## ON SOME POINTS IN THE EARLY HISTORY OF ASTRONOMY.[1]

### II.

WE have next to deal with the astronomical relations of the horizon of any place, in connection with the worship of the sun and stars at the times of rising or setting, when of course they are on or near the horizon; and in order to bring this matter nearer to the ancient monuments, we will study this question for Thebes, where they exist in greatest number and have been most accurately described.

The French and Prussian Governments have vied with each other in the honourable rivalry of mapping and describing the monuments. The French went to Egypt at the end of the last century, while the Scientific Commission which accompanied the army, a Commission appointed by the Institute of France, published a series of volumes containing plans of all the chief temples in the valley of the Nile, as far as Philæ.

In the year 1844, after Champollion had led the way in deciphering the hieroglyphics, we became almost equally indebted to the Prussian Government, who also sent out a Commission to Egypt, under Lepsius, which equalled the French one in the importance of the results of the exploration; in the care with which the observations were made, and in the perfection with which they were recorded. Hence it is that in attempting to get information from ancient temples it is wise to study the region round Thebes, where the information is so abundant and is ready to our hand.

We have then to consider an observer on the Nile at Thebes, and to adjust things properly we must rectify the globe to the latitude of 25° 40′, or, in other words, incline the axis of the globe at that angle to the wooden horizon.

It will be at once seen that the inclination of the axis to the horizon is very much less than in the case of London. Since all the stars which pass between the North Pole and the horizon cannot set, all their apparent movement will take place above the horizon. All the stars between the horizon and the South Pole will never rise. Hence, stars within the distance of 25° from the North Pole will never set at Thebes, and those stars within 25° of the South Pole will never be visible there. At any place the latitude and the elevation of the pole are the same. It so happens that all these places with which archæologists have to do in studying the history of early peoples, Chaldæa, Egypt, Babylonia, China, Greece, &c., are all in middle latitudes, therefore we have to deal with bodies in the skies which do set and bodies which do not, and the elevation of the pole is neither very great nor very small. In each different latitude the inclination of the equator to the horizon as well as the elevation of the pole will vary, but there will be a strict relationship between the inclination of the equator at each point and the elevation of the pole. Except at the poles themselves the equator will cut the horizon due east and due west. Therefore everything to the north of the equator which rises or sets will cut the horizon between the east or west point and the north point; those bodies which do not set will of course not cut the horizon at all.

The sun and stars near the equator, in such a latitude as that of Thebes, will appear to rise or set at no very considerable angle from the vertical; but when we deal with stars rising or setting near to the north or south points of the horizon they will seem to skim along the horizon instead of rising directly.

Now it will at once be obvious that there must be a strict law connecting the position of the sun or a star with its place of rising or setting. Stars at the same distance from the celestial pole or equator will rise or set at the same point of the horizon, and if a star does not change its place in the heavens it will always rise or set in the same place. Here it will be convenient to introduce one or two technical terms: we generally define a star's place by giving, as one ordinate, its distance in degrees from the equator: this distance is called its declination. Further, we generally define points on the horizon by dividing its whole circumference into 360°, so that we can have *azimuths* of 90° from each pole to the east and west points. We also have *amplitudes* from the east and west points towards each pole. We can say then that a star of a certain declination will rise or set at such an azimuth; or at such an amplitude. This will apply to both north and south declinations.

The following table gives the amplitudes of rising or setting (north or south) of celestial bodies having declinations from 0° to 64°; bodies with higher declinations than 64° never set at Thebes if they are north, or never rise if they are south, as the latitude (and therefore the elevation of the pole) there is nearly 26°.

