THE COPERNICUS OF ANTIQUITY (ARISTARCHUS OF SAMOS)

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(ARISTARCHUS OF SAMOS)

BY

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PART I.

GREEK ASTRONOMY TO ARISTARCHUS.

THE title-page of this book necessarily bears the name of one man; but the reader will find in its pages the story, or part of the story, of many other Pioneers of Progress. The crowning achievement of anticipating the hypothesis of Copernicus belongs to Aristarchus of Samos alone; but to see it in its proper setting it is necessary to have followed in the footsteps of the earlier pioneers who, by one bold speculation after another, brought the solution of the problem nearer, though no one before Aristarchus actually hit upon the truth. This is why the writer has thought it useful to prefix to his account of Aristarchus a short sketch of the history of the development of astronomy in Greece down to Aristarchus's time, which is indeed the most fascinating portion of the story of Greek astronomy.

The extraordinary advance in astronomy made by the Greeks in a period of little more than three centuries is a worthy parallel to the rapid development, in their hands, of pure geometry, which, created by them as a theoretical science about the same time, had by the time of Aristarchus covered the ground of the Elements (including solid geometry and the geometry of the sphere), had established the main properties of the three conic sections, had solved problems which were beyond the geometry of the straight line and circle, and finally, before the end of

the third century B.C., had been carried to its highest perfection by the genius of Archimedes, who measured the areas of curves and the surfaces and volumes of curved surfaces by geometrical methods practically anticipating the integral calculus.

To understand how all this was possible we have to remember that the Greeks, pre-eminently among all the nations of the world, possessed just those gifts which are essential to the initiation and development of philosophy and science. They had in the first place a remarkable power of accurate observation; and to this were added clearness of intellect to see things as they are, a passionate love of knowledge for its own sake, and a genius for speculation which stands unrivalled to this day. Nothing that is perceptible to the senses seems to have escaped them; and when the apparent facts had been accurately ascertained, they wanted to know the *why* and the *wherefore*, never resting satisfied until they had given a rational explanation, or what seemed to them to be such, of the phenomena observed. Observation or experiment and theory went hand in hand. So it was that they developed such subjects as medicine and astronomy. In astronomy their guiding principle was, in their own expressive words, to "save the phenomena". This meant that, as more and more facts became known, their theories were continually revised to fit them.

It would be easy to multiply instances; it must suffice in this place to mention one, which illustrates not only the certainty with which the Greeks detected the occurrence of even the rarest phenomena, but also the persistence with which they sought for the true explanation.

Cleomedes (second century A.D.) mentions that there were stories of extraordinary eclipses which "the more ancient of the mathematicians" had vainly tried to

explain; the supposed "paradoxical" case was that in which, while the sun seems to be still above the western horizon, the *eclipsed* moon is seen to rise in the east. The phenomenon appeared to be inconsistent with the explanation of lunar eclipses by the entry of the moon into the earth's shadow; how could this be if both bodies were above the horizon at the same time? The "more ancient" mathematicians essayed a geometrical explanation; they tried to argue that it was possible that a spectator standing on an *eminence* of the spherical earth might see along the generators of a *cone*, i.e. a little downwards on all sides instead of merely in the plane of the horizon, and so might see both the sun and the moon even when the latter was in the earth's shadow. Cleomedes denies this and prefers to regard the whole story of such cases as a fiction designed merely for the purpose of plaguing astronomers and philosophers; no Chaldæan, he says, no Egyptian, and no mathematician or philosopher has recorded such a case. But the phenomenon is possible, and it is certain that it had been observed in Greece and that the Greek astronomers did not rest until they had found out the solution of the puzzle; for Cleomedes himself gives the explanation, namely that the phenomenon is due to atmospheric refraction. Observing that such cases of atmospheric refraction were especially noticeable in the neighbourhood of the Black Sea, Cleomedes goes on to say that it is possible that the visual rays going out from our eyes are refracted through falling on wet and damp air, and so reach the sun although it is already below the horizon; and he compares the well-known experiment of the ring at the bottom of a jug, where the ring, just out of sight when the jug is empty, is brought into view when water is poured in.

The genius of the race being what it was, the Greeks

must from the earliest times have been in the habit of scanning the heavens, and, as might be expected, we find the beginnings of astronomical knowledge in the earliest Greek literature.

