and planets. For the stars her orbit is employed.

Bearing.—The bearing of an object or place is the angle contained between the meridian and the direction of the object, and is the same as the course towards it. A distinction must of course be made between true bearing and compass bearing.

Binary Stars.—Two stars comparatively near, and in actual physical connection with each other.

Bode's Law.—A law of numbers relating to the distances of the various planets from the Sun. By adding 4 to 0, 3, 6, 12, 24, 48, 96, and 192, we obtain 4, 7, 10, 16, 28, 52, 100, and 196. These numbers practically represent the distances of the Sun from the chief planets of the Solar System, except in the case of Neptune.

Body.—A heavenly body means any celestial sphere in the universe, from the Sun, Moon, and planets to the outermost star.

Bolometer.—A thermometer invented by Prof. Langley, actuated by electricity, and by means of which he has been able to estimate the amount of heat at the surface of the Sun, Moon, and other heavenly bodies. It is so sensitive that it can "feel" the heat given off by a candle-flame 1½ miles distant.

Canopus.—A giant sun, possibly the central sun of a surrounding group of stars; many thousand times the size and brilliancy of our Sun. Distance practically immeasurable, but thought to be some 280 light-years distant.

Capella.—A star of the first magnitude in Auriga (α). It is one of the brightest stars in our hemisphere, and is presumed to be similarly constituted to our Sun. It is a very close double star with a period of 104 days. The duplicity was first recognised by the spectroscope, but has since been visually detected with the Mount Wilson 100-inch reflector.

Celestial Body.—(See *Body*.)

Celestial Concave.—The imaginary surface of the sky surrounding the Earth; in other words, the background upon which we see the heavenly bodies apparently superimposed, the position of the observer being, of course, the centre of the celestial concave.

Celestial Equator.—The terrestrial equator extended to the celestial concave.

Celestial Globe.—A globe upon which the constellations are

placed as they would appear if we saw them from *outside* the celestial concave.

Celestial Meridian.—The circle in which the terrestrial meridian extended meets the celestial concave.

Celestial Poles.—The points in the celestial sphere where the axis of the Earth appears to be directed. In the Northern Hemisphere, the region of the Pole Star.

Celestial Sphere.—(See *Celestial Concave*.)

Celestial Vault.—(*Idem*.)

Charts.—(See *Mercator's Charts*.)

Chronometer.—(See *Standard and Local Time*.)

Centre of Gravity.—The point about which all the parts of a body balance and support one another.

Circle, Great.—A section of a sphere made by a plane passing through its centre.

Circle, Small.—A section of a sphere made by a plane which does not pass through its centre.

Circle, Diurnal.—The circle a heavenly body describes in its apparent daily movement in the celestial concave; or, the parallel of declination passing through the body in question. If the heavenly body is in the equinoctial, the diurnal circle is a great circle. At the equinoxes the Sun's diurnal circle is the equinoctial.

Circle of Altitude, or Vertical Circle.—A great circle passing through the zenith and nadir.

Circle of Perpetual Apparition.—The parallel of declination beyond which all the diurnal circles lie wholly *above* the horizon.

Circle of Perpetual Occultation.—The parallel of declination beyond which all the diurnal circles lie wholly *below* the horizon.

Circles of Declination.—Great circles passing through the poles of the heavens.

Circles of Latitude.—Great circles passing through the poles of the ecliptic.

Circles, Polar.—Two small circles about 23° 27′ distant from either pole. In the Northern Hemisphere it is known as the *Arctic*, and in the Southern, the *Antarctic Circle.*

Circles, Tropical.—Two small circles situated about 23° 27′ on either side of the Equator. The northern circle is known as the *Tropic of Cancer*, and southern as the *Tropic of Capricorn.*

Civil Day.—This is the day in general use; beginning at midnight and ending at the following midnight; generally divided into two parts of 12 hours each, marked A.M. and P.M., meaning before and after noon respectively. This system is gradually being superseded, and 24-hour time is being largely introduced on the Continent. It is already used officially in Great Britain for astronomical and meteorological observations. At present an astronomical day begins at mid-day and ends at mid-day, thus making the noon of civil day coincide with the commencement of the astronomical day, but these are about to be brought into coincidence, so that from the commencement of the year 1925 both days will be synchronised, and the astronomical day will be made equal to the civil day.

Circum-Meridian Altitude.—Altitudes taken when a body is near the meridian with a view to solving problems, by first finding from these the meridian altitude.

Clock, Ship's.—(See *Standard and Local Time.*)

Clock-Stars.—Stars whose right ascensions can be utilised in obtaining sidereal time.

Coal-Sacks.—Dark openings in the Milky Way; supposed to be actual gaps or openings, where the nebulous matter of the Galaxy has drained off to form stars.

Co-latitude.—The complement of the latitude to 90°, or the amount required to make it 90°.

Colour of Stars.—Stars are said to be bluish-white (Sirian) in the early stages of development, passing from yellow to red as they advance in age. The Sun belongs to the yellow (Solar) type.

Colures.—The equinoctial colure is the great circle which passes through the equinoctial points and the poles of the Earth.

The solstitial colure is the great circle which passes through the solstitial points and the poles of the Earth.

Comets.—Celestial bodies owing their origin possibly to some pre-historic catastrophe, when having been thrown out into space yet remain in the Solar System, but with immense elliptical and parabolic orbits, except those of short period, which have been "captured" by the powerful attraction of Jupiter or Saturn (*q.v.*, Chap. VI., p. 71).

Compass.—(See *Mariner's Compass.*)

Compass Course.—The course as steered by compass as differentiated from the *true* course.

Constellations.—Groups of stars, each given a distinctive name, the brighter stars being designated by letters of the Greek Alphabet. (See *Appendix IV.*)

Cosmogony.—The theories of the origin of the Universe.

Course steered.—The angle between the magnetic meridian and the direction of the ship's head.

Course (true) made good.—The angle between the true meridian and the ship's real track on the surface of the globe.

Course.—This is reckoned from N. towards E. or W. when the ship's head is less than eight points from N. or from S. towards E. or W., when the vessel's head is less than eight points from the S. It is unusual to reckon a course as more than 8 points from N. or S. In this way we should call E.S.E., S. 6 pts.; E., not N. 10 points E., though either term would really express the same point of the compass.

Course (Departure).—This is the course a ship would have made if she had sailed from a particular point the bearing of which has been taken on leaving land. By reversing this bearing and estimating the distance the object, or point of departure, is from the ship (the exact distance being known) we get a course and a distance, which are put into the Day's Work or Traverse Table, and afterwards reckoned as an ordinary course and distance.

Current.—The "set" of a current is the direction *towards* which it runs.

Date, Greenwich.—The approximate Greenwich time, including the day of the month, at which an observation is taken; it is obtained by applying the longitude in time to the approximate time at the place of observation.

Day.—The interval of time between the departure of any meridian from a heavenly body and its succeeding return thereto, taking its name from the body with which the motion of the meridian is compared; thus, we have an apparent *solar day*, a *lunar day*, and a *sidereal day*, being respectively the interval of time between the *Sun*, *Moon*, or *any fixed star* successively coming to the meridian. The last named day is approximately 23h 56m. 4s. of ordinary clock or watch time in length. A mean solar day is the average of all the apparent solar days, or such a day as the Sun would show if moving uniformly in right ascension.

