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HISTORY OF THE PLANETARY SYSTEMS

FROM
THALES TO KEPLER

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CHAPTER VI.

HERAKLEIDES AND ARISTARCHUS.

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CHAPTER VI.

HERAKLEIDES AND ARISTARCHUS.

WHILE Plato and Aristotle, as we have seen, never abandoned the idea of the daily rotation of the heavens from east to west, their contemporary, Herakleides of Pontus, clearly and distinctly taught that it is the earth which turns on its axis from west to east in twenty-four hours.

We know very little about the life of this philosopher. His life seems to have extended over the greater part of the fourth century B.C., since he described the destruction of the town of Helike in Achaia by an earthquake (B.C. 373) as having happened in his own lifetime¹, and lived till after the foundation of Alexandria². He was born at Heraklea in Pontus, but emigrated to Athens, where he became a pupil of Speusippus the Platonist, and afterwards possibly of Plato himself³, but at the same time he is said to have attended the schools of the Pythagorean philosophers. Finally, he seems also to have received instruction from Aristotle. As a philosopher, he appears to have carried some of Plato's views about the Kosmos rather further than his master did, as he called the world a god and a divine mind, and attributed divinity to the planets⁴, but, on the other hand, we are also told that he considered the Kosmos to be infinite, and that he, with the Pythagoreans, considered each planet to be a world

¹ Strabo, viii. pp. 384-85.

² Plutarch, *Alexander*, xxvi.

³ Proklus (in *Tim.* p. 281 E) says expressly that Herakleides had *not* heard Plato, but in another place (p. 28 C) he mentions that Herakleides himself claimed to have been on intimate terms with Plato, and this agrees with what Simplicius (in *Arist. Phys.*, Brandis, *Scholia*, p. 362 a) tells us, that H. like Aristotle and Hestieus had taken down Plato's lectures in writing.

⁴ Cicero, *De Natura Deorum*, i. 13, § 34.

with an earth-like body and an atmosphere¹. He was fond of telling "puerile fables" (as Cicero tells us) and of embellishing his books with marvellous stories. Diogenes Laertius gives a list of his writings, which appear to have dealt with a great variety of subjects, one being "On the things in the Heavens" (*Περὶ τῶν ἐν οὐρανῷ*), which, however, possibly did not altogether deal with astronomical matters, since the next book mentioned is "On the things in Hades," of which Diogenes says that it was written in the style of the Tragedians. His writings are unfortunately all lost, so that what we know of the astronomical doctrines of Herakleides is only derived from the allusions of later writers, but these are sufficiently detailed to make it quite certain that he really held some views which were more advanced than those of his contemporaries. We have no way of knowing whether these doctrines were published before Aristotle wrote his book on the heavens, but the absence of any reference to them in that work seems to point to their having been unknown to Aristotle at the time when he wrote it. It is much to be regretted that the opinions of Herakleides are not included among those discussed in that work, since we cannot, in one or two instances, be sure that subsequent commentators did not, in their interpretation of the doctrines of Herakleides, view them a little too much in the light of knowledge acquired by astronomers long after his time. But this does not in any way affect the credibility of the principal doctrine for which he is famous.

The statement of Diogenes, that Herakleides attended the Pythagorean schools², is of special importance to us, as it is extremely likely that their influence (which is also perceptible in his ideas about atoms, which he calls masses, *ὄγκοι*), tended to convince him of the truth of the very simple explanation of the daily motion of the stars proposed by Hiketas and Ekphantus. We have already seen his name coupled with that of Ekphantus³, but the accounts given by Simplicius do not mention the latter. He first alludes to Herakleides when dis-

¹ Plac. II. 13, Diels, p. 343. Comets he held to be clouds at a very great height, illuminated from above. Plac. III. 2, Diels, p. 366.

² Diog. v. 86.

³ See above, p. 51.

cussing the chapter in which Aristotle considers the motion of the starry vault¹. Aristotle first remarks that, taking for granted that the earth is at rest, the starry sphere (the *aplanes*) and the planets might either both be at rest, or both be in motion, or one be at rest and the other in motion. And these cases he considers (says Simplicius) "on account of there being some, among whom were Herakleides of Pontus and Aristarchus², who believed they could save the phenomena (account for the observed facts) by making the heavens and the stars be immovable, but making the earth move round the poles of the equator (*τοῦ ἰσημερινοῦ*) from the west, each day one revolution as near as possible; but 'as near as possible' is added on account of the [daily] motion of the sun of one part (degree³); so that, if then the earth does not move, which presently he (Aristotle) is going to show, the hypothesis of both being at rest cannot possibly save the phenomena." Again, when considering what Aristotle might have held to be Plato's meaning in the disputed passage about the earth and its axis, Simplicius winds up the discussion by adding that Aristotle in this chapter deals with all the various theories as to the earth's position and figure; "but Herakleides of Pontus, assuming the earth to be in the middle and to move in a circle, but the heavens to be at rest, considered the phenomena to be accounted for⁴." Once more Simplicius, when defending and commenting on Aristotle's statement that the observed phenomena only agree with the assumed position of the earth in the centre of the world, refers to those who gave it a progressive motion, and also alludes to the doctrine of Herakleides, that the earth "moved in a circle round its centre, while the heavenly things were at rest⁵."