*Amplitudes at Thebes.*

| Declination. | Amplitude at Thebes. | Declination. | Amplitude at Thebes. |
|---|---|---|---|
| ° | ° ′ | ° | ° ′ |
| 0 | 0 0 | 33 | 37 11 |
| 1 | 1 7 | 34 | 38 21 |
| 2 | 2 13 | 35 | 39 31 |
| 3 | 3 20 | 36 | 40 42 |
| 4 | 4 26 | 37 | 41 53 |
| 5 | 5 33 | 38 | 43 5 |
| 6 | 6 40 | 39 | 44 17 |
| 7 | 7 47 | 40 | 45 30 |
| 8 | 8 53 | 41 | 46 43 |
| 9 | 9 59 | 42 | 47 56 |
| 10 | 11 6 | 43 | 49 10 |
| 11 | 12 13 | 44 | 50 25 |
| 12 | 13 20 | 45 | 51 41 |
| 13 | 14 27 | 46 | 52 57 |
| 14 | 15 34 | 47 | 54 14 |
| 15 | 16 41 | 48 | 55 32 |
| 16 | 17 49 | 49 | 56 51 |
| 17 | 18 56 | 50 | 58 12 |
| 18 | 20 3 | 51 | 59 34 |
| 19 | 21 10 | 52 | 60 58 |
| 20 | 22 17 | 53 | 62 23 |
| 21 | 23 25 | 54 | 63 51 |
| 22 | 24 33 | 55 | 65 21 |
| 23 | 25 41 | 56 | 66 54 |
| 24 | 26 49 | 57 | 68 31 |
| 25 | 27 58 | 58 | 70 12 |
| 26 | 29 6 | 59 | 71 59 |
| 27 | 30 15 | 60 | 73 55 |
| 28 | 31 23 | 61 | 76 1 |
| 29 | 32 32 | 62 | 78 25 |
| 30 | 33 41 | 63 | 81 19 |
| 31 | 34 51 | 64 | 85 42 |
| 32 | 36 1 | | |

This being premised, we now pass to the yearly path of the sun, with a view of studying the relation of the various points of the horizon occupied by the sun at different times in the year. In the very early observations that were made in Egypt, Chaldæa, and elsewhere, when the sun was considered to be a god who every morning got into his boat and floated across space, there was no particular reason for considering the amplitude at which the boat left, or came to, shore. But a few centuries showed that this rising or setting of the sun in widely varying amplitudes at different parts of the year

[1] From shorthand notes of a course of lectures to working men delivered at the Museum of Practical Geology, Jermyn Street, in November 1890. The notes were revised by me at Aswan during the month of January. I have found, since my return from Egypt in March, that part of the subject-matter of the lectures has been previously discussed by Herr Nissen, who has employed the same materials as myself. To him, therefore, so far as I at present know, belongs the credit of having first made the suggestion that ancient temples were oriented on an astronomical basis. His article is to be found in the *Rheinisches Museum für Philologie*, 1885. Continued rom vol. xliii. p. 563.

depended upon a very definite law. We now, of course, more fortunate than the early Egyptians, know exactly what this law is. We saw in the last lecture that not many years ago Foucault gave us a means of demonstrating the fact that the earth rotates on its axis. We have also a perfect method of demonstrating that the earth not only rotates on its axis once a day, but that it moves round the sun once a year, an idea which was undreamt of by the ancients. As a pendulum shows us the rotation, so the determination of the aberration of light demonstrates for us the revolution of the earth round the sun.

We have, then, the earth endowed with these two movements—a rotation on its axis in a day, and a revolution round the sun in a year. To see the full bearing of this on our present inquiry, we must for a time return to the globe or model of the earth.

To determine the position of any place on the earth's surface we say that it is so many degrees distant from the equator, and also so many degrees distant from the longitude of Greenwich: we have two rectangular co-ordinates, latitude and longitude. When we conceive the earth's equator extended to the heavens, we have a means of determining the positions of stars in the heavens exactly similar to the means we have of determining the position of any place on the earth. We have already defined distance from the equator as north or south declination in the case of a star, as we have north latitude or south latitude in case of a place on the earth. With regard to the other co-ordinate, we can also say it is at a certain distance from our first point of measurement, whatever that may be, along the celestial equator; speaking of the stars we call this distance right ascension, as speaking of matters earthy we measure from the meridian of Greenwich and call this distance longitude.

The movement of the earth round the sun is in a plane which is called the plane of the ecliptic, and the axis of rotation of the earth is inclined to that plane at an angle of something like $23\frac{1}{2}^\circ$. We can if we choose use the plane of the ecliptic to define the positions of the stars as we use the plane of the earth's equator. In that case we talk of distance above the ecliptic as celestial latitude, and along the ecliptic as celestial longitude. The equator, then, cuts the ecliptic at two points: one of these is chosen for the start-point of measurement along either the equator or the ecliptic. It is called the first point of Aries.