Dead Reckoning.—The account kept of the ship's place, without reference to astronomical observations. It is usually written *D.R.*

Declination.—The arc of the circle of declination intercepted between the place of a heavenly body and the celestial equator. Declination is reckoned in the heavens exactly as latitude is measured on a terrestrial meridian. (Written *Dec^l^.*).

Degree (Written °).—The 360th part of the circumference of a circle, or the 90th part of a right angle. It is subdivided into 60 minutes, which are again divided into 60 seconds.

Degree of Latitude.—The 360th part of any meridian on the surface of the Earth, measured N. or S. of the Equator.

Degree of Longitude.—The 360th part of any parallel of latitude E. or W. of a given place; such as the meridian of Greenwich, Paris, or Washington. Most longitudes are now measured from the meridian of Greenwich.

Density.—Technically applied to the degree of closeness with which matter is contained in a given bulk or size.

Depression.—(See *Dip.*)

Departure.—The amount of easting or westing in going from one place to another.

Departure Course.—(See *Course.*)

Departure, Taking a.—When a ship leaves land it is usual to take the bearing and distance of some known object, the position of which has been obtained either from a chart, or from its latitude and longitude, from which the vessel's position can be ascertained. The departure may be taken by a single compass bearing on the object, and the distance estimated by the eye. A more accurate method of fixing the ship's position is by cross bearings of two known objects. The distance, if necessary, from either being afterwards measured on the chart.

Deviation.—(See *Mariner's Compass.*)

Difference.—Difference of latitude between two places is the portion of the meridian included between their parallels. Also called "northing" and "southing," as the difference of latitude is actually the distance made good in a N. or S. direction. When two places are on the same side of the Equator, their different latitude is found by substracting the less from the greater; when they are on opposite sides, add together to obtain the difference.

Difference, Meridional, of Latitude.—The difference, or sum, of the meridional parts of two given latitudes.

Dip of Horizon, or Depression.—The angle by which the sea horizon appears depressed owing to the elevation of the spectator.

Dip Circle.—(See fig. 2.)

Disc, or Disk.—Technically applied to the round visible surface of the Sun or Moon, or, as seen with the telescope, the larger planets. No appreciable disc can be formed even by the most powerful telescopes on the fixed stars, owing to their great distances.

Diurnal Circle.—This is the circle a heavenly body describes in its apparent daily movement in the celestial vault, or the parallel of declination passing through it. If the body is in the equinoctial then the diurnal circle is the great circle.

Diurnal Motion.—The apparent daily motion of all the celestial bodies from E. to W., caused by the rotation of the Earth in the opposite direction.

Double Altitudes.—Two altitudes taken in order to solve the same problem. These may be of the same body, taken at different times or different ones observed simultaneously, or of different bodies observed at different times.

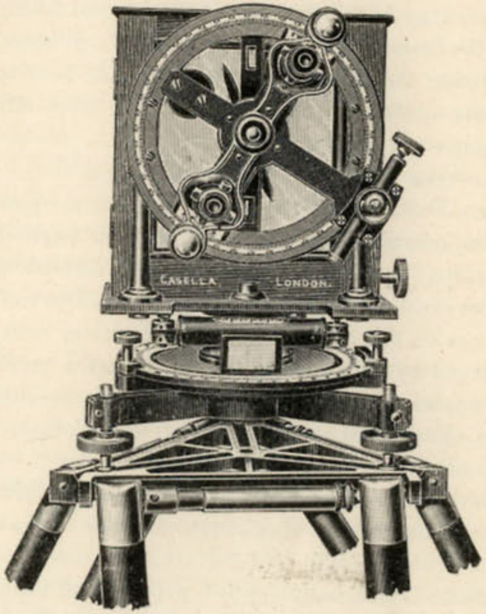


FIG. 2.—Dip Circle (Kew Pattern).

Double Stars, Optical.—These, in contradistinction to the true *binaries* (*q.v.*) only *appear* to be near one another in the line of sight, but do not really belong to the same system.

Drift.—The drift of a current is the distance through which it runs in a given time.

Dynamics.—The branch of physics that deals with the action of Force. It is divided into Statics and Kinetics. Hence we speak of Static energy, the action of which prevents change of motion, and Kinetic energy, which causes or changes motion.

Earth.—The globe upon which we dwell, and the third planet of the Solar System in order of distance from the Sun. She revolves around her primary (the Sun) in 365d. 6h. 9m. 9s., at an average velocity of a little over 18½ miles per second. During the course of a year she covers a circuitous route of about 580 millions of miles (*q.v.* Chapter I., p. 1).

Earth's Axis.—(See *Axis.*)

Eccentricity.—Meaning a departure from the centre. Technically applied to the proportion which the distance between the centre and one of the foci of an ellipse bears to the semi-major axis, or half the longer diameter.

Eclipse.—The disappearance of a celestial body in the shadow of another, except in the case of the Sun, where it is the actual body of the Moon that obscures our luminary. As the Moon and all the planets and satellites of the Solar System receive their light from the Sun, they cast conical shadows behind them on the opposite side to that body. When one of the satellites, as it moves in its orbit, becomes enveloped in the shadow of the planet around which it revolves, it is said to undergo eclipse; for example, when our Moon is wholly or partly in the shadow of the Earth, she is said to be totally or partially eclipsed, as the case may be. The shadows of the satellites are not long enough even to cover the whole body of their primary when interposed between them and the Sun. Thus the shadow of the Moon, even when our satellite is nearest us, can generally only cover about 170 miles of the Earth's surface, but it may be more with a low sun. (See *Eclipses of Sun and Moon*, Chaps. II., III., pp. 17 and 29).

Ecliptic.—The great circle in the celestial sphere to which the plane of the Earth's orbits is directed, so that the Sun's apparent place is always in it. It is so called because eclipses can only occur when the Moon is in or near that plane. The ecliptic is practically the orbit of the Earth extended to the celestial concave. The obliquity of the ecliptic is the angle which it makes with the Equator, which at present is about 23° 27′. (See Chap. I., p. 6.)

Elevated Pole.—The pole which is above the horizon of the observer. In Great Britain, for instance, the elevated pole is the N. Pole of the heavens.

Ellipse.—An oval figure. A parabola is formed by cutting a cone parallel to one side, the edge of which section is a parabola; an ellipse is formed by cutting the cone by a plane which makes a smaller angle with its base than one parallel to either side, whence the word's derivation. It is one of the conic sections.

Elongation.—Venus and Mercury are at their greatest elongation E. or W. of the Sun when they appear as evening or morning stars respectively, appearing at those times at the greatest distances possible from the central luminary; about 45° for the former and about 28° for the latter planet.

Emersion.—The moment of re-appearance of a celestial body after eclipse or occultation by another.

Ephemeris, Ephemerides.—An almanack showing the daily position of the heavenly bodies; such as the *Nautical*, *Brown's Nautical*, and *Whitaker's Almanacks*, etc., etc.

Equal Altitudes.—Altitudes of a celestial body taken on opposite sides of the meridian when the body has the same altitude.

Equation of Equal Altitudes.—The correction to be applied to the mean of the times shown by the chronometer, A.M. and P.M. when finding its error by equal altitudes of the Sun.

Equation of Equinoxes.—The difference between their mean and apparent places.

Equation of Light.—The time taken by light to reach the Earth from the Sun, *viz.*, 8 min. 18 secs.

Equation of the Centre.—The difference between the place of a heavenly body moving with uniform angular velocity and its place with its actual variable velocity.