All this agrees perfectly with the statement which we have already quoted from Aëtius, that Herakleides and Ekphantus

¹ Simplicius to Arist. *De Cælo*, II. pp. 444—445 (Heib.).

² Aristotle cannot have alluded to Aristarchus, who lived much later, so we may also doubt that he thought of Herakleides in this connection.

³ Herakleides would therefore seem to have been aware of the difference between the sidereal and the mean solar day.

⁴ Simplicius, p. 519. An anonymous scholiast to Aristotle uses almost the same words (Brandis, *Scholia*, p. 505 b, 46).

⁵ Simplicius, p. 511.

the Pythagorean let the earth move, "not progressively, but in a turning manner, like a wheel fitted with an axis, from west to east round its own centre¹." Proklus also contrasts Herakleides with Plato, who held the earth to be at rest, and says that "Herakleides of Pontus, not having heard Plato, held this doctrine, that the earth moves in a circle²." The doctrine of the earth's rotation was certainly not taught in the Academy, but Herakleides must have been quite capable of discovering it for himself, since he was also, with regard to the motion of the planets, much in advance of Plato. Chalcidius, in his commentary to the *Timæus*³, tells us that Herakleides let Venus move round the sun instead of round the earth, so that it is sometimes nearer to us and sometimes farther off than the sun. We have seen that there was considerable difference of opinion among philosophers as to whether Mercury and Venus were nearer than the sun or not, and it is indeed strange that this, in connection with the fact that these two planets are never seen at any great distance from the sun, were not sufficient indications of the true nature of their orbits. Chalcidius possibly goes further than Herakleides did, when he states that the sun itself moves on a small circle or epicycle with which the larger orbit of Venus is concentric, though it is very likely indeed that Herakleides, like Kalippus, was aware of the variable velocity of the sun in the course of a year, and we shall presently consider another passage which seems to point to his having possessed

¹ Plac. III. 13, Diels, p. 378. Compare above, p. 51.

² Proklus in *Tim.* p. 281 E. This has naturally roused the ire of Gruppe, who devotes a chapter in his book (*Die kosm. Systeme der Griechen*, pp. 126 ff.) to an attempt to prove that Herakleides got the idea of the earth's rotation from the *Timæus* and published it as his own, at the same time as he falsified the Pythagorean system by pretending that only the properly initiated knew that the central fire was in the interior of the earth, while the antichthon really was the other hemisphere of the earth or even the moon. Whether the later Pythagoreans, who modified the system of Philolaus, really endeavoured to give their own ideas weight by claiming that these represented the old system correctly, may be doubtful, but this anyhow does not concern Herakleides, as there is nothing to prove that Simplicius alluded to him or to the rotation of the earth when mentioning the modified doctrine (see above p. 52). Compare Boeckh, *Untersuchungen*, pp. 127—133.

³ Cap. CX—CXII. ed. Wrobel, pp. 176—178, reprinted by Martin, *Theonis Smyrnæi Astr.* p. 423. Chalcidius lived about three hundred years after Theon.

this knowledge. Martin suggests that Chalcidius may have copied this sentence about the solar epicycle from Theon or from the lost commentary to Plato's *Republic* written by Adrastus, from which writers he borrowed all the astronomical parts of his treatise; indeed he copies their mistakes as well, for instance when he gives the greatest elongation of Venus from the sun as 50° , or when he attributes to Plato a knowledge of the theory of epicycles. Chalcidius does not mention Mercury in connection with Herakleides, but he has already described the motions of both the interior planets, and evidently makes no distinction between them. There is a chapter in Theon's *Astronomy* bearing on this question¹. Theon (or rather Adrastus) first suggests that the sun, Mercury and Venus each moves on its own sphere (or epicycle), the centres of which move with equal velocity on separate spheres (deferents) round the earth, that of the sun being the smallest², "but it may also be, that there is one hollow sphere (or deferent) common to the three stars, and that the three solid spheres (or epicycles) have a common centre in this, of which the smallest and truly solid one is the sun, and round it the sphere of Stilbon³, and surrounding them both, and occupying the whole depth of the hollow and common sphere, the sphere of Phosphorus." After this Theon goes on to describe the advantage of this arrangement, which would only allow Mercury to be at most 20° and Venus at most 50° from the sun. Theon does not mention Herakleides in connection with this theory, and the system first suggested no doubt belongs to some astronomer of Alexandria and has probably nothing to do with Herakleides.