We have, then, two systems of co-ordinates, by each of which we can define the position of a star in the heavens: equatorial co-ordinates dealing with the earth's equator, ecliptic co-ordinates dealing with the earth's orbit. Knowing that the earth moves round the sun once a year, the year to us moderns is defined with the most absolute accuracy. In fact, we have three years: we have a sidereal year—that is, the time taken by the earth to go through exactly $360^\circ$ of longitude; we have what is called the tropical year, which indicates the time taken by the earth to go through not quite $360^\circ$, to go from the first point of Aries till she meets it again; and since the equinoctial point advances to meet the earth, we talk about the precession of the equinoxes; this year is the sidereal year minus twenty minutes; then there is also another year called the anomalistic year, which depends upon the movement of the point in the earth's orbit where the earth is nearest to the sun; this is running away, so to speak, from the first point of Aries, instead of advancing to meet it, so that in this case we get the sidereal year plus nearly five minutes.

The angle of the inclination of the earth's plane of rotation to the plane of its revolution round the sun, which, as I have said, is something like $23\frac{1}{2}^\circ$, is called *the obliquity of the ecliptic*. This obliquity is subject to a slight change; 6000 years ago it was over $24^\circ$.

In order to give a concrete idea of the most important points in the yearly path of the sun round the earth, I have here four globes representing the earth, with another globe in the middle representing the sun, showing the four practically opposite points of the earth's orbit, in which the north pole of the axis is most inclined to the sun; the north pole of the axis is most inclined away from the sun; and the two opposite and intermediate points where the axis is not inclined to or from the sun, but is at right angles to the line joining the earth in these two positions.

A diagram (Fig. 6) shows what will happen under these conditions. If we take the two points at which the axis, instead of being inclined towards the sun, is inclined at right angles to it, it is perfectly obvious that we shall get a condition of things in which the movement of the earth on its axis will cause the dark side of the earth

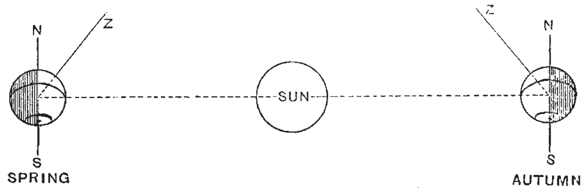


FIG. 6.—Diagram showing the equality of the sun's zenith distance at the two equinoxes. N, north pole of the earth; S, south pole; Z, zenith of Greenwich.

and also the light side represented by the side nearest to the sun both being of equal areas, to extend from pole to pole; so that any place on the earth rotating under those conditions will be brought for half a period of rotation into the sunlight, and be carried for half a period of the rotation out of the sunlight; the day, therefore, will be of the same length as the night, and the days and nights will therefore be equal all over the world.

We call that the period of the equinoxes; the nights are of the same length as the day in both these positions of the earth with regard to the sun.

But in Fig. 7 we have a very different condition. Here the north pole is inclined at the greatest angle of $23\frac{1}{2}^\circ$ towards, and away from, the sun. If I take a point very near the north pole, that point will not, in summer, be carried by the earth's rotation out of the light,

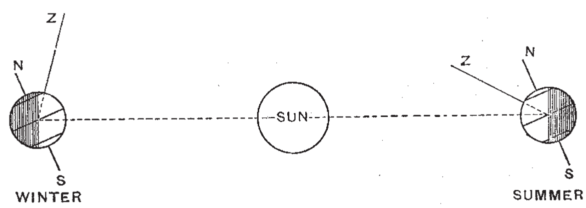


FIG. 7.—Diagram showing the variation of the sun's zenith distance from solstice to solstice. N, north pole of the earth; S, south pole; Z, zenith of Greenwich.

and a part equally near the south pole will not be able to get into it. These are the conditions at and near two other points called the solstices.