Equation of Time.—Mentioned in almanacks as "before or after clock," it being the interval of time that the true Sun comes to the meridian either before or after the mean Sun, or civil time, being the time as shown by our clocks and watches, as differentiated from sundial time (*q.v.* Chap. I., p. 6).

Equator.—(See *Celestial Equator*.)

Equatorial Telescope.—An instrument mounted on a stand made to revolve about an axis parallel with that of the Earth. In this way an object can be kept in the field of view so long as it is above the horizon. Some telescopes of this kind are clock-driven and require no attention after once the object to be observed has been got into the centre of the field of the object-glass.

Equinoxes, Precession of.—A movement of 50″ of arc which carries the "First Point of Aries" at that rate through the Zodiac, so that it is now situated in the constellation Pisces. (See Chap. I., p. 8.)

Equinoctial Colure.—(See *Colures*.)

Equinoctial Points.—Those points at which the ecliptic cuts the Equator. The First Points of Aries and Libra.

Equinoctial Year.—The time occupied by the successive return of the Sun to the vernal or autumnal equinox. A solar year.

Eros.—A minor planet, only 20 miles in diameter, but of great importance owing to its approaching the Earth more nearly than any other celestial object (except, of course, the Moon),* and also to his usefulness in determining the parallax, and therefore the distance of the Sun. His next favourable opposition and close approach to the Earth will be in 1931. (See Chap. IV., p. 42)

Establishment of the Port.—The average amount of time intervening between the Moon passing the meridian and the time of high tide at any particular port. High water occurs at a

* There are two other minor planets with even more eccentric orbits, which approach the Earth about as closely as Eros, viz., Albert, discovered by Dr. Palisa, of Vienna, in 1911, and Alinda, discovered by Prof. Wolf in 1918.

different interval after the Moon passes the meridian for each separate place, and this has to be determined by observation.

Ether.—The supposed substance which fills space beyond the limits of our atmosphere.

Evolution.—The changes which are continually taking place in the universe. Prof. Hale gives the following order for the evolution of stars:—Nebulæ, Helium Stars, Hydrogen Stars, Solar Stars, Titanium Oxide or Carbon Stars, Dark Stars. The last named are in the last stages of evolution or development.

Ex-Meridian Altitudes.—(See *Circum-Meridian Altitudes.*)

Faculae, or Torches.—Bright spots, or streaks, on the surface of the Sun, generally surrounding the dark sunspots, and also governed by the 11-year cycle.

False Dawn.—The zodiacal light when it appears in the E. before sunrise (*q.v.*).

First Meridian.—(See *Prime Meridian*).

First Point of Aries.—(See *Equinoxes, Precession of*, also Chap. I., p. 8).

First Point of Libra.—As the First Point of Aries is now in Pisces, so the First Point of Libra is now in the constellation Virgo. The former point is the Sun's ascending node at the vernal equinox, the latter his descending node at the autumnal one.

Fixed Stars.—The stars beyond our own Solar System are termed "fixed" not because they really are stationary, but being at such immense distances they appear, except for the diurnal and seasonal motions due to the movement of the Earth, always to be at the same, or almost the same, part of the sky. The apparently small, though really, in some cases, very great, *real* motions, discovered by modern astronomical methods, have been characterised as their *proper motions.*

Focus.—A place where rays of light meet, as in the eye-piece of a telescope. It is an optical term, which has also been transferred to the uses of mathematics and astronomy. The focus of a parabola is the point within it to which all rays of light falling on it from a distance and parallel to its axis converge after reflection. An ellipse has two foci; all rays of light diverging from either focus would, after reflection at the ellipse, converge to the other focus. All the planetary orbits and those of periodical comets are ellipses, the Sun being in one focus. (See *Ellipse.*)

Frigid Zones.—The N. frigid zone extends from the N. Pole to the Arctic Circle (67¾° N.), and the S. one from the S. Pole to the Antarctic Circle (67¾° S.).

Galaxy.—(See *Milky Way.*)

Gamma Draconis.—The third star in order of brightness in Draco. Its declination being 51½° N. it is in the zenith, or right overhead in London, and is employed at the Royal Observatory, Greenwich, in investigations on nutation, aberration, and variation of latitude. This is the star which Flamsteed, the first Astronomer-Royal, is said to have descended a well to observe. The well was covered over about a century ago, but is believed to be still in existence at the present time.

Geocentric Place.—The position of a celestial body in latitude or longitude in the heavens as it would be seen from the centre of the Earth.

Greek Alphabet.—(See *Appendix IV.*)

Greenwich Date.—(See *Date.*)

Greenwich Mean Time.—The legal time of Great Britain, and many other countries.* It is mean solar time at Greenwich; *i.e.*, the moment of the mean Sun passing the meridian at Greenwich is taken as *mean noon*, allowing, of course, for the correction for equation of time (*q.v.*).

Greenwich Observatory.—Founded by Charles II. in 1675, who made Flamsteed first Astronomer-Royal.

Great Circle.—(See *Circle.*)

Great Circle Sailing.—A method of navigating a ship so as to keep her on a great circle which joins the place left with the place bound to. In actual practice the course is changed only at

* See Appendix IV.

certain intervals, which are determined on according to circumstances. The usual method of procedure is to take several points in the arc of the great circle, at, say, 5°, or more, of longitude, apart. Then steer by chart from one point to the next, and so on in succession; called *Approximate G.C.S.*

Gulf Stream.—A stream of relatively warm water flowing from the Gulf of Mexico. It tempers the climate of the British Isles and Western Europe, owing to the prevailing south-westerly winds continually blowing from the regions of relatively warm water. Otherwise it would have no effect.

Gyro-Compass.—(See *Mariner's Compass.*)

Gyroscope.—An instrument on the principle of a spinning top, by means of which the motion of the vessel in a heavy sea can be neutralised for the working of compasses, etc. (*q.v.*).

Halley's Comet.—A comet which though appearing at intervals varying between 74½ and 79½ years since B.C. 240 and probably before, was first identified as a periodic visitor to our neighbourhood in 1682 by Edmund Halley, the second Astronomer-Royal, hence the name. (See Chap. VI., p. 71).

Harvest Moon.—The full Moon which occurs nearest to the 23rd of September. (See Chap. III., p. 28).

Heave of the Sea.—The effect of the rough sea in bad weather on the "way" of the ship. This has to be taken into account when working out the dead reckoning.

Heavenly Body.—(See *Body.*)

Heliacal Rising or Setting.—Rising or setting nearly simultaneously with the Sun.

Heliocentric Place.—The place of a planet reckoned from the centre of the Sun.

Horizon, Apparent or Visible.—Where the Earth (or sea) and sky apparently meet.

Horizon, Celestial.—A great circle, parallel to the apparent horizon, the plane of which passes through the Earth's centre, dividing the celestial concave into two equal parts. Owing to the Earth's surface curving about 8 inches per mile, rather more than half the sky can be seen from an elevated position when looking over the sea. This is termed the *Depression*, or more commonly, the *Dip of the Horizon* (*q.v.*).

Hour Angle.—The angle a heavenly body makes at the elevated pole (E. or W.) between the celestial meridian and the hour circle passing through the body. The hour angle of the Sun reckoned always westward from the meridian is the apparent time, or time shown by a sundial.

Hour Circles.—Great circles passing through the 2 poles of a sphere, perpendicular to the Equator. The name is also given to the graduated circle of an equatorial telescope, for movement in R.A.

Hour Circle—6 o'clock.—The meridian which cuts the horizon at the E. and W. points.

