ASTRONOMY.

1. ASTRONOMY was first studied as an art, subservient to the purposes of social life. Some knowledge of the celestial motions was necessary, in every state of society, that we might mark the progress of the seasons, which regulate the labours of the cultivator, and the migrations of the shepherd. It is necessary for the record of past events, and for the appointment of national meetings.

While the motions of the heavenly bodies afford us the means of attaining these useful ends, they also present to the curious philosopher a series of magnificent phenomena, the operation of the greatest powers of material nature; and thus they powerfully excite his curiosity with respect to their causes. This circumstance alone makes the celestial motions the proper objects of attention to a student of Mechanical Philosophy, and he has less concern in the beautiful regularity and subordination which have made them so subservient to the purposes of Navigation, of Chronology, and the occupations of rural life.

But the purposes of the mechanical philosopher cannot be attained without attending to that beauty, regularity, and subordination. These features are exhibited in every circumstance of the celestial motions that renders them susceptible of scientific arrangement and investigation; and a philosophical view cannot be taken, without the same accurate knowledge of the motions that is wanted for the arts of life. It must be added, that society never would have derived the benefits which it has received from astronomy, without the labours of the philosopher; for, had not Newton, or some such exalted genius as Newton, speculated about the deflecting forces which regulate the motions of the solar system, we never should have acquired that exquisite knowledge of the mere phenomena that is absolutely necessary for some of the most important applications of them to the arts. It was these speculations alone that have enabled our navigators to proceed with boldness through untried seas, and in a few years have almost completed the survey of this globe. And thus do we experience the most beneficial alliance of philosophy and art.

Since the motions of bodies are the only indications, characteristics, and measures of moving forces, it is plain, that the celestial motions must be accurately ascertained, that we may obtain the data wanted for the purpose of philosophical inference. To ascertain these is a task of great difficulty; and it has required the continual efforts of many ages to acquire just notions of the motions exhibited to our view in the heavens. For the same general appearances may be exhibited, and the same perceptions obtained, and the same opinions will be formed, by means of motions very different; and it is frequently very difficult to select those motions which alone can exhibit *every* observed appearance. If a person who is in motion imagines that he is at rest, and assumes this principle in his reasonings about the effects of the motions which he perceives, he mistakes the conclusions which he draws for real perceptions; and calls that a deception of sense, which is really an error in judgment. Errors, in our opinions concerning the motions of the heavenly bodies, are necessarily accompanied by false judgments concerning their causes. Therefore, an accurate examination of the motions which really obtain in the heavens, must precede every attempt to investigate their causes.

The most probable plan for acquiring a just and satisfactory knowledge of these particulars, is to follow the steps of our predecessors in this study, and first to consider the more general and obvious phenomena. From these we must deduce the opinions which most obviously suggest themselves, to be corrected afterwards, by comparing them with other phenomena, which may happen to be irreconcilable with them.

ASTRONOMICAL PHENOMENA.

2. To an observer, whose view on all sides is bounded only by the sea, the heavens appear a concave sphere, of which the eye is the centre, studded with a great number of luminous bodies, of which the Sun and Moon are the most remarkable. This sphere is called the SPHERE OF THE STARRY HEAVENS.

The only distances in the heavens which are the immediate objects of our observation, are arches of great circles passing through the different points of the starry heavens. Therefore, all astronomical computations and measurements are performed by the rules of spherical trigonometry.

3. We see only the half of the heavens at a time, the other half being hid by the earth on which we are placed. The great circle H B O D, (Fig. 1.) which separates the visible hemisphere H Z O from the invisible hemisphere H N O, is called the HORIZON. This is marked out on the starry heavens by the farthest edge of the sea. The point Z immediately over the head of the observer is called the ZENITH; and the point N, diametrically opposite to it, is called the NADIR.

4. The zenith and nadir are poles of the horizon.

5. If an observer looks at the heavens, while a plummet is suspended before his eye, the plumb line will mark out on the heavens a quadrant of a circle, whose plane is per-

pendicular to the horizon, and which therefore passes through the zenith and nadir, and through two opposite points of the horizon. Z O N H and Z B N D are such circles. They are called VERTICAL CIRCLES and AZIMUTH CIRCLES.

6. The ALTITUDE of any celestial phenomenon, such as a star A, is the angle A C B, formed in the plane of the vertical circle Z A N, by the horizontal line C B and the line C A. This name is also given to the arch A B of the vertical circle which measures this angle. The arch Z A is called ZENITH DISTANCE of the phenomenon.

7. The AZIMUTH of the phenomenon is the angle O C B, or O Z B, formed between the plane of the vertical circle Z A B passing through the phenomenon, and the plane of some other noted vertical Z O N. The arch C B of the horizon, which measures this angle, is also frequently called the azimuth.

8. The starry heavens appear to turn round the earth, which seems pendulous in the centre of the sphere; and by this motion, the heavenly bodies come into view in the east, or RISE; they attain the greatest altitude, or CULMINATE, and disappear in the west, or SET. This is called the FIRST MOTION.