Although the name of Herakleides had not been connected with this planetary system until Martin drew attention to the above-mentioned passage in Chalcidius, the system itself has always been known to have had some adherents among the ancients. Martianus Capella, a writer in the fifth century of

¹ Theon, ed. Martin, p. 296.

² That is, the sun is always nearer to the earth than Mercury or Venus, and the line from the earth to the sun produced always passes through the centres of the epicycles of the two planets. Chalcidius also mentions this arrangement and attributes it to Plato!

³ Mercury.

our era and the author of a curious encyclopædic work, "*De nuptiis Philologie et Mercurii*," in which he treats of the various free arts, has in his eighth book, on astronomy, set forth this system. He says that although Mercury and Venus rise and set daily, yet their circles do not go round the earth, but round the sun in a wider circuit, so that, when they are beyond the sun, Mercury is nearer to us than Venus, and the reverse when they are on our side of the sun¹. The Roman author who calls himself Vitruvius, in his celebrated book on architecture, when describing sun-dials, deals with the periods of revolution of the various planets, but without setting forth any particular system of the world. His remarks about Mercury and Venus have been supposed to show that he was an adherent of the heliocentric motion of these planets. But it seems to me that his words (clothed in his usual affected language) can equally well apply to the first of the two above-mentioned proposals of Theon of Smyrna, viz., that of letting the epicycles of Mercury and Venus move round the earth on circles concentric with the orbit of the sun, in such a manner that the centres of the epicycles are always in a line with the sun and the earth². At all events, he says nothing about the orbits or the varying distances from the earth, and in a preceding paragraph, when first mentioning the planets, he distinctly says that they move from west to east, in the order: Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn³. But as this pseudo-Vitruvius was, almost certainly, not what he pretends to be, a contemporary of Augustus, but a rather ignorant compiler who lived much later (perhaps about A.D. 400), his opinion would not be of much value unless we could be sure

¹ Martianus Capella, viii. § 857, ed. Eyssenhardt, p. 317.

² *De Architectura*, lib. ix. cap. 4, §§ 18—21. Mercurii autem et Veneris stellæ circum solis radios, solem ipsum uti centrum, itineribus coronantes, regressus retrorsum et retardationes faciunt. Etiam stationibus propter eam circinationem morantur in spatiis signorum. Id autem ita esse, maxime cognoscitur ex Veneris stella, quod ea cum solem sequatur, post occasum ejus apparens in cœlo, clarissimeque lucens, Vesperugo vocitatur; aliis autem temporibus eum antecurrens et oriens ante lucem Lucifer appellatur. Ex eoque nonnumquam plures dies in uno signo commorantur, alias celerius ingrediuntur in alterum signum.—After this he goes on describing the stations and retrogradations of both planets, but there is not a word about the actual orbits.

³ Ibid. § 15.

where he had borrowed it. It seems probable that in many cases his authority was the encyclopædia (*De novem disciplinis*) of Terentius Varro, and it is probably this author who is responsible for the paragraph in question. But, as already remarked, it does not seem to state that the sun is in the centre of the orbits of Mercury and Venus¹.

For ages this system, in which Mercury and Venus alone move round the sun, has been known as "the Egyptian," on the authority of a somewhat questionable passage in the commentary on Cicero's fragment, *Somnium Scipionis*, by Macrobius, who lived towards the end of the fourth century. Cicero himself, both in his *Somnium Scipionis* and elsewhere, adheres to the geocentric system, placing the planets in the order: Moon, Mercury, Venus, Sun, etc.² Macrobius³ remarks that Cicero in this followed Archimedes and the Chaldeans, while "Plato followed the Egyptians, the parents of all sciences, who placed the sun between the moon and Mercury." He then describes how, according to the same, the sphere of Saturn is the outermost, how those of Jupiter and Mars come next, how Venus is so much inferior to Mars that a year is enough for it to pass round the zodiac, Mercury and the sun coming next, so that these three go round the heavens in about a year. This does not look as if Macrobius believed the Egyptians to have made the two planets go round the sun. But the next passage is different, in which he, after pointing out that the nearness to each other of Venus, Mercury, and the sun confused the order in which they had been placed, continues thus: "But the theory did not escape the skill of the Egyptians, and it is the following: the circle by which the sun moves round is surrounded by the circle of Mercury, but the circle of Venus encloses that again, being above it, and thus it happens that these two stars, when they run through the upper part of their circles, are found to

¹ About the authorship of Vitruvius see Ussing's memoir, "Observations sur Vitruve," in the Memoirs of the R. Danish Academy of Science, *Hist. philos. Afd.* vi. Series, Vol. 4, p. 93 (1896).