Hyperbola.—One of the conic sections. A plane cutting both halves of a double cone.

Immersion.—The disappearance of a star, planet, or satellite during occultation or eclipse. The opposite of Emersion (*q.v.*).

Inclination of Earth's Axis.—(See *Obliquity of Ecliptic.*)

Inclination of Orbit.—Angular distance between the plane of an orbit and the plane of the ecliptic.

Inferior Planets.—(See *Planets.*)

Ingress.—The moment one celestial body passing on to the disc of another.

Jupiter ♃.—The giant planet of the Solar System. (See Chap. IV., p. 43).

Latitude.—The latitude, measured in the same way as declination in degrees, minutes, and seconds of arc, is the distance N. or S. of the Equator terrestrially, as decl. is celestially. A minute (or nautical mile) contains 6082 feet, or 1013 fathoms, a second contains about 101 feet, or nearly 17 fathoms. A degree is about 69 miles.

Latitude, Circles of.—(See *Circles.*)

Latitude, Magnetic.—The irregular curve traced on the Earth's surface by a line of equal dip.

Latitude, Parallels of.—Small circles parallel to the Equator. Two places in the same latitude are termed as lying in the same parallel.

Leeway.—When a ship is under sail, and the wind is blowing on her side, she may be pushed by its force to leeward of her intended course. This lateral pressure causes leeway, the amount can be ascertained by observing the angle made by the direction of her keel, and the line of wake the vessel leaves behind her on the water's surface.

Leonids.—An annual shower of meteors, due Nov. 13—15; special displays took place at intervals of 33 years until 1899, when they were only observed to any great extent in America.

Librations of the Moon.—A slight swaying motion, which reveals to us a small fraction of the "invisible hemisphere." (See Chap. III., p. 25).

Light, Velocity of.—Light travels at about 186,330 miles per second, or 670 millions of miles an hour. Light from the Sun takes 8m. 18s. to reach us; about 1.33 secs. from the Moon, but 4¼ *years* from the nearest fixed star (α Centauri). The term "light-year" is used to measure the stellar distances.

Light-Year.—(See *Light, Velocity of.*)

Line of Sight, Motion in.—Motion of a body in a direct line towards the observer.

Logarithms.—The logarithm of a number is the power to which a certain number (usually 10) must be raised to equal that number.

Longitude.—The longitude of a place is the distance, measured on the Equator, between the meridian of a given place and that of another meridian (the prime, or first meridian) which with us is that of Greenwich. Longitude is E. or W. of Greenwich, and is measured, like latitude, in degrees,° minutes,′ and seconds″ of arc.

1 hour of time is equal to	15° of longitude.	
1 minute ,, ,,	15′	,,
1 second ,, ,,	15″	,,

Longitude can be turned into time, or time into longitude by the table of haversines, or any other table which gives both time and angle: usually there is nowadays a special table of time and angle equivalents.

Longitude, Celestial.—The angular distance of a body measured eastward from the First Point of Aries along the ecliptic.

Longitude, Difference of.—The difference of longitude between two places is that part of the Equator between their respective meridians.

Lunation.—The period occupied from the time of one new Moon to that of the next. (See *Synodic Period.*)

Magellanic Clouds.—Situated in the southern celestial hemisphere; they are masses of stars, star clusters and nebulæ, appearing like the Milky Way, but quite unconnected with it. Probably external galaxies.

Magnetic Field.—The region round any magnetised substance, in which there is an appreciable magnetic force.

Magnetism, Terrestrial.—The magnetic influence of the Earth. It is shown by variation, dip,* and intensity.

Magnetic Amplitude.—The bearing of a celestial body at rising or setting from the E. and W. points as shown by a compass, and is found by observation with an azimuth compass.

Magnetic Azimuth.—The bearing of a celestial body from N. or S. points as shown by the compass. It is deduced as above.

Magnetic Compass.—(See *Mariner's Compass.*)

Magnetic Dip.—The line of inclination to the horizon of a freely suspended compass needle. This factor gradually increases on either side of the magnetic Equator: like variation it is a

* Magnetic "dip" must not be confused with the "dip" of the horizon. For the latter, the term "depression" seems the better word. (See *Dip of the Horizon.*)

variable factor. It is an important element in considering the changes of the magnetic state of iron or steel ships.

Magnetic Equator.—An irregular line encircling the Earth. Here there is no dip, the compass needle remaining perfectly horizontal. It cuts the geographical Equator at four points and is generally inclined to it at an angle of 12°.

Magnetic Intensity.—The amount of magnetism acting upon a freely suspended compass needle. There is horizontal and vertical intensity.

Magnetic Latitude.—An irregular curve traced on the Earth's surface by a line of equal dip.

Magnetic Poles.—Those places on the globe where a freely suspended compass needle hangs vertically, the same end of the needle being attracted in opposite directions in the two hemispheres.

Magnetic Storms.—Disturbances on the Earth synchronous with great outbursts of sunspot activity. The greatest magnetic storms occurred in 1871 and 1903.

Magnitude.—(See *Stars.*)

Mariner's Compass.—(Fig. 3). This consists of a bar of magnetised steel, moving over a card divided into 32 " points of the compass," of which the " cardinal points " are N., E., S., and W. These being again divided give us N.E., S.E., S.W., and N.W. Again subdividing we obtain N.N.E., E.N.E., E.S.E., S.S.E., S.S.W, W.S.W., W.N.W., and N.N.W., with further subdivisions, making the 32 above named points in all. Compasses are also divided into degrees from 0° to 360°. *Deviation* of the compass is the *error* due to the iron and steel in the ship's hull. *Variation* is the *known error* of the compass from the true north in various parts of the world. At present (1922) at *Greenwich* it is about 13° 49′ W. By about the end of the century it will be *zero.* In other words, the magnetic and true north will then coincide. The annual diminution is about 10′.

Mars ♂.—The fourth planet of the Solar System in order of

distance from the Sun. Its orbit is between those of the Earth and Jupiter. His sidereal " day " is 24 hrs. 37 mins. 22.66 secs. His " year " is 687 days. (See Chap. IV., p. 38.)

Mass.—The quantity of matter contained in a heavenly body.

Mean Distance.—The distance mid-way between the greatest and least distances, as we speak of the Sun's mean distance from us as being about 93 millions of miles.

Mean Noon.—The time at which the mean Sun is said to cross the meridian. (See *Equation of Time.*)

Fig. 3.—Mariner's Compass.

Mean Solar Day.—Average length of all the apparent solar days in the year.

Mean Sun.—An imaginary Sun which moves uniformly along the equinoctial with the average velocity of the apparent Sun along the ecliptic.

Mean Time.—(See *Time,* and also *Greenwich Mean Time.*)

Meridian.—(See *Celestial Meridian.*)

Meridian Altitude.—The altitude of a celestial object when on the meridian of any place. For example, the Sun is said to attain its meridian altitude at apparent noon each day.

Meridian, First.—(See *Prime Meridian.*)

Meridian, Reduction to the.—The correction to be applied to an altitude taken near the meridian to reduce it to the meridian altitude (*q.v.*).

Meridional Difference.—The difference, or sum, of the meridional parts of two particular latitudes.

Mercator's Charts.—These are employed by navigators in making sea voyages. They are made on a projection invented by Gerard Mercator who was born in 1512, and his charts were first published in 1568. They were first applied to navigation by Edward Wright about the year 1599. In these charts all meridians are parallel straight lines, and all degrees of longitude are equal. Parallels of latitudes in Mercator's charts are at right angles to the meridian, and degrees of latitude are increased in length from the Equator to the Poles in equal proportion as the degrees of longitudes are also increased by the meridians being drawn parallel. A plane chart is used for coasting purposes only.

