THE

STORY OF THE HEAVENS.

"THE Story of the Heavens" is the title of our book. We have indeed a wondrous story to narrate; and could we tell it adequately, it would prove of boundless interest and of exquisite beauty. It leads to the contemplation of the mightiest efforts of nature and the greatest achievements of human genius.

Let us enumerate a few of the questions which will be naturally asked by one who seeks to learn something of those glorious bodies which adorn our skies: What is the Sun—how hot, how big, and how distant? whence comes its heat? What is the Moon? What scenery do its landscapes show? how does the moon move? how is it related to the earth? What of the planets—are they globes like the earth? how large are they, and how far off? What do we know of the satellites of Jupiter and of the rings of Saturn? What was the memorable discovery of Uranus? and what was the supreme intellectual triumph which brought the planet Neptune to light? Then, as to the other bodies of our system, what are we to say of those mysterious objects, the comets? can we perceive order to reign in their seemingly capricious movements? do we know anything of their nature and of the marvellous tails with which they are often decorated? What can be told about the familiar shooting-star which so often dashes into our atmosphere to perish in a streak of splendour? What do we know of those constellations which have been from all antiquity, and of the myriad hosts of smaller stars which our telescopes disclose?

Can it be true that these countless orbs are really majestic suns, sunk to an appalling depth in the abyss of unfathomable space? What have we to tell of all the different varieties of stars—of coloured stars, of variable stars, of double stars, of multiple stars, of stars that move, and of stars that seem at rest? What of those most supremely glorious objects, the great star clusters? What of the milky way? And lastly, what can we tell of those marvellous nebulæ which our telescopes disclose, poised at an immeasurable distance on the very confines of the universe? Such are a few of the questions which occur, when we ponder on the mysteries of the heavens.

The history of Astronomy is, in one respect, only too like many other histories. The earliest part of it is completely and hopelessly unknown. The stars had been studied, and some great astronomical discoveries had been made, untold ages before those to which our earliest historical records extend. For example, the perception of the apparent movements, of the sun and of the moon, and the recognition of the planets by their movements, are both to be classed among these discoveries of the pre-historic ages. Nor is it to be said that these achievements were all of a very obvious or elementary character. To us of the present day who have been familiar with such truths from childhood, they may now seem simple and rudimentary; but in the infancy of science, the first man who arose to demonstrate one of these great doctrines was indeed a most sagacious philosopher.

Of all the phenomena of Astronomy, the first and the most obvious is that of the rising and the setting of the sun. We may fairly conjecture, that in the dawn of the growth of the human intellect this was probably one of the very first problems to engage the attention of those whose thoughts rose above the animal anxieties of everyday existence. A sun sets and disappears in the west; that sun is obviously a very brilliant body, and the simplest reflection suggests that it is a body of very considerable importance. The following morning a sun arises in the east, moves across the heavens, and it too disappears in the west; the same process happens every day. To us it is obvious that the sun, which appears each day,

is the same sun; but this would not be an obvious truth to one who thought his senses showed him that the earth was a flat plane of indefinite extent, and that around the inhabited regions on all sides extended, to vast distances, either desert wastes or trackless oceans. How could the sun, which plunged into the ocean at a fabulous distance in the west, reappear the next morning at an equally great distance to the east? The old mythological account asserted that after the sun had dipped in the western ocean at sunset (the Iberians, and other ancient nations, actually imagined that they could hear the hissing of the waters when the glowing globe was plunged therein), he was seized by Vulcan and placed in a golden goblet, and thus navigated the ocean round by the north, so as to reach the east again in time for sunrise the following morning. Even the more sober physicists of old, as we are told by Aristotle, believed that in some manner the sun was conveyed round over the earth's surface by the north, and that the darkness of night arose from the elevation of the northern lands, which cut off the sun's light during his midnight voyage.

Even in very early times it was found more rational to suppose that the sun actually pursued his course down below the solid earth during the darkness of night. The earliest astronomers had, moreover, learned to recognise the fixed stars. It was seen that, like the sun, many of these stars rose and set in the course of the diurnal movement, while the moon obviously followed the same law. It thus became plain that the various heavenly bodies possessed the power of actually going below the solid earth. Once it was realised that the whole contents of the heavens performed these movements, it became possible to take a very important step in the knowledge of the constitution of the universe. It was clear that the earth could not be a plane extending to an indefinitely great distance. It was also obvious that there must be a finite depth to the earth below our feet. Nay, more, it became certain that whatever be the shape of the earth, it was at all events something detached from all other bodies, and poised without visible support in space. When first presented to the mind of man, this must have appeared a very startling truth. It was surely difficult to realise

that the solid earth on which we stand reposed on nothing! What is to keep it from falling? How can it be poised, like the legendary coffin of Mahomet, without tangible support? But difficult as it may have been to receive this doctrine, yet its necessary truth commanded assent, and the first great step in Astronomy had been made.