9. This motion is performed round an axis N S (Fig. 2.) passing through two points, N, S, called the poles of the world. In consequence of this motion, a celestial object A describes a circle A D B F, through the centre C of which the axis N S passes, perpendicularly to its plane. This motion may be very distinctly perceived as follows: Let a point, or sight, be fixed in the inside of a sky-light fronting the north, and inclined southwards from the perpendicular at an angle equal to the latitude of the place. An eye placed at this point will see the stars through the glass of the window. Let the points of the glass, through which a star appears from time to time, be marked. The marks will be found to lie in the circumference of a circle,

the centre of which will mark the place of the pole in the heavens.

10. Those stars which are farthest from the poles will describe the greatest circles; and those will describe the largest possible circles which are in the circumference of the circle Æ W Q E, which is equidistant from both poles. This circle is called the EQUATOR, and, being a great circle, it cuts the horizon in two points, E, W, diametrically opposite to each other. They are the east and west points of the horizon.

11. If a great circle A N Q S Æ passes through the poles perpendicularly to the horizon H W O E, it will cut it in the north and south points; and any star A will acquire its greatest elevation when it comes to the semicircle N A S, and its greatest depression when it comes to the semicircle N B S; and the arch D A F of its apparition will be bisected in A.

12. If the circle A D B F of revolution be between the equator and that pole N which is above the horizon, the greatest portion of it will be visible; but if it be on the other side of the equator, the smallest portion will be visible. One half of the equator is visible. Some circles of revolution are wholly above the horizon, and some are wholly below it. A star in one of the first is always seen, and one in the last is never seen.

13. The distance A Æ of any point A from the equator is called its DECLINATION, and the circle A D B F, being parallel to the equator, is called a PARALLEL OF DECLINATION.

14. The angle Æ C H, contained by the planes of the equator and horizon, is the complement of the angle N C O, which is the elevation of the pole.

15. The revolution of the starry heavens is performed in $23^h\ 56'\ 4''$. It is called the DIURNAL REVOLUTION. No appearance of inequality has been observed in it;

and it is therefore assumed as the most perfect measure of time.

16. The time of the diurnal apparition or disparition of a point of the starry heavens is bisected in the instant of its culmination or greatest depression. The Sun, therefore, is in the circle N A S Q at noon. For this reason the circle N A S Q is called the MERIDIAN.

17. A phenomenon whose circle of diurnal revolution A D B F is on the same side of the equator with the elevated pole, is longer visible than it is invisible. The contrary obtains if it be on the other side of the equator.

18. Any great circle N A Æ S, or N B L S, (Fig. 3.) passing through the poles of the world, is called an HOUR CIRCLE.

19. The angle Æ C L, or Æ N L, contained between the plane of the hour-circle N B L S, passing through any phenomenon B, and the plane of the hour circle N Æ S, passing through a certain noted point Æ of the equator, is called the RIGHT ASCENSION of the phenomenon. The intercepted arch Æ L of the equator, which measures this angle, is called by the same name.

20. In assigning the place of any celestial phenomenon, we cannot use any points of the earth as points of reference. The starry heavens afford a very convenient means for this purpose. Most of the stars retain their relative situations, and may therefore be used as so many points of reference. The application of this to our purpose requires a knowledge of the positions of the stars. This may be acquired. The difference between the meridional altitude of a star B, and of the equator, gives the arch A Æ, intercepted between the equator and the parallel of declination, or circle of diurnal revolution A B D, described by the star. And the time which elapses between the passage of this star over the meridian, and the passage of that point Æ of the equator from which the right of ascensions are computed, gives the arch Æ L of the equator which has

passed during this interval. Therefore, an hour circle N L S being drawn through the point L of the equator, and a circle of revolution A B D being drawn at the observed distance A Æ from the equator, the place of the star will be found in their intersection B.

21. Globes and maps have been made, on which the representations of the stars have been placed, in positions similar to their real positions; and catalogues of the stars have been composed, in which every star is set down with its declination and right ascension, this being the most convenient arrangement for the practical astronomer. Their longitudes and latitudes (to be explained afterwards) are also set down, in separate columns. The most noted of all these is the BRITANNIC CATALOGUE, constructed by Dr Flamstead, from his own observations in the Royal Observatory at Greenwich. This catalogue contains the places of 3000 stars. It is accompanied by a collection of maps, known to all astronomers by the title of ATLAS CELESTIS. An useful abridgment of both has been published by *Bode* in *Berlin*, and by *Fortin* in *Paris*, in small quarto. Two planispheres have also been published by *Senex*, in *London*, constructed from the same observations, and executed with uncommon elegance; as also a particular map of that zone of the heavens to which all the planetary motions are limited. This is also executed with superior elegance and accuracy. The place of any phenomenon may be ascertained in it within 5′ of the truth, by mere inspection, without calculation, scale, or compasses. No astronomer should be unprovided with it.

22. All these representations and descriptions of the starry heavens become obsolete, in some measure, in consequence of a gradual change in the declination and right ascension of the stars. But as this may be accurately computed, the maps and catalogues retain their original value, requiring only a little trouble in accommodating them to the present state of the heavens. The Britannic

Catalogue and Atlas are adjusted to the state of the heavens in 1690; and the planispheres, &c. by Senex, are the same. The editions of Paris and Berlin are for 1750.