Mercury ☿.—The planet of the Solar System nearest to the Sun. (See Chap. IV., p. 35).

Meteors.—Technically a name generally given to small dark bodies moving in space and unseen until reaching the upper regions of the Earth's atmosphere, when friction therewith causes them to become incandescent and therefore visible as luminous objects. They are popularly known as "Shooting Stars."

Meteoroids.—Small meteors moving in groups, such as the Perseids, Leonids, etc.,

Moon ☽.—Our satellite, or those of Jupiter, Saturn, etc. The word is derived from a Saxon root meaning "to measure," the Moon being looked upon as a measure of time. (See Chap III., p. 22.)

Nadir.—The point apparently under one's feet; exactly the opposite to the zenith, which is over one's head.

Navigation.—This is the science by means of which the place

of a ship on the sea, and the course to and from any given place are determined from positions of the celestial bodies in conjunction with chronometers showing Greenwich time. Lunar distances are no longer used except for practice. When cloudy weather prevails the vessel is navigated by means of dead reckoning (*q.v.*) in which mariner's compass, log line and chart are used.

Nebula.—Faint luminous objects of an appreciable area and irregular shape in the stellar heavens. Some are shown by the spectroscope to be gaseous. Others (the spiral nebulæ) give a continuous spectrum, hence are not wholly gaseous. The term is generally applied to a mass of gaseous matter resembling a small cloud, hence the name.

Nebular Hypothesis.—The theory of Kant and Laplace that the Solar System was formed by the cooling and contracting of a vast nebula, rotating more rapidly as it contracted so that rings were ejected forming the planets. This theory has been lately subjected to doubt, however, the more modern one being that of appulses of two suns as promulgated by Chamberlin and Moulton, and supported by Jeans. (See *Sun.*)

Neptune ♆.—The planet of the Solar System furthest from the Sun. (See Chap. IV., p 51).

Node.—A term used for the points in the orbit of the Moon or planets where it crosses the plane of the Earth's orbit.

Nutation.—An oscillatory motion of the Earth's axis, by which it periodically increases or decreases its inclination to the plane of the ecliptic.

Object-Glass.—The lens of a telescope. (See *Achromatic Lens*; also Chap. VII., p. 76).

Obliquity of the Ecliptic.—The angle at which the Sun's apparent path is inclined to the celestial Equator; now 23° 27′ (See Chap. I., p. 41.)

Oblate Spheroid.—(See *Spheroid.*)

Oblique Sphere.—The sphere in the position in which the diurnal circles are oblique to the horizon.

Observed Altitude.—The altitude of a celestial object as it is taken by a sextant or quadrant before being corrected for error, dip, etc.

Occultation.—The hiding of one celestial body by another.

Opaque Body.—One like the Moon, having no light of its own, but shining by reflected light.

Parallels of Altitude.—Small circles parallel to the horizon.

Parallels of Declination.—Small circles parallel to the celestial Equator.

Parallels of Latitude.—(See *Latitude.*)

Parallel Sphere.—That which is in that position in which the diurnal circles are parallel to the horizon.

Parallax in Altitude.—The angular depression of a celestial object, owing to its being observed from the surface instead of from the centre of the Earth.

Parallax, Horizontal.—Parallax at the horizon. It is the amount of apparent change in the direction of an object as seen from two different places.

Parsec.—The distance of a star whose annual parallax is one second. The *parsec* is gradually superseding the *light-year* as a unit of distance; *e.g.*, in speaking of Sirius, instead of saying he is about 8¼ light-years away from us, we should state his distance as being 2.6 parsecs. One parsec is equal to 3¼ light-years.

Perigee.—The point in the real orbit of the Moon and planets, or the apparent path of the Sun, when any of these bodies is nearest the Earth.

Perihelion.—The point in the orbit of any planet nearest the Sun.

Phase.—The apparent varying shapes of our Moon and the inferior planets (Venus and Mercury) due to their receiving the whole of their light from the Sun.

Photosphere.—The visible surface of the Sun.

Plane Charts.—(See *Mercator's Charts.*)

Planet.—A wandering star; the name given to the various members of the Solar System.

Points of Compass.—(See *Mariner's Compass.*)

Poles.—The extreme points of the Earth's axis; the N. and S. Poles respectively.

Pole, Elevated.—(See *Elevated Poles.*)

Polar Circles.—Two small circles about 23° 27′ distant from either Pole.

Polar Distance.—The arc of the circle of declination intercepted between the celestial object and the Pole. When the latitude and declination are of the same names, *i.e.*, both N. or both S. of the Equator, the polar distance is the declination less 90°; when of different names, *i.e.*, the declination is N. and latitude S., or *vice versa*, the polar distance will be the sum of the declination plus 90°.

Pole Star.—Polaris (α Ursæ Minoris) the final star in the tail of the Little Bear. At present it is about 1° 8′ from the Pole, but in about 100 years will be only ½° from it. No bright star marks the region of the S. Celestial Pole.

Precession of Equinoxes.—(See *Equinoxes, Precession of.*)

Prime Meridian.—(See *Meridian, Prime.*)

Prime Vertical.—The circle of altitude which cuts the meridian at right angles at the zenith, and cuts the horizon at the E. and W. points.

Proper Motion.—The apparent motion of the fixed stars due to their own real motion in space and also to the motion in the opposite direction of the observer on the Earth, which motion is due to the movement of the whole Solar System in space. (See *Ant-Apex.*)

Quadrant.—An instrument for measuring angles and altitudes. A quarter of a circle of 360°; therefore a quadrant is an arc of 90°.

Quadrature.—When two celestial bodies are 90° apart. The relative positions of the Sun and Moon when the latter is at first or last quarter.

Quarter, First or Last, of Moon.—(See *Quadrature.*)

Radiant Point.—The position in the sky from which meteor showers apparently have their commencement, *i.e.*, the point where they become visible on entering the Earth's atmosphere; *e.g.*, the radiant point of the Perseid meteors is the constellation Perseus, after which they are named.

Radius Vector.—A straight line drawn from the centre of a heavenly body to the centre of its orbit. The radius vector of the Earth, for example, is a line drawn from its centre to that of the Sun.

Rational Horizon.—A circle parallel to the visible horizon, which, passing through the centre of the Earth, extends to the celestial concave. (See *Horizon.*)

Reduction to the Meridian.—A correction applied to an altitude taken near the meridian to reduce it to the meridian altitude.

Reflection.—A change in direction given to light rays when thrown directly back from a surface upon which they are falling.

Refraction.—The bending of a light ray passing through the atmosphere or through water or other medium. The refraction of the air, or atmospheric refraction, as it is termed, raises an object, so that it appears to be higher in the sky than it really is. At the horizon this is about ½°, or almost exactly the apparent diameter of the disc of the Sun or Moon; hence, when we see either of these objects apparently just above a sea horizon, they are really below it. Thus it is possible at certain seasons, given a clear sea horizon, to see the setting Sun and the partly eclipsed full Moon above the horizon at the same time, though technically one should be below it (fig. 4).