² Cic. *De Nat. Deorum*, II. 20, §§ 52-53, where the places of the sun and moon are not mentioned and Venus is put nearest to the earth. In the *Somnium* and *De Divinat.* II. 43, § 91, Venus is placed third, between Mercury and the sun.

³ In *somn. Scip.* lib. I. cap. 19.

be placed above the sun, but when they go through the lower parts of their circles, the sun is considered to be above them."

At first sight it looks as if Macrobius here simply enunciates the geocentric system¹, but if so, there is no sense in the last paragraph. If we, however, assume² that he, like Chalcidius, means epicycle when he uses the word *circulus*, his theory is exactly the same as that which Chalcidius ascribes to Herakleides, and this seems indeed to have been what Macrobius meant, as he, in the preceding passage, when explaining the order of the planets according to Plato, used the word sphere for orbit, which Chalcidius expresses by *globus*³. All the same, he ascribes both the Platonic arrangement and the heliocentric motion of Mercury and Venus to the Egyptians, so that his testimony is quite worthless as to the origin of the system which has so long borne the name of the Egyptian. There is, indeed, no proof whatever that the astronomers or priests of ancient Egypt, either during the time of the Pharaohs or later, were aware of the fact that Mercury and Venus travel round the sun. On the contrary, Achilles states distinctly that the Egyptians placed the sun fourth in order, "which the Greeks call the sixth⁴."

Chalcidius is thus the only author who ascribes this important discovery to Herakleides; but when we remember the intimate connection between Chalcidius and the previous most reliable writer, Adrastus, and when we also bear in mind what enlightened views Herakleides must have held, since he acknowledged the rotation of the earth, we may consider it as thoroughly proved that he also made this other step forward. Though all his writings are lost, we are not without proofs that he had devoted some attention to other astronomical questions besides the movements of the interior planets. In his commentary to the *Physics* of Aristotle, Simplicius gives us an interesting quotation from a commentary to the *Meteorology* of Posidonius, written by

¹ Martin, *Études*, II. pp. 132–133, and Humboldt, *Kosmos*, III. p. 466, are of this opinion.

² As already done by Schiaparelli, *I Precursori di Copernico*, p. 27.

³ It is deserving of notice that Macrobius in the following chapter, when discussing the dimensions of the sun, twice writes *orbis* instead of *sphæra*.

⁴ Isagoge in Arati Phenom. § 17, Petavius, III. p. 80.

Geminus in the first half of the first century B.C.¹ Dealing with the difference between physics and astronomy, Geminus says that to the former science belongs the examination of the nature, power, quality, birth, and decay of the heavens and the stars; but astronomy does not attempt any of this, it makes known the arrangement of the heavenly bodies, it investigates the figure and size and distance of earth and sun and moon, the eclipses and conjunctions of stars and the quality and quantity of their motions; in which numerical investigations astronomy obtains help from arithmetic and geometry. But although the astronomer and the physicist often prosecute the same research, such as the size of the sun or the sphericity of the earth, still they do not proceed in the same manner, the latter seeking for causes and moving forces, while the astronomer finds certain methods, adopting which the observed phenomena can be accounted for. "For why do sun, moon, and planets appear to move unequally? Because, when we assume their circles to be excentric or the stars to move on an epicycle, the appearing anomaly can be accounted for (*σωθήσεται ἡ φαινόμενη ἀνωμαλία αὐτῶν*), and it is necessary to investigate in how many ways the phenomena can be represented, so that the theory of the wandering stars may be made to agree with the etiology in a possible manner. Therefore also a certain Herakleides of Pontus stood up and said that also when the earth moved in some way and the sun stood still in some way, could the irregularity observed relatively to the sun be accounted for. In general it is not the astronomer's business to see what by its nature is immovable and of what kind the moved things are, but framing hypotheses as to some things being in motion and others being fixed, he considers which hypotheses are in conformity with the phenomena in the heavens. He must accept as his principles from the physicist, that the motions of the stars are simple,

¹ Simplicii in Aristot. phys. ed. Diels, p. 291, reprinted in Gemini *Elem. Astr.* ed. Manitius, p. 283. Compare Boeckh's *Untersuchungen*, p. 134, and about the commentary of Geminus see also Boeckh, *Ueber die vierjährigen Sonnenkreise der Alten*, p. 12. In the passage (*Phys.* II, 1, p. 193 b, 22) commented on by Simplicius, Aristotle explains the difference between the points of view from which a mathematician and a natural philosopher consider the phenomena of nature.

uniform, and regular, of which he shows that the revolutions are circular, some along parallels, some along oblique circles."