The changes of the seasons and the recurrence of seed-time and of harvest must, from the earliest times, have been associated with certain changes in the position of the sun. In the summer at mid-day the sun rises high in the heavens, in the winter the sun is always low. The sun, therefore, had an annual movement up and down in the heavens, combined with the diurnal movement of rising and setting. But besides these movements of the sun there was another of no less importance, which was not quite so obvious, though still capable of being detected by the simplest observations, when combined with a philosophical habit of reflection. The very earliest observers of the stars can hardly fail to have noticed, that the constellations visible at night varied with the season of the year. For instance, the constellation of Orion, which is so well seen during the winter nights, becomes invisible in the summer, and the place it occupied is then taken by quite different stars. So it is with other constellations; and, indeed, in ancient days, the time for commencing the cycle of agricultural occupations was sometimes indicated by the position of the constellations in the evening.

Reflection on this subject must have demonstrated in very early times the apparent annual movement of the sun. It was seen that the places of the stars, relatively to each other, did not alter appreciably, and there could be no explanation of the changes in the constellations with the seasons, except by supposing that the place of the sun was altering, so as to make the complete circuit of the heavens in the course of the year. The same conclusion is easily confirmed by looking from time to time at the west after sunset, and watching the stars. As the season progresses, it will be noticed that each evening the western constellations sink lower and lower towards the sun, until at length they come so near the

sun that they set at the same time as he does. This is simply explained by the supposition that the sun is gradually but continually rising up from the west to meet the stars. This motion is of course not to be confounded with the ordinary diurnal motion, in which all the heavenly bodies alike participate; inasmuch as besides this motion of the whole heavens, the sun has a slow motion in the opposite direction; so that while the sun and a star may set to-day at the same time, by to-morrow the sun will have moved a little towards the east, relatively to the star, and thus the star will set a few minutes before the sun.*

The patient watchings of the early astronomers enabled the sun's track through the heavens to be ascertained, and it was found that in its annual circuit the sun invariably pursued the same path and traversed the same constellations. The belt of constellations thus specially distinguished is known by the name of the *zodiac*, while the circle traversed by the sun is called the *ecliptic*. The zodiac was divided into twelve equal portions or "signs," and thus the stages on the sun's great journey were conveniently indicated. In the very earliest ages, also, it seems that the duration of the year, or the period required by the sun to run its course around the heavens, became accurately known. The skill of the ancient geometers was also demonstrated by the accurate measures they succeeded in making of the position of the ecliptic with regard to the equator, and in measuring the angle between these two most important circles on the heavens.

The principal phenomena presented by the motion of the moon have also been understood from an antiquity beyond all historical record. The slightest attention reveals the important truth that the moon does not occupy a fixed position in the starry heavens. Indeed, the motion of the moon among the stars is a phenomenon much more easy to recognise than that of the sun among the stars, as during the course of a single night the movement of the moon from west to east across the heavens can be perceived with but very moderate attention. It is most probable that the motion of

* It may, however, be remarked that a star is never *seen* to set, as owing to our atmosphere it ceases to be visible before it reaches the horizon.

the moon among the stars was a discovery prior to that of the annual motion of the sun, inasmuch as it depends upon simple observation, and involves but little exercise of any intellectual power. The time of revolution of the moon had also been discovered, and the phases of the moon had been correctly attributed to the varying aspect under which the sun-illuminated side of the moon is turned towards the earth.

But even this does not exhaust the list of great discoveries which have come down to us from prehistoric times. The striking phenomenon of a lunar eclipse, in which the brilliant surface is plunged temporarily into darkness, and the still more imposing spectacle of a solar eclipse, in which the sun himself undergoes a partial, or even a total obscuration, had also been correctly explained. Then, too, the acuteness of the early astronomers had detected the five wandering stars or planets: they had traced the movements of Mercury and Venus, Mars, Jupiter, and Saturn. They had observed with awe the various configurations of these planets; and just as the sun, and in a lesser degree the moon, were intimately associated with the affairs of daily life, so in the imagination of these early investigators the movements of the planets were thought to be pregnant with human weal or human woe. At length a certain degree of order was perceived to govern the capricious movements of the planets. It was found that they obeyed certain laws. The cultivation of the science of geometry went hand in hand with the study of astronomy; and as we emerge from the dim pre-historic ages into the historical period, we find that a theory possessing some degree of coherence had been established, to explain the phenomena of the heavens.