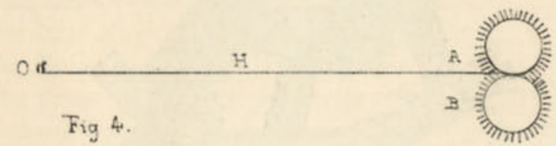
Rhumb Line.—The line over which a ship sails without altering her course, or curve of the Earth's surface which cuts all meridians at the same angle.

Right Ascension (**Abbreviation R.A.**)—The arc of the Equator included between the First Point of Aries and the celestial meridian of a heavenly body reckoned from W. to E. Right ascension is

the astronomer's longitude, but instead of being reckoned in degrees, minutes, and seconds of arc is given in hours, minutes, and seconds of time.

Saros Cycle.—The cycle of about 18 years and 11 days after which period eclipses recur in the same order, though owing to an excess of 8 hours over the exact 11 days in the period, the region of visibility moves about 120° westward on the Earth after one Saros cycle.

Satellite.—Technically the smaller, or secondary, planets, or moons, which attend the larger planets in their journey round the Sun; *e.g.*, the Moon is a satellite of the Earth. The word comes from a Latin root meaning *attendant*.



In this diagram O=observer's eye, H the horizon, and A and B the apparent and actual Sun respectively.

FIG. 4.—Refraction.

Saturn ♄.—The second largest planet of the Solar System. (*See* Chap. IV., p. 47.)

Secondary.—(See *Satellite.*)

Second of Arc.—The smallest division in the circumference of a circle (sign ″.)

Secular Variation.—Inequalities of motion in the orbits of the Earth and other planets.

Selenography.—The science of lunar topography.

Set of Current.—(See *Current.*)

Semi-Duirnal Arc.—The angle at the pole between the meridian and the declination of a body at rising or setting.

Sextant.—An instrument used in navigation made in the form of the sixth part of a graduated circle, and fitted with mirrors for measuring the altitude of the Sun and other heavenly bodies by reflection, (figs. 5 and 6).

Shooting Stars.—(See *Meteors.*)

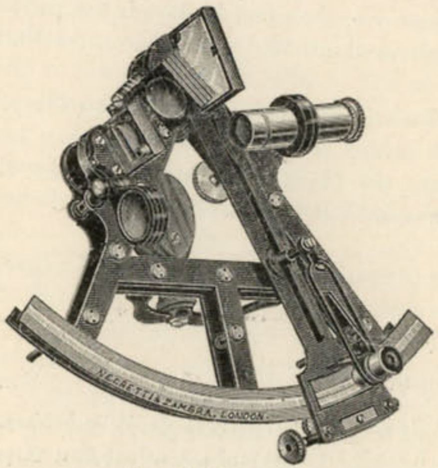


Fig. 5.—Sextant.

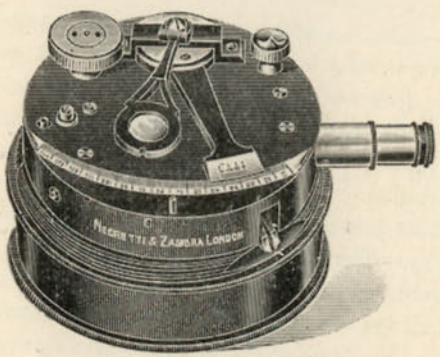


Fig. 6—Pocket Sextant. Reading to 1′.

Shortest Distance.—The arc of the great circle intercepted between one place and another on the globe.

Sidereal day.—Consists of 23h. 56m. 4s. of solar mean time, as measured by ordinary watches or clocks. It is the period between two returns of a given fixed star to the meridian. It is also the interval during which the equinoctial colure (*q.v.*) makes one revolution westward from the celestial meridian one day to its return to it the next. The sidereal day begins and ends when the First Point of Aries is on the meridian.

Sidereal Time.—The polar angle in time going westward from the celestial meridian of any place. Sidereal time at mean noon is the R.A. of the meridian at the time the Sun would be on it if he moved at a uniform rate.

Small Circle.—(See *Circle, Small.*)

Solar Day.—(See *Apparent and Mean Solar Day.*)

Solar System.—(See Chap. II., p. 15.)

Solar Time.—(See *Apparent Time* and *Mean Time.*)

Southern Cross.—A constellation of the Southern Hemisphere. Greatly over-rated. Alpha and Beta Crucis are, however, two most important navigational stars.

Southing.—The moment of a celestial body crossing the meridian (that is, when they are *due south*) in the *Northern Hemisphere*. Celestial objects appear to go round by the *north* from E. to W. in the *Southern Hemisphere*, hence in those regions "northing" is the correct term to use.

Spectroscope.—An instrument for viewing the spectrum of any object by light which has passed through a prism. (See Chap. V., p. 63.) Also *Solar Spectrum*, Chap. II., p. 20.

Spheroid.—A solid body which approaches the form of a sphere, the latter being completely round like a ball. An *oblate spheroid* is a body shaped like an orange with flattened ends, or "poles." Our Earth is of that shape. A *prolate spheroid* may be taken to be a spheroid generated by the revolution of an ellipse round its major axis.

Stars.—(See *Fixed Stars.*)

Sun ⊙.—This name is from an Anglo-Saxon root meaning *to beget*, the Sun being considered as the "begetter" or "life-producer." The Sun (*q.v.*, Chap. II., p. 11) is the centre of the Solar System; the Earth and other planets circling about him in diverse orbits. The latest theory of the origin of the Solar System holds that it was caused by the appulse of two mighty suns, the one retiring again into space, the other remaining as our Sun, the planets and comets being the fragments thrown off from the effects of the appulse. It is known as *Jeans' Theory.*

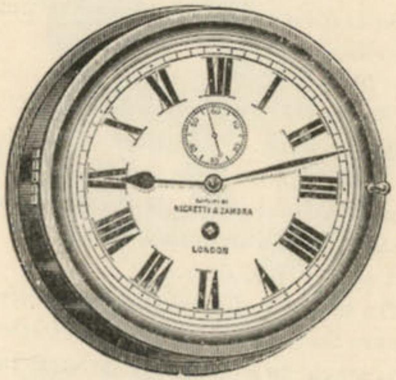


Fig. 7.—Ship's or Engine Room Clock.

Standard and Local Time.—For the purposes of civil time-keeping the globe is divided into zones 15 degrees each in breadth, that is equal to one hour in time. Greenwich time is now in use in Great Britain, Ireland, France, Belgium, Spain, Portugal, etc., whilst Sweden, Norway, Germany, Austria, etc., use time one hour fast of Greenwich. A full list of time zones will be found in *Whitaker's Almanack.* The ship's clock (fig. 7) should show local, or zone time; the chronometer (fig. 7A) keeping G.M.T.*

* It is usual for a ship to carry *two*, or more, chronometers.

Fig. 7a.—Chronometer.

Although zone time has now been adopted in the British Navy, the Mercantile Marine has not yet (1922) come into line.

Standard Ships' Time Zones.—(See *Appendix IV.*)

Telescope.—An instrument for viewing an object at a distance (*q.v.*, Chap. VII., p. 77).

Temporary Stars.—Stars that appear unexpectedly in a part of the sky hitherto devoid of any bright object, blaze out brilliantly for a few days', weeks' or months' period, and then slowly decline. Theories to account for these apparitions (*Novæ*, as they are called) are Prof. Bickerton's Grazing Contact Theory in which he supposes two celestial bodies to impinge obliquely on one another in space, the impinging portions uniting to form an expanding third body. There are also theories which ascribe the occurrences to collisions between two nebulæ and also between a nebula and a star. The latest of these novæ to be discovered is that recently found in the constellation Cygnus by Mr. W. F. Denning, F.R.A.S. (See *note, Appendix V.*)

Terrestrial Magnetism.—The magnetic influence of the Earth, shown at its surface by variation, dip, and intensity. (See *Magnetism.*)

Trade Winds.—Regular winds prevailing about 30° on either side of the Equator. They are moving from E. to W. in the hot zone of the tropics. Owing, however, to the rotation of the Earth on its axis the E. wind north of the Equator becomes N.E., and south of the Equator S.E.