This paragraph is remarkable in more ways than one. It distinguishes clearly between the physically true causes of observed phenomena and a mere mathematical hypothesis which (whether true or not) is able to "save the phenomena." This expression is rather a favourite one with Simplicius, who doubtless had it from the authors long anterior to himself, from whose works he derived his knowledge. It means that a certain hypothesis is able to account for the apparently irregular phenomena revealed by observation, which at first sight are puzzling and seem to defy all attempts to make them agree with the assumed regularity of all motions, both as to velocity and direction. In this passage Geminus points out that an astronomer's chief duty is to frame a theory which can represent the observed motions and make them subject to calculation, while it is for this purpose quite immaterial whether the theory is physically true or not. The passage in which he among such theories mentions one put forward by Herakleides, presents many difficulties and has been the subject of a great deal of controversy. In the original it runs thus:

διὸ καὶ παρελθὼν τις φησὶν Ἡρακλείδης ὁ Ποντικός, ὅτι καὶ κινουμένης πῶς τῆς γῆς, τοῦ δὲ ἡλίου μένοντός πῶς δύναται ἢ περὶ τὸν ἥλιον φαινομένη ἀνωμαλία σώζεσθαι.

In the first place we must mention that formerly, that is in the Aldine edition of Simplicius and in Brandis' collection of *Scholía* (p. 348 b), the word ἔλεγεν appeared after ὁ Ποντικός, so that the passage could only be translated "therefore somebody stood up, said Herakleides of Pontus, and said that," etc. It appears, however, that this word does not occur in the best codices, which somewhat simplifies matters. "Therefore also one Herakleides of Pontus stood up (came forward) and said, that also when the earth moved in some way and the sun stood still in some way, could the irregularity observed relatively to the sun be accounted for." That a well-known philosopher is mentioned as *τις*, as if he were an obscure person, looks

strange¹, and so does the expression "stood up" (*παρελθών*), as if Herakleides came forward and spoke in an assembly or a conference, like that at Athens between Kalippus, Polemarchus and Aristotle, at which the theory of Eudoxus was discussed, to which Simplicius alludes elsewhere. But it does not seem unreasonable to assume that the passage has been corrupted, when we bear in mind that it had gone through several hands before Simplicius wrote it down. He says that he took it from the commentator Alexander of Aphrodisias, who had it from an abstract (epitome) of a commentary written by Geminus on the *Meteorology* of Posidonius. The passage taken by itself ought therefore not to be made a foundation for far-reaching theories. And yet that is precisely the use which has recently been made of the second half of the passage².

How are we to interpret the expression, that even if the earth had some motion the irregularity connected with the sun could be accounted for? As the words stand they can only refer to the want of uniformity of the annual motion of the sun, which causes the four seasons to be of unequal length³. We have seen that Kalippus had accounted for this by adding two other spheres to the solar theory of Eudoxus. What Herakleides did was probably merely to throw out the suggestion, that it might *also* be possible to account for this irregularity by assuming that the earth was not absolutely at rest but moved in some way or other (*πως*). Every word in the sentence seems to indicate that it was in no way intended to formulate a theory of any kind, but merely to hint in a general manner that there might be more than one way of "saving the phenomena," and that this might *also* be done by abandoning the usual idea of the earth being at rest. The whole argumentation of Geminus about hypotheses, the actual physical truth of

¹ Gomperz, *Griechische Denker*, I. p. 433 (2nd ed.), suggests that the words Ἡρακλείδης ὁ Ποντικός have been interpolated by some well-informed reader.

² By Schiaparelli in his memoir, "Origine del sistema planetario eliocentrico presso i Greci" (*Mem. del R. Istituto Lombardo*, Vol. XVIII. Fasc. 5, 1898).

³ This obvious explanation has been thought sufficient by Martin (*Mém. de l'Acad. des Inscriptions*, T. xxx. 2^e Partie, p. 34), and Bergk, *Fünf Abhandlungen zur Geschichte der griechischen Philosophie und Astronomie*, Leipzig, 1883, p. 151.

which was of no consequence, so long as they represented the phenomena geometrically, seems to point to the correctness of this view. The vagueness of the expressions renders it rather useless to speculate about what kind of motion Herakleides may have been thinking of¹. He may merely have thought of some sort of libration or oscillation along a straight line, whereby the distance of the earth from the sun became variable, or he may more likely have thought that the rotation of the earth was not quite uniform, so that the length of the day was not quite the same during the different seasons. No doubt the latter hypothesis would have been contrary to the principle of uniformity of motion, which the Greeks always upheld; still a Greek philosopher may in passing have thrown out a hint of this kind—for it was nothing more than a hint.

