THE MOVEMENTS OF THE EARTH[1]

I.—Measurement of Space

IN proceeding to deal with the application of the various branches of physical science to the investigation of those phenomena which lie beyond the earth, there is a very large field from which to make choice of a subject which will show, now the application of one branch of science, and now the application of another, and bring us, in this way, somewhat nearer to the truths and the beauties which lie in the most distant realms of space for all who will take the trouble to look for them. But perhaps it may be more desirable to select that part of the subject which, so to speak, lies nearer home, and endeavour to point out how, by means of the application of principles, and methods, and instruments which are generally familiar, and which at all events are of daily use, the various movements with which our planet is endowed may be studied, not only with reference to the phenomena themselves, but with reference also to the causes which lie at the bottom of them.

The various branches of knowledge which will have to be drawn upon in furnishing the materials necessary for this inquiry were really started long before it was imagined that the earth had any movements at all; but still, on the whole, the growth of the knowledge of its movements has been so beautifully continuous, that we cannot do better now than consider historically the way in which those sciences have grown up, which enable us to make certain measurements, and to get out correctly certain quantities, which must necessarily lie at the bottom of any sound knowledge.

What particular things do we want to measure? It has been already said that when the sciences to which attention will have to be called later on were founded, very few people on this planet knew that it moved at all, but it is now generally known that the earth does move. It will be obvious however that, whether the earth moves or not (and that may be considered still a moot question), if we wish to form a basis for our judgment in any direction, we must be able to measure time and space. It has been well said that "time and space are the moulds in which phenomena are cast;" for when it is desired to gain any useful knowledge concerning any fact, the relation which it bears to the things around it, and the time of its occurrence must be known, and that is the only thing an astronomer tries to do when he is investigating that portion of his subject to which we must first turn our attention. We will begin then by considering those measurements of space which are of the first importance to the astronomer. I do not here refer to the ordinary familiar measurement of inches, yards, and miles, but to the measurement of angles, and it will be well to get a good notion of this angular measurement as soon as possible.

There is no special necessity for dividing the circle into 360 parts, but the greatest number of people have made that division, and it is still continued to be done. When the Chinese began to make circles they divided them, not into 360 parts, but into 365¼. Now there was a great advantage, and a great disadvantage about that. The advantage was that this number of divisions in the Chinese circle was the same as the number of days in the year; the disadvantage was that they were not dealing with whole numbers, and their 365¼ was not such a convenient number to halve and quarter, and so on, as is 360. In quite recent times it has been suggested that 400 parts should be taken instead of 360, but that is a suggestion which up to the present time has not been acted upon.

We have then an angle defined as the inclination of two straight lines starting from a centre; if we get one of these lines traversing an entire circumference, the other remaining at rest, the travelling line will have traversed 360°; we have what is called a right angle when one of the lines has been separated from the other through a quarter of a circumference—that is, 90°. This is the fundamental idea of angular measurement, the only measurement of space with which we shall have to deal at present.

For instance, if a little ivory rule be opened, its two parts become inclined to each other, and include what is known as an angle. That angle may be made large or small by opening and closing the two parts, A and B (see Fig. 1) of the rule. Suppose the rule to be shut, the point on which it turns being in the centre of the circle, C D E F, and that, whilst A remains at rest, B is made to travel successively through B and B^1 to B^2. It will then have travelled half the circumference of the circle C D E F but civilised people, . order to get perfectly clear notions about this measurement, and to be able to tell each other what particular measurement they have made in this way, instead of talking of a circumference merely,

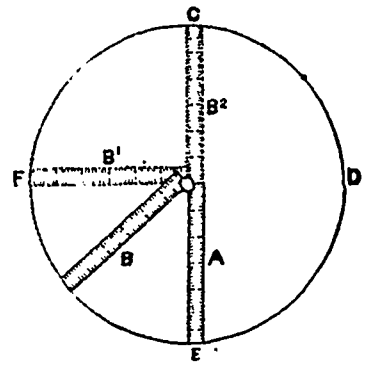

FIG. 1.—Use of a two-foot rule to explain angular measurement. With the point A at rest, the movement of the other to B, B^1 and B^2 gives us 45°, 90°, and 180°.

and of certain rough divisions of it, have divided all circles into 360 parts called degrees, and say that the travelling part, B, of the rule has travelled through not a quarter, or a half circumference, but through 90 and 180 degrees respectively.

Why are these measurements of space required? For the reason that when we are dealing with the heavenly bodies and seeking to define the position of any object, two facts at least are required to be known before its exact position can be determined. An observer going out at night upon an extended plain would see some celestial bodies near where the earth meets the sky all round, which is called the circle of the horizon, and he might happen to see another body exactly overhead, in what is called the zenith. In passing from this zenith to the horizon it will be obvious that a quarter of a circumference is traversed (see Fig. 2). That distance may therefore be divided into 90°.

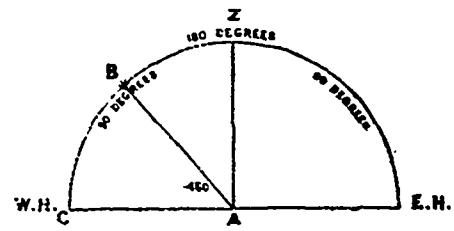

FIG. 2.—Measurement of altitudes.

Similarly in passing from the eastern horizon to the western horizon half a circumference is travelled over. This distance therefore is divided into 180° of angular measurement in the same way that the half of the circumference traversed by the travelling rule was divided into 180°.

Now if it can be ascertained of any body that it is exactly in the zenith, the position of that one body has been definitely stated for the particular time at which the observation is made. But consider the case of another body not in the zenith. Suppose that the lines, the one A B (see Fig. 2), passing from the observer to the object, and the other, A C, passing from the observer to the horizon, include an angle of 45°. This angle is called the star's altitude. But to say simply that the altitude of a star is 45° does not sufficiently define its position. Let the reader imagine himself to be standing in the Albert Hall. He knows that he may look up and see rows of panes of glass and ornamented work running around the hall at different heights above the floor. He may also notice, let us say, various series of ornamentation arranged vertically from floor to roof. Now suppose it were desired to define the position of any one pane of glass or piece of ornamentation in any one of these horizontal or vertical rows. It is obvious that to say of any pane of glass at one level that it is at a certain height above the floor will not suffice, for all the panes of glass in that row are at the same

[1] Report of Lectures to Working Men given at the Royal School of Mines by J. Norman Lockyer, F.R.S.