In each of these globes I have placed a wire to represent the overhead direction from Jermyn Street, London, and if I observe the angle between this direction of the zenith to the sun in winter I get a considerable one; but if I take the opposite six-monthly condition and take the same zenith point, I get a very small angle. In other words, under the first condition the sun will be far from the zenith of Jermyn Street, we shall have winter; and in the other condition the sun will be as near as it can be to the zenith of Jermyn Street, we shall have summer. These two points represent the two points in the earth's orbit at which the sun has the highest declination north or south. With the greatest north declination the sun will come up high, appear stationary for a day or two, as it does at our summer solstice, and then go down again; at the other point, when it has the greatest southern declination, it will go down to the lowest point, as it does in our winter, stop, and come up again—that is, the sun will stand still, and the Latin word solstice exactly expresses that idea. We have then two points in the annual revolution of the earth round the sun at which we have equal altitudes of the sun at noon, two others when the altitude is greatest and least. We get the equal altitudes at the equinoxes and the greatest and the least at the solstices. These altitudes depend upon the change of the sun's declination. The change of declination will affect the azimuth and amplitude of the sun's rising and setting, this is why the sun sets most to the north in summer and most to the south in winter. At the equinoxes the sun has always 0° Decl., so it rises and sets due east and west all over the world. But at the solstices it has its greatest declination of $23\frac{1}{2}°$ N. or S.; it will rise and set therefore far from the east and west points; how far, will depend upon the latitude of the place we consider. The following are approximate values:

| Latitude of place (°) | Amplitude of sun at solstice. (° ′) |
|---|---|
| 25 ... ... ... ... | 26 5 |
| 30 ... ... ... ... | 27 24 |
| 35 ... ... ... ... | 29 8 |
| 40 ... ... ... ... | 31 21 |
| 45 ... ... ... ... | 34 40 |
| 50 ... ... ... ... | 38 20 |
| 55 ... ... ... ... | 44 0 |

At Thebes, representing Egypt, we find that the sun's azimuth at the summer solstice will be 26° N. of E. at rising, and it will be 26° N. of W. at setting.

These solstices and their accompaniments are among the striking things in the natural world. In the winter solstice we have the depth of winter, in the summer solstice we have the height of summer, while at the equinoxes we have but transitional changes; in other words, while the solstices point out for us the conditions of greatest heat and greatest cold, the equinoxes point out for us those two times of the year at which the temperature conditions are very nearly equal, although of course in the one case we are saying good-bye to summer and in the other to winter. To people who live in tropical or sub-tropical countries a summer solstice is a very much more definite thing than it is to us. In Egypt the summer solstice was paramount, for it heralded the rise of the Nile. Next came the autumnal equinox, for it marked the height of the inundation.

Did the ancients know anything about these solstices and these equinoxes? That is one of the questions which we have to discuss. Dealing with the monumental evidence in Egypt alone, the answer is absolutely overwhelming. The evidence I propose to bring before you consists of that afforded by some of the very oldest temples that we know of in Egypt. Among the most ancient and sacred fanes in Egypt was one at Abydos, which, the tradition runs, was built by the Shosou-Hor or servants of Horus (therefore sun-worshippers) before the time of Menes; Menes, as we have seen, having reigned at a date certainly not less than 4000, and possibly 5000 years B.C.

First a word as to the general plan of a temple such as we find it in Egypt. They may be arranged architecturally into two main groups. Edfou is the most perfect example of one of the first group, characterized by having a pylon consisting of two massive structures right and left of the entrance, which are somewhat like the two towers that one sometimes sees on the west front of some of our English cathedrals. The Temple of Ramses II. in the Memnonia at Thebes is another example (Fig. 8).

From the entrance-pylon the temple goes stretching along through various halls of different sizes and details until at last at the extreme end of the temple what is called the Sanctuary, Naos, or Holy of Holies, is reached. The end of the temple at which the pylons are situated is open, the other is closed. These lofty towers, and indeed the walls, are sometimes covered with the most wonderful drawings and hieroglyphic figures and records. Stretching in front of the pylons, extending sometimes very far in front, are rows of sphinxes. This prin-