Not content with the simple and plain interpretation of the words of this passage, Schiaparelli has endeavoured to found on them a claim for Herakleides as a precursor of Copernicus. He believes the expression *ἡ περὶ τὸν ἥλιον ἀνωμαλία* to be the same as what Ptolemy afterwards called *ἡ πρὸς* or *ἡ παρὰ τὸν ἥλιον ἀνωμαλία*, that is, the irregularities in the motion of the *planets*, of which the period is the synodic revolution, or the time between two successive oppositions to the sun, which therefore show a dependence on the position of the planet relatively to the sun (*πρὸς τὸν ἥλιον*), and which we now know to be caused by the earth's motion round the sun. Schiaparelli therefore concludes that already at the time of Alexander the Great the idea had been suggested in Greece, that the anomalies of planetary motions might be explained by letting the earth be in motion. But this seems to be an interpretation of the words of Herakleides which does too much honour to that philosopher. In the paragraph in question *περὶ* can only refer

¹ Martin (l. c. p. 35) maintains that Herakleides must have thought of an annual motion of the earth in a small circle, but this would only account for the solar anomaly and not for those of the planets, so that it could only have been as an example of a hypothesis that Herakleides brought it forward. Besides (as remarked by Schiaparelli, p. 91), the period would have had to be six and not twelve months, and then summer and winter would have been equal in length, and spring and autumn likewise. But Martin is all the same right in holding that Herakleides was merely giving an *example* of an hypothesis.

to an anomaly in the motion of the sun itself, and though no doubt a transcriber might change *παρὰ* into *περὶ*, how can we account for the fact that the authorities to whom we owe our knowledge of the doctrine of Herakleides concerning the rotation of the earth, do *not* credit him with having taught any progressive motion of the earth? Simplicius, as we have seen, says that Herakleides assumes the earth to be in the middle, and in another place that he lets it move in a circle round its own centre, while Aëtius most particularly states that Herakleides lets the earth move *not progressively* (οὐ μὴν γε μεταβατικῶς) but in a turning manner¹. If Herakleides had really taught the orbital motion of the earth as an alternative to the intricate system of Eudoxus, the doxographers could hardly have been ignorant of it, nor Simplicius, nor Chalcidius (Adrastus) when describing his theory of Mercury and Venus, nor the writers who mention Aristarchus as having let the earth be in motion. There would really be no way of accounting for this conspiracy of silence. For if Herakleides had seriously believed that he had found the true explanation of the complicated motions of the planets, he would not have been afraid to publish his theory, judging by all we know of him. No doubt it is very tempting to assume that the motion of the earth, which was taught by Aristarchus in the following century, had already fifty or sixty years earlier been known to the man who had made the first step in the right direction by discovering the heliocentric motion of Mercury and Venus. But to build this assumption on a vague and probably corrupted passage, and on the supposition that *παρὰ* and *περὶ* are equivalent, or that *παρὰ* has been changed into *περὶ*, and to do this in the face not only of the absolute silence of all writers, but of the directly opposing testimony of Aëtius, seems too hazardous.

Before we consider the question what inducement there might be to abandon the theory of Eudoxus for the theory of the earth's motion round the sun, we shall set forth the evidence we possess, showing that this was actually done. The man

¹ Compare Simplicius, p. 541 (already quoted), where those who gave the earth a progressive motion (*μεταβατικὴν κίνησιν*) are first mentioned, and then Herakleides who gave it a rotating one only.

who adopted this novel way of "saving the phenomena" was Aristarchus of Samos, a pupil of Strato (called *ὁ φυσικός*) the disciple and successor of Theophrastus. He must have flourished about the year 281 B.C., as he is said by Ptolemy to have observed the summer solstice of that year¹. The only book of his which has been preserved is a treatise "On the dimensions and distances of the sun and moon²," in which we find the results of the first serious attempt to determine these quantities by observation. He observed the angular distance between the sun and the moon at the time when the latter is half illuminated (when the angle at the moon in the triangle earth-moon-sun is a right angle) and found it equal to twenty-nine thirtieths of a right angle or 87° . From this he deduced the result that the distance of the sun was between eighteen and twenty times as great as the distance of the moon. Although this result is exceedingly erroneous³, we see at any rate that Aristarchus was more than a mere speculative philosopher, but that he must have been an observer as well as a mathematician. This treatise does not contain the slightest allusion to any hypothesis on the planetary system, so that we have to depend on the statements of subsequent writers when we endeavour to give Aristarchus his proper place in the history of cosmical systems. The principal authority is Archimedes (287—212 B.C.), a younger contemporary of Aristarchus, who, in the curious book (*ψαμμίτης*) in which he attempts to find a superior limit to the number of grains of sand which would fill the universe, incidentally gives the following account of the ideas of Aristarchus about the universe⁴.