23. In these maps and catalogues, it has been found convenient to distribute the stars into groupes, called CONSTELLATIONS; and figures are drawn, which comprehend all the stars of a group, and give them a sort of connexion and a name. Each star is distinguished by its number in the constellation, and also by a letter of the alphabet. Thus, the most brilliant star in the heavens, the Dog star, or Sirius, is known to all astronomers as No 9, or as α *Canis Majoris*. The numbers always refer to the Britannic catalogue, it being considered as classical.

24. Since the publication of that work, however, great additions have been made to our knowledge of the starry heavens, and several catalogues and atlases have been published in different parts of Europe. Of the catalogues, the most esteeemed are, 1. a small catalogue of 389 stars, the places of which have been determined with the utmost care by Dr Bradley, at the Greenwich Observatory; 2. a catalogue of the southern stars by Abbé de la Caille; 3. a catalogue of the zodiacal stars by Tobias Mayer at Gottingen; and, *lastly*, a new atlas celestis, consisting of a catalogue and maps of the whole heavens, and containing above 15,000 stars, by Mr Bode of Berlin. The Rev. Mr Fr. Wollaston published, in 1780, a specimen of a general astronomical catalogue of the fixed stars, arranged according to their declinations, folio, London, 1780. This is a most valuable work, containing the places of many thousand stars, according to the catalogues of Flamstead, La Caille, Bradley, and Mayer. These being arranged in parallel columns, we see the differences between the determinations of those astronomers, and are advertised of any changes which have occurred in the heavens. The catalogue is accompanied by directions for prosecuting this

method of obtaining a minute survey of the whole starry heavens.

In the valuable astronomical tables published in 1776 by the academy of Berlin, Mr Bode has given a similar synopsis of the catalogues of Flamstead, La Caille, Bradley, and Mayer, not indeed so extensive, nor so minute, as Wollaston's, but of great use.*

25. Having thus obtained maps of the heavens, the place of a celestial phenomenon is ascertained in a variety of ways. 1. By its observed distance from two known stars. 2. By its altitude and azimuth. 3. Most accurately, by its right ascension and declination.

26. This last being the most accurate method of ascertaining the place of any celestial phenomenon, observations of meridional altitude, and of TRANSITS over the meridian, are the most important. For an account of the manner of conducting these observations, and a description of the instruments, we may consult Smith's Optics, vol. II.; Mr Vince's Treatise of Practical Astronomy; La Lande's Astronomy, &c.† The MURAL QUADRANT, TRANSIT INSTRUMENT, and CLOCK, are therefore the capital furniture of an observatory; to which, however, should be added an EQUATORIAL INSTRUMENT for observing phenomena out of the meridian. Other instruments, such as the EQUAL ALTITUDE INSTRUMENT, the RHOMBOIDAL RETICULA, the ZENITH SECTOR, and one or two more, are fitted for astronomers on a voyage.

27. The position of the meridian, and the latitude of the observatory, must be accurately determined. There are va-

* This Catalogue, reduced to 1820, is published in the EDINBURGH ENCYCLOPÆDIA, Art. ASTRONOMY, vol. II. p. 745.——ED.

† An account of the modern astronomical instruments, as made by Mr Troughton, and the method of using them, will be found in the EDINBURGH ENCYCLOPÆDIA, Articles ASTRONOMY, CIRCLE, OBSERVATORY, &c.——ED.

rious methods of determining the meridian. The most accurate is to view a circumpolar star through a telescope which has an accurate motion in a vertical plane, and to change the position of the telescope till the times which elapse between the successive upper and lower transits of the star are precisely equal. The instrument is then in the plane of the meridian (Fig. 4.)

28. In order to find the declination of a phenomenon more readily, it is convenient to know the inclination of the axis of diurnal revolution N S (Fig. 2.) to the horizon, or the elevation of the pole N. The best method for this purpose is to observe the greatest elevation I O, and the least elevation K O, of some circumpolar star. The elevation of the pole N is half the sum of those elevations.

29. The elevation of the pole is different in different places. An observer, situated 69½ statute miles due north of another, will find the pole elevated about a degree more above his horizon. From observations of this kind, the bulk and shape of the earth are determined. For it is plain that 360 times 69½ miles must be the circumference of the globe. It is found to be nearly an elliptical spheroid, of which the axis is 7904 miles, and the greatest diameter 7940 miles. This deviation from perfect sphericity has been discovered by measuring, in the way now mentioned, a degree of the meridian in different latitudes. One was measured in Lapland, in latitude 66° 20′, and it measured 122,457 yards, exceeding 69½ miles by 137 yards*. Another was measured at Peru, crossing the very equator. It contained 121,027 yards falling short of 69½ miles by 1293 yards, and wanting 1430 yards, or almost a mile, of the other. Other degrees have been measured in intermediate latitudes; and it is clearly established, that the degrees gra-

* This degree is supposed to be 200 French toises too great by M. Svanberg, who lately remeasured it.—Ed.