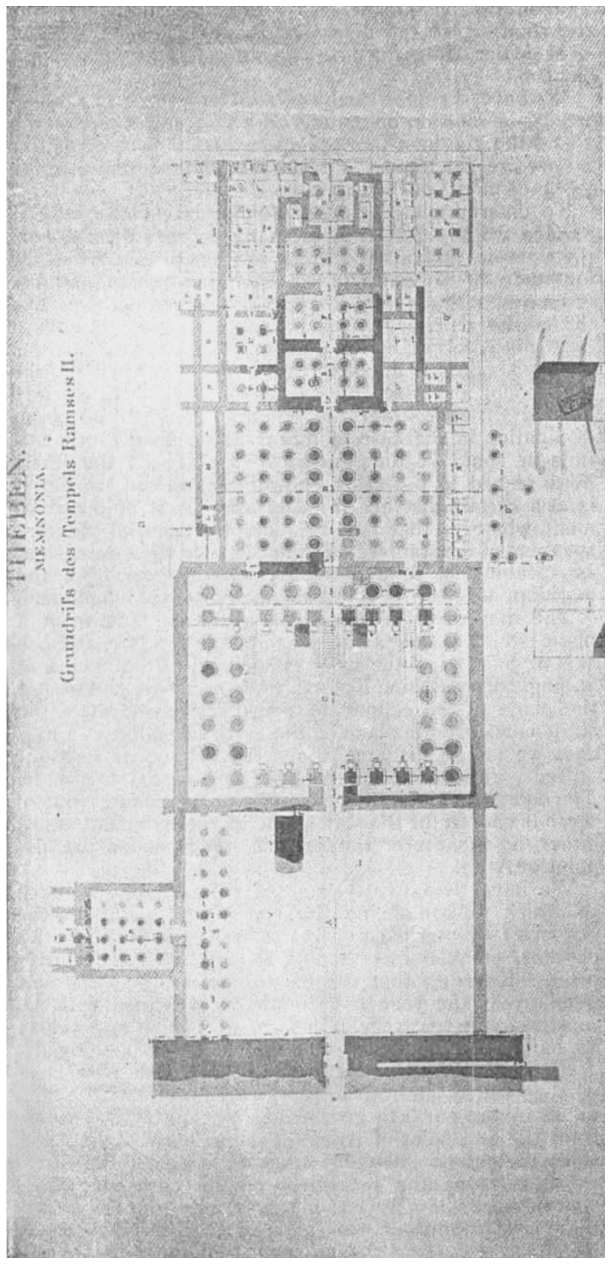


FIG. 8.—Plan of the Temple of Ramses II. in the Memnonia at Thebes (from Lepsius), showing the pylon at the open end, and the sanctuary at the closed one.

ciple is carried to such an extent that in some cases separate isolated gates have been built right in front and exactly in the alignment of the temple. At Karnak there really are two such temples back to back, and the distance which separates the outside entrances of both is greater than the distance from Pall Mall to Piccadilly; the great temple covers about twice the area covered by

St. Peter's at Rome, so that these were temples of a vastness absolutely unapproached in the modern world.

In Denderah we have an example of the second group, in which the massive pylon is omitted. In these the front is entirely changed; instead of the pylon we have now an open front to the temple with columns—the Greek form of temple is approached (Fig. 9).

I shall not have time to get to the astronomical side of the Greek temples in this course of lectures, but I am anxious to take this opportunity to refer to the transition from the Egyptian form of temple to the Greek one. The east front of the Parthenon at Athens very much more resembles the temple of Denderah than it does the early Egyptian temple—that is to say, the eastern front is open; it is not closed by pylons.

In many Egyptian temples, in the progress from one end to the other, one goes through various halls of different styles of architecture and different stages of magnificence. But in the Greek temple this is entirely changed; the approach to the temple was outside, the temple representing, so to speak, the core, almost the Holy of Holies, of the Egyptian temple, and any magnificent approach to it

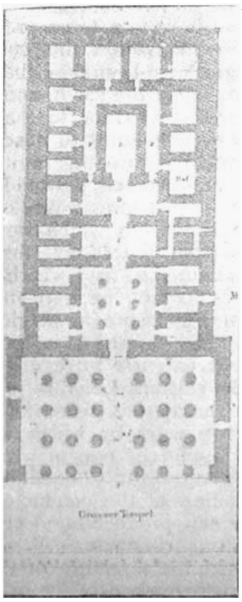

FIG. 9.—Plan of the Temple of Denderah (from Lepsius), showing the absence of a pylon.

which could be given, was given from the outside. But although they were quite different in their aspects, they were quite similar in their objects. Some Egyptian temples took hundreds of years to build; the obelisks were all in single blocks like that on the Embankment, and all were brought for hundreds of miles down the Nile. A temple meant to the Egyptians a very serious thing indeed.