"You know that according to most astronomers the world (*κόσμος*) is the sphere, of which the centre is the centre of the earth, and whose radius is a line from the centre of the earth to

¹ Probably in Alexandria (*Almag.* III. 1, p. 206, Heiberg).

² "Traité d'Aristarque de Samos sur les grandeurs et les distances du Soleil et de la Lune, traduit en français par le Comte de Fortia d'Urban." Paris, 1823. The Greek text was first published by Wallis (Oxford, 1688); there is a modern edition by E. Nizze, Stralsund, 1856, 4°, 20 pp.

³ Because the method, though theoretically correct, is not practical, as the moment when the moon is half illuminated cannot be determined accurately. The angle of "dichotomy" is in reality $89^\circ 50'$ instead of 87° .

⁴ Arenarius 4-6 (Heiberg, *Quæstiones Archimedææ*, Hafniæ, 1879, p. 172).

the centre of the sun. But Aristarchus of Samos has published in outline certain hypotheses¹, from which it follows that the world is many times larger than that. For he supposes (*ὑποτιθέται*) that the fixed stars and the sun are immovable, but that the earth is carried round the sun in a circle which is in the middle of the course²; but the sphere of the fixed stars, lying with the sun round the same centre, is of such a size that the circle, in which he supposes the earth to move, has the same ratio to the distance of the fixed stars as the centre of the sphere has to the surface. But this is evidently impossible, for as the centre of the sphere has no magnitude, it follows that it has no ratio to the surface. It is therefore to be supposed that Aristarchus meant that as we consider the earth as the centre of the world, then the earth has the same ratio to that which we call the world, as the sphere in which is the circle, described by the earth according to him, has to the sphere of the fixed stars."

In this interesting and important passage we see that Archimedes first defines "the world" as the sphere of which the orbit of the sun is a great circle. Obviously this does not imply that there is nothing outside this orbit, but it either means that Mars, Jupiter, Saturn, and the fixed stars, being all situated at distances as to which no estimates could be made, were assumed to be immediately outside the orbit of the sun; or it is an allusion to the Pythagorean division of the universe into three regions, the Olympos, the Kosmos, and the Uranos,

¹ *ὑποθεσίων τινῶν ἐξέδωκεν γραφάς*. Bergk (*Fünf Abh.* p. 160) explains *γραφάς* as "sketched in outline," not worked out or proved.

² *τὰν δὲ γὰρ περιφερέσθαι περὶ τὸν ἄλιον κατὰ κύκλον περιφέρειαν, ὅς ἐστιν ἐν μέσῳ τῷ δρόμῳ κείμενος*. Barrow translates: *Terram ipsam circumferri circa circumferentiam circuli qui est in medio cursu constitutus*. The circle which we now call the ecliptic was in those days called the middle circle of the zodiac, the latter being a broad belt inside which the planets moved, and Aristarchus seems to have meant that the earth (and not the sun) moved in this circle in the middle of the belt. This interpretation is not mentioned by Bergk (p. 162) who says: "Die Worte *ὅς ἐστιν*...bezieht man auf *ἄλιος*, und eine andere Beziehung ist nicht möglich; dann befremdet aber die ungewöhnliche Stellung des Relativsatzes." He therefore proposes to read *οὐρανῷ* for *δρόμῳ*, the circle lying in the middle of the heavens. If *ὅς* should refer to the sun, it would show that Aristarchus assumed the sun to be in the centre of the earth's orbit and ignored the difference in length of the four seasons.

the Kosmos being the region of uniform and regular motions. This, then, is the sphere whose capacity of holding grains of sand Archimedes is going to consider, and this leads him to refer to an hypothesis proposed by Aristarchus, that the sun is the centre of the universe. He does not attempt to argue for or against this hypothesis, he merely objects to the unmathematical idea of there being a certain ratio between a point, which has no magnitude, and the surface of a sphere. Of course the meaning of Aristarchus is clear enough, that if we suppose the earth to move round the sun in a large orbit, the distance of the fixed stars must be immensely great as compared with that of the sun, as our motion round the latter would otherwise produce apparent displacements among the stars, if they are at different distances from the centre of the world, or at any rate, if they are on the surface of a sphere, make the stars in the neighbourhood of the ecliptic appear to close up or spread out according as the earth is at the part of its orbit farthest from them or nearest to them.