In the Homeric poems and in Hesiod the earth is a flat circular disc; round this disc runs the river Oceanus, encircling the earth and flowing back into itself. The flat earth has above it the vault of heaven, like a sort of hemispherical dome exactly covering it; this vault remains for ever in one position; the sun, moon and stars move round under it, rising from Oceanus in the east and plunging into it again in the west.

Homer mentions, in addition to the sun and moon, the Morning Star, the Evening Star, the Pleiades, the Hyades, Orion, the Great Bear ("which is also called by the name of the Wain"), Sirius, the late-setting Boötes (the ploughman driving the Wain), i.e. Arcturus, as it was first called by Hesiod. Of the Great Bear Homer says that it turns round on the same spot and watches Orion; it alone is without lot in Oceanus's bath (i.e. it never sets). With regard to the last statement it is to be noted that some of the principal stars of the Great Bear do now set in the Mediterranean, e.g. in places further south than Rhodes (lat. 36°), γ, the hind foot, and η, the tip of the tail, and at Alexandria all the seven stars except α, the head. It might be supposed that here was a case of Homer "nodding". But no; the old poet was perfectly right; the difference between the facts as observed by him and as seen by us respectively is due to the Precession of the Equinoxes, the gradual movement of the fixed stars themselves about the pole of the ecliptic, which was discovered by Hipparchus (second century B.C.). We know from the original writings of the Greek astronomers that in Eudoxus's time (say 380 B.C.) the whole of the Great Bear remained always well

above the horizon, while in the time of Proclus (say A.D. 460) the Great Bear "grazed" the horizon.

In Homer astronomical phenomena are only vaguely used for such purposes as fixing localities or marking times of day or night. Sometimes constellations are used in giving sailing directions, as when Calypso directs Odysseus to sail in such a way as always to keep the Great Bear on his left.

Hesiod mentions practically the same stars as Homer, but makes more use of celestial phenomena for determining times and seasons. For example, he marked the time for sowing at the beginning of winter by the setting of the Pleiades in the early twilight, or again by the early setting of the Hyades or Orion, which means the 3rd, 7th, or 15th November in the Julian calendar according to the particular stars taken; the time for harvest he fixed by the early rising of the Pleiades (19th May), threshing time by the early rising of Orion (9th July), vintage time by the early rising of Arcturus (18th September), and so on. Hesiod makes spring begin sixty days after the winter solstice, and the early summer fifty days after the summer solstice. Thus he knew about the solstices, though he says nothing of the equinoxes. He had an approximate notion of the moon's period, which he put at thirty days.

But this use of astronomical facts for the purpose of determining times and seasons or deducing weather indications is a very different thing from the science of astronomy, which seeks to explain the heavenly phenomena and their causes. The history of this science, as of Greek philosophy in general, begins with Thales.

The Ionian Greeks were in the most favourable position for initiating philosophy. Foremost among the Greeks in the love of adventure and the instinct of new

discovery (as is shown by their leaving their homes to found settlements in distant lands), and fired, like all Greeks, with a passion for knowledge, they needed little impulse to set them on the road of independent thought and speculation. This impulse was furnished by their contact with two ancient civilisations, the Egyptian and the Babylonian. Acquiring from them certain elementary facts and rules in mathematics and astronomy which had been handed down through the priesthood from remote antiquity, they built upon them the foundation of the science, as distinct from the mere routine, of the subjects in question.

THALES.

Thales of Miletus (about 624-547 B.C.) was a man of extraordinary versatility; philosopher, mathematician, astronomer, statesman, engineer, and man of business, he was declared one of the Seven Wise Men in 582-581 B.C. His propensity to star-gazing is attested by the story of his having fallen into a well while watching the stars, insomuch that (as Plato has it) he was rallied by a clever and pretty maidservant from Thrace for being so "eager to know what goes on in the heavens when he could not see what was in front of him, nay at his very feet".

Thales's claim to a place in the history of scientific astronomy rests on one achievement attributed to him, that of predicting an eclipse of the sun. The evidence for this is fairly conclusive, though the accounts of it differ slightly. Eudemus, the pupil of Aristotle, who wrote histories of Greek geometry and astronomy, is quoted by three different Greek writers as the authority for the story. But there is testimony much earlier than this. Herodotus, speaking of a war between the Lydians and the Medes, says that, "when in the sixth year they