Although the Ptolemaic doctrine is now known to be framed on an utterly extravagant estimate of the true place of the earth in the scheme of the heavens, yet the apparent movements of the celestial bodies are accounted for by the theory with considerable accuracy. This theory is described in the great work of Ptolemy, known as the "Almagest," which was written in the second century of our era, and for fourteen centuries was regarded as the final authority on all questions of astronomy.

Ptolemy saw that the shape of the earth was globular, and he demonstrated this by the arguments which we employ at the present day. He also saw how this mighty globe was poised, in what he believed to be the centre of the universe. He admitted that the diurnal movement of the whole heavens could be accounted for by the revolution of the earth upon its axis, but he assigned reasons for the deliberate rejection of this view. The earth according to him was a fixed body; it possessed neither rotation nor translation, but remained constantly at rest at the centre of the universe. The sun and the moon he supposed to move in circular orbits around the earth in the centre. The movements of the planets were more complicated, as it was necessary to account for the occasional retrograde motions as well as for the direct motions. The ancient geometry refused to admit that any movement, except circular, could be perfect, and accordingly a contrivance was devised by which each planet revolved in a circle, while the centre of that circle described another circle around the earth. It must be admitted that this scheme, though so widely divergent from what is now known to be the truth, did really present a fairly accurate account of the movements of the planets.

Such was the system of Astronomy which prevailed during the Middle Ages, and which was only finally overturned by the great work to which Copernicus devoted his lifetime. The discovery of the true system of the universe was nearly simultaneous with the discovery of the New World by Columbus. The first principles which were established by the labours of Copernicus, stated that the diurnal movement of the heavens was really due to the rotation of the earth on its axis. He showed the difference between real motions and apparent motions; he proved that all the appearances of the daily rising and setting of the sun and the stars could be just as well accounted for by the supposition that the earth rotated, as by the more cumbrous supposition of Ptolemy. He showed that the latter supposition would attribute an almost infinite velocity to the stars, and that the rotation of the entire universe around the earth was really a preposterous supposition. The second great point, which it is the immortal glory of Copernicus to have

demonstrated, assigned to the earth its true position in the fabric of the universe. He transferred the centre, about which all the planets revolve, from the earth to the sun; and he established the somewhat humiliating truth, that our earth is after all merely one of the system of planets revolving around the sun, and pursuing a track between the paths of Venus and of Mars.

Such was, in brief outline, the great revolution which swept from astronomy those distorted views of the earth's importance, arising from the fact that we are domiciled on that particular planet. The achievement of Copernicus was soon to be followed by the invention of the telescope, that wondrous instrument by which the modern science of astronomy has been created. To the consideration of this most important subject we may well devote the first chapter of our book.

PLATE II.

A TYPICAL SUN-SPOT.

(AFTER LANGLEY.)

CHAPTER I.

THE ASTRONOMICAL OBSERVATORY.

Early Astronomical Observations—The Observatory of Tycho Brahe—The Pupil of the Eye—Vision of Faint Objects—The Telescope—The Object-Glass—Advantages of Large Telescopes—The Equatorial—The Observatory—The Power of a Telescope—Reflecting Telescopes—Lord Rosse's Great Reflector at Parsonstown—How the mighty Telescope is used—The Instruments of Precision—The Meridian Circle—The Spider Lines—Delicacy of pointing a Telescope—The Precautions necessary in making Observations—The Ideal Instrument and the Practical one—The Elimination of Error—The ordinary Opera-Glass as an Astronomical Instrument—The Great Bear—Counting the Stars in the Constellation—How to become an Observer.

THE earliest traces of the Astronomical Observatory are as little known, as the earliest discoveries in astronomy itself. Probably the first application of instruments to the observations of the heavenly bodies, consisted in the extremely simple operation of measuring the length of the shadow cast by the sun at noonday. The variations in the length of this shadow from day to day, and its periodical maxima and minima, furnished valuable information in the early attempts to investigate the movements of the sun. But even in very early times there were astronomical instruments employed which possessed considerable complexity, and showed no small amount of astronomical knowledge.

The first great advance in this subject was made by the celebrated Tycho Brahe, who was born in 1546, three years after the death of Copernicus. His attention seems first to have been directed to astronomy by the eclipse of the sun which occurred on the 21st August, 1560. It amazed his reflective spirit to find that so surprising a phenomenon admitted of actual prediction, and he determined to devote his life to the study of a science possessed of such wonderful precision. In the year 1576 the King of