This is indeed a very startling hypothesis to meet with so far back as the third century before our era, and our regret is great that Archimedes did not tell us something more about it. It would almost seem that there was nothing more to say; that Aristarchus had merely thrown out this suggestion or hypothesis without devoting a book or essay to its discussion, and the fact, that his book on the distance of the sun does not contain anything on the subject, tends to confirm this impression. We possess only two other very brief references to the hypothesis by other writers.

The first of these is in Plutarch's book *On the face in the disc of the Moon* (§ 6). One of the persons in the dialogue, being called to account for turning the world upside down, says that he is quite content so long as he is not accused of impiety, "like as Kleanthes held that Aristarchus of Samos ought to be accused of impiety for moving the hearth of the world (ὡς κινεῦντα τοῦ κόσμου τὴν ἐστίαν), as the man in order to save the phenomena supposed (ὑποτιθέμενος) that the heavens stand still and the earth moves in an oblique circle at the same time as it turns round its axis."

This is as clear as possible, and shows that the hypothesis of Aristarchus included the rotation of the earth, as might be expected. The other reference is by the doxographers and occurs in the paragraph on the cause of solar eclipses¹: "Aristarchus places the sun among the fixed stars but lets the earth move along the solar circle, and [says] that it² becomes overshadowed according to its inclination." Galenus does not say anything about the motion of the earth but has merely: "Aristarchus [said] that the disc of the sun is obscured by the earth." Evidently the text has in the course of time become greatly corrupted so far as the cause of eclipses is concerned³, but the passage referring to the motion of the earth in the ecliptic is distinct enough.

We must therefore accept it as an historical fact, that Aristarchus proposed as a way of "saving the phenomena" that the earth performed an annual motion round the sun⁴.

The hypothesis does not appear to have attracted much attention, since it is only alluded to in these three passages, while his doctrine of the daily rotation of the earth probably appeared less fanciful and therefore was taken more notice of. Thus an anonymous scholiast to Aristotle⁵ states that "it is the opinion of Aristarchus and his followers that the stars and the heavens stand still and that the earth is moved from east to west and reversely (*ἀνάπαλιν*)." He meant well, no doubt, that scholiast, but his ideas got mixed somehow! The well-known sceptic Sextus Empiricus, who lived in the first half of the third century after Christ, alludes to the diurnal motion of the earth in these words⁶: "Those who do not admit the motion of the world and believe that the earth moves, such as

¹ Aet. ii. 24; Stobæus, i. 25 (Diels, p. 355); Galenus, 66 (Diels, p. 627).

² In the *Placita*: "the disc."

³ The meaning is probably that an eclipse takes place or not according as the line from the earth to the moon coincides with that from the earth to the sun or is inclined to it.

⁴ We are unable to fix a date for this remarkable proposal, unless we are to assume with Sussemihl (*Gesch. d. griech. Litteratur in der Alexandrinerzeit*, i. p. 719) that it must have been after 264/3, in which year Kleantes became leader of the Stoa.

⁵ Brandis, *Scholia*, p. 495 a.

⁶ *Adversus mathematicos*, x. 174.

the followers of Aristarchus the mathematician, are not hindered from discerning the time."

We shall hardly be justified in inferring from the words, "the followers of Aristarchus (οἱ περὶ Ἀρίσταρχον)," that the proposer of the earth's motion founded a school in which his doctrines were taught. One man there was, however, who took up the doctrine of the diurnal motion (if not that of the annual one), although he cannot have been an immediate disciple of Aristarchus, since he lived more than a hundred years later, about the middle of the second century B.C. Seleukus was a Babylonian, according to Strabo an inhabitant of Seleukia on the Tigris¹, but we know very little about him. Plutarch associates him with Aristarchus in the eighth of his Platonic Questions, in which he considers the question what Plato's meaning was in the disputed passage in the *Timæus*. He asks, whether Plato held that the earth is fixed round its axis and rotates with it, "as Aristarchus and Seleukus have afterwards shown, the one supposing it only (ὑποτιθέμενος μόνον), but Seleukus affirming it as true (ἀποφαινόμενος)²." We know from Strabo, that Seleukus was an observer of the tides, and that he also had his own theory as to their origin appears from the following passage of the doxographers³.

¹ Strabo, p. 739, speaking of the Chaldean astrologers, mentions "Seleukus of Seleukia" as one of them. On p. 174 he tells us (on the authority of Posidonius) that a certain