Transit.—The passage of a celestial body over any point or circle. The meaning of the word is "passing across."

Tropical circles.—Two small circles situated at 23° 27′ on either side of the Equator. (See *Circles.*)

True Place.—The point in the celestial vault in which an object would be seen if it could be observed from the centre of the Earth through a uniform medium without refraction.

Twilight Circle.—A line about 18° below the horizon, the Sun having passed which, twilight ends at that particular place.

Universe.—The whole system of stars, planets, satellites, comets, etc., are described as the *Universe.*

Uranus ♅.—One of the planets of the solar system discovered in modern times (*q.v.*, Chap. IV., p. 52).

Variation of Compass.—(See *Mariner's Compass.*)

Variation of Latitude.—A change of latitude due to a change in the position of the Earth's axis. There are two periodic fluctuations, of 14 and 12 months respectively.

Venus ♀.—The second planet from the Sun (*q.v.*, Chap. IV., p. 36).

Vertical Circles.—Circles of Altitude (*q.v.*).

Weight.—Gravitation causes what is termed *weight.* Hence it is that certain planets are said to "weigh" more or less according to their *mass.* A man who can get about comfortably on the *Earth* could jump over a church steeple on the Moon, but would be pinned to the ground by his own "weight" on Jupiter.

Year.—The time taken by the Earth to revolve around the Sun. When we speak of a planet's "year" we refer to the period of its revolution around the Sun.

Zenith.—The point vertically overhead, making an angle of 90° with the rational horizon at every point thereof.

Zenith Distance.—The angular distance of a heavenly body from the zenith of the place of observation.

Zodiac.—A zone extending 8° on either side of the ecliptic. So called from the Greek word meaning "living creature" or "animal" as most of the constellations of the zodiac are supposed to represent living creatures (*q.v.*).

(A complete glossary of Astronomical Terms will be found in Mrs. Periam Hawkins' *A.B.C. Guide to Astronomy.* (Simpkin, Marshall & Co., 2s. 6d.)

APPENDICES.

APPENDICES.

APPENDIX I.

OBJECTS SUITABLE FOR BINOCULARS, ORDINARY TELESCOPES, AND ASTRONOMICAL TELESCOPES.

BINOCULARS.

The Sun: Sunspots; faculæ; rice-grains, etc. (For this eyepieces must be smoked according to instructions given in Chapter II.)

The Moon: Lunar topography (craters, seas, etc.); occultations; eclipses.

Mars, Jupiter (and four Satellites), Saturn (ring system); and under favourable circumstances the crescent of Venus.

ORDINARY TELESCOPES.

Practically the same as above.

A THREE-INCH ASTRONOMICAL TELESCOPE.

This will show much more clearly all the above, but the appearance will be *inverted*, *i.e.*, the top or north point will become the bottom or south point.

In addition this instrument will show Mercury, the satellites of Jupiter and Saturn, Uranus and under favourable circumstances, Neptune.

In short, a good 3-inch telescope on an altazimuth stand, will show the Moon and all the planets as well as they are shown in the illustrations given in this book.*

* A "N.P.L. Certificate" can be obtained from the National Physical Laboratory, Teddington, for eyepieces, etc., for a small fee.

APPENDIX II.

SUITABLE POWERS FOR DIFFERENT OBJECTS.

From actual experience with a 3-inch telescope the author would not recommend a beginner in astronomical observations to use too high a power for the Sun, Moon, or planets; to start with a power of ×50 for the Sun, or ×80 for the Moon and planets will suffice. When we become more efficient in the use of an altazimuth stand, and are able to keep an object in the field of view with greater ease, then we can begin to use a power of ×120 on the Moon, ×160 on Mercury and Venus, ×204 on Mars and Saturn and as high as ×250 on Uranus and Neptune.

With regard to Jupiter the author found a power of ×80 most suitable for observing satellite phenomena and ×150 to 204 for the Jovian markings.

Double-star work requires a power of about ×160, Gamma Arietis being easily divided with such a power.

Low powers are more suitable for star-groups such as the Pleiades and Hyades, and also for the nebulæ as they give a wider field of vision; they are also suitable for comets for the same reason.

To sum up, if we wish merely to show our friends the Moon or planets through our telescope it will always be better to use a power of less than ×100 diameters, but if on the contrary we wish to make accurate drawings at the telescope in which clearness of detail is essential then much higher powers must be employed.

APPENDIX III.

FUTURE SOLAR ECLIPSES VISIBLE IN GREAT BRITAIN.*

1921, April 8, annular in Scotland *; 1927, June 29, total across Wales, Lancashire and Durham; 1954, June 30, track of totality just north of Shetlands; 1999, August 11, South Cornwall to Havre ; 2081, September 3, just south of Lizard to Jersey, probably total at Lizard; 2090, September 23, also south of Lizard to Paris, and probably total at Lizard also ; 2133, June 3, West Lewis, W. of Shetlands; 2135, October 7, Isle of Mull to North Berwick; 2142, May 25, Etaples to St. Omer, but may be total at Dover ; 2151, June 14, Belfast, Isle of Man, Manchester, Cambridge ; 2160, June 4, S.W. of Land's End ; 2189, November 8, total at Land's End; 2200, April 14, Mull of Galloway, Hartlepool; 2290, June 7, grazes West of Lewis and Shetlands; 2381, July 22, wide track, total at Glasgow and Edinburgh; 2426, September 2, Ayr, Morpeth, also total at Glasgow and Edinburgh; 2442, April 11, Limerick to Edinburgh; 2545, April 12, Bideford, Portsmouth ; 2600, May 5, Beachy Head, Thanet ; 2681, June 8, Orkneys and Shetlands ; 2726, July 21, total in Channel Isles, and of maximum duration for any European totality.

THE LENGTH OF A DEGREE OF LATITUDE AND LONGITUDE.

The length of a degree of latitude on the Earth's surface is practically 69 miles everywhere. The late Mr. C. T. Whitmell,

* From the *English Mechanic and World of Science*, No. 2858, p. 283.

* Since this note was printed in " E.M.", this eclipse has, of course, taken place, so is no longer in the " future."

F.R.A.S., calculated that its length only increases about ¾ of a mile from the Equator to the Pole.

A degree of longitude is also 69 miles in length, when measured along the Equator, diminishing to *zero* (that is, having no length at all) at the poles. Its actual length is 69 miles × cosine of latitude.

THE SIGNS OF THE ZODIAC.

♈ Aries, the Ram	0°	♎ Libra, the Balance	180°
♉ Taurus, the Bull	30	♏ Scorpio, the Scorpion	210
♊ Gemini the Twins	60	♐ Sagittarius, the Archer	240
♋ Cancer, the Crab	90	♑ Capricornus, the Goat	270
♌ Leo, the Lion	120	♒ Aquarius, the Water Bearer	300
♍ Virgo, the Virgin	150	♓ Pisces, the Fishes	330

⁂ The figures give the number of degrees from the "First Point of Aries" to the First Point of each sign.