So much, then, for a general idea of an ancient temple.

Another point is very striking in these temples, notably in the chief one at Karnak.

From one end of the temple to the other we find the axis marked out by narrow apertures in the various pylons, and many walls with doors crossing the axis. There are 17 or 18 of these limiting apertures, and in the other temple which is back to back to this one we have pylons in exactly the same way limiting the light which falls into the Holy of Holies or the Sanctuary. This construction gives one a very definite impression that every part of the temple was built to subserve a special object, viz. to limit the sunlight which fell on its front into a narrow beam, and to carry it to the other extremity of the temple—into the sanctuary—which extremity was always blocked. There is no case in which the beam of light can pass absolutely through the temple.

The idea is strengthened by considering the construction of the astronomical telescope. Although the Egyptians knew nothing about telescopes, it would seem that they had the same problem before them which we solve by a special arrangement in the modern telescope—they wanted to keep the light pure, and to lead it into their sanctuary, as we lead it to the eyepiece. To keep the light that passes into the eyepiece of a modern telescope pure, we

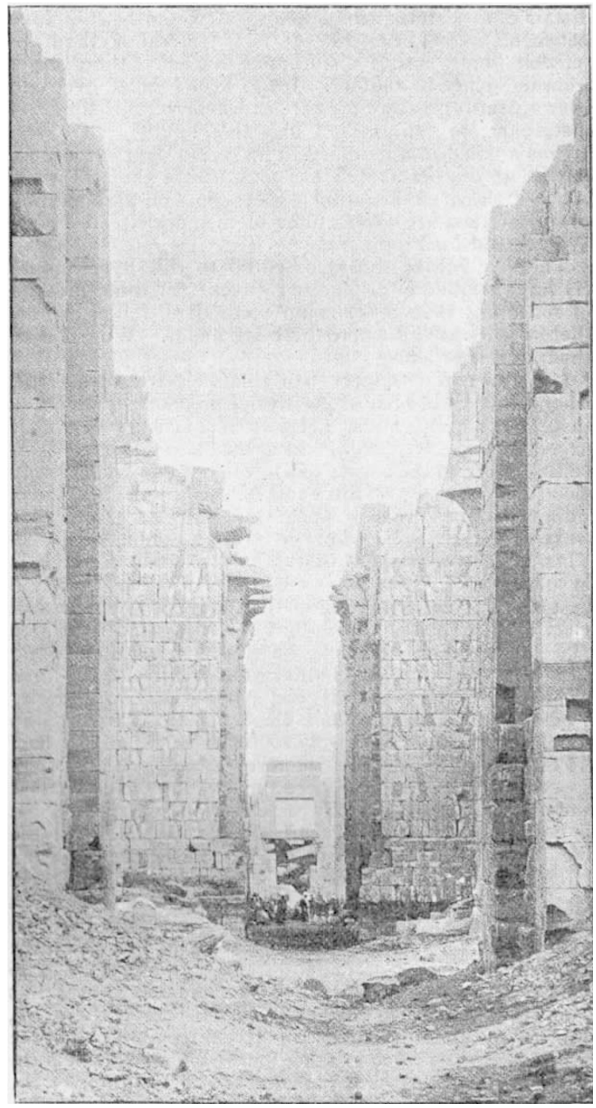

FIG. 10.—The axis of the Temple of Karnak, looking south-east, from outside the north-west pylon (from a photograph by the author).

have between the object-glass and the eyepiece a series of what are called diaphragms; that is a series of rings right along the tube, the inner diameters of the rings being greatest close to the object-glass, and smallest close to the eyepiece; these diaphragms must so be made, that all the light from the object-glass shall fall upon the eyepiece, without loss, or reflection by the tube.

These apertures in the pylons and separating walls of Egyptian temples exactly represent the diaphragms in the modern telescope. J. NORMAN LOCKYER.

(*To be continued.*)