APPENDIX IV.

THE GREEK ALPHABET.

[In the text of this book the fixed stars are referred to as Alpha Centauri, Beta Draconis, Gamma Ursæ Majoris, etc., but in many works on Astronomy the actual Greek letter is given, so it will be advisable to know the Greek alphabet. The stars in the constellations are differentiated by the Greek letter, with the name of the constellation itself in the Latin genitive case; if there are more stars to be enumerated than there are Greek letters, then Latin characters are employed.]

α Alpha.	ν Nu.
β Bēta.	ξ Xī (Ksī).
γ Gamma.	ο Omicron.
δ Delta.	π Pī.
ε Epsilon.	ρ Rho.
ζ Zēta.	σ Sigma.
η Eta.	τ Tau.
θ Theta.	υ Upsilon
ι Iōta.	φ Phī.
κ Kappa.	χ Chī.
λ Lambda.	ψ Psī.
μ Mu.	ω Omēga.

SIGNS DENOTING THE CELESTIAL BODIES, ETC.

☉ The Sun	♅ Uranus
☾ The Moon	♆ Neptune
☿ Mercury	☌ Conjunction
♀ Venus	△ Trine
♁ The Earth (Terra)	□ Quadrature
♂ Mars	☊ Ascending Node
♃ Jupiter	☋ Descending Node
♄ Saturn	☍ Opposition

ABBREVIATIONS.

N.P.=North preceding limb of a celestial body.
N.F.=North following " " "
S.P.=South preceding " " "
S.F.=South following " " "
R.A.=Right Ascension " " "
Decl.=Declination " " "

In expressing terms of Declination +30° would mean 30° N., whilst −30° would equal 30° S.

G.M.T.=Greenwich Mean Time.

S.T.=Summer Time. B.S.T.=British Summer Time.
Z.T.=Zone Time. C.T.=Civil Time.

Time keeping similar to the zone time system was adopted by the British Admiralty in 1919 for use at sea, the ship's clocks being made to show the hour of the time zone in which the vessel happens to be, being altered every time a ship enters a new zone. What is known as a "zero-zone" extends 7½° E. and W. of Greenwich, and then zones of 15° each in width stretch eastward and westward, those to the E. being enumerated thus:— −1, −2, −3, and so on up to −12, and those to the W. numbered +1, +2, +3, and so on up to +12; the two notations meeting on either side of the "date line"; *i.e.*, approximately the 180th meridian, where the day changes in going from E. to W., or W. to E. longitude.

The "zone description" has to be given in the "log," Greenwich time for any event being deducted therefrom. Although "summer Time" does not affect seamen when at sea, they, when on land, and landsmen as well, must remember that both astronomical and meteorological observations are affected during the period it is in force, making all phenomena and observations come one hour *later*. For instance, a lunar eclipse timed to take place at midnight does not occur till 1 a.m. (S.T.),* and similarly weather observations due to be taken at 9 a.m., must not be essayed until 10 a.m., and so on throughout.

* As that of May 2-3, 1920.

APPENDIX V.

A NEW STAR IN CYGNUS.

This object was discovered by Mr. W. F. Denning of Bristol on 20th August, 1920, when it was of about 3½ mag. Its position was in the northern region of Cygnus at R.A. 19h. 56m. 24s. and Declination N. 53° 24′. The star was increasing in brightness and reached a maximum on 24th August when it was of the 1.8 mag. as observed at the Royal Observatory, Greenwich. A decline in lustre then occurred so that by the end of August the mag. was only 4¼ and by September 14 it had fallen to 5½ and was only faintly visible to the naked eye.

It is still being observed at the time of writing (September, 1920) at all the chief observatories in England and abroad, and has aroused a remarkable extent of interest. In the years of the future it will continue to be examined as a small telescopic star or possibly a nebula for some of these novæ apparently display a nebulous appearance in their later stages. New stars shone out in Cygnus on two occasions in past history, namely, in August, 1600, and in November, 1876.

APPENDIX VI.

NAUTICAL ASTRONOMY.

The various definitions given in the Glossary may be illustrated by means of the diagrams given below (figs. 8a, 8b and 9).*

The first diagram is supposed to be drawn on the plane of the Horizon, for a latitude of 30° N. In such a diagram the altitude of Pole above the Horizon, **P.N.** in this case, will indicate the approximate latitude.

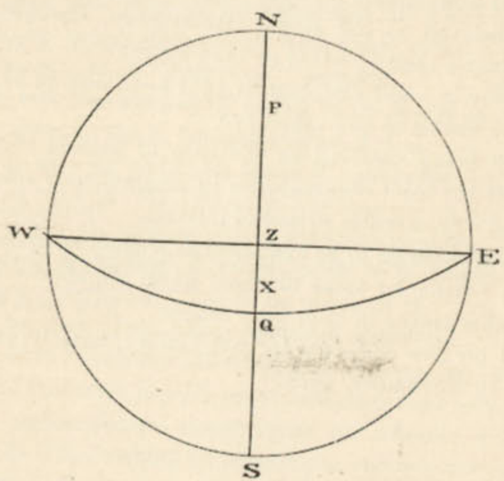


Fig. 8a.

* The diagrams and subject matter of Appendix VI. are reproduced from *Roy's Navigation*, by permission of Mr. J. D. Potter, Admiralty Chart Agent, Minories, London

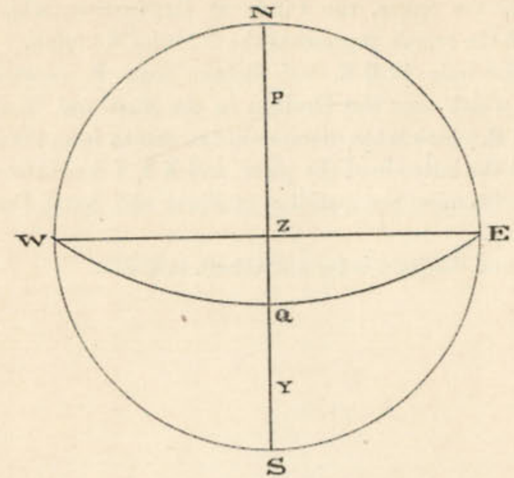


Fig. 8b.

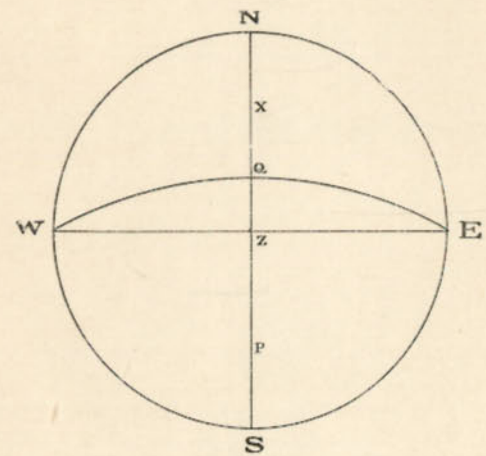


Fig. 9.

N Z S in the figure, the Circle of Declination, which passes through **Z** the zenith, represents the Celestial Meridian.

The semicircle **W Q E**, 90° distant from **P**, represents the Equator, which cuts the Horizon in the East and West points. The arc **Z Q**, which is the distance of the Zenith from the Equator, represents the latitude of the place, and **X S**, **Y S** are the altitudes of two bodies upon the meridian of North and South Declination respectively.

The second diagram is for a southern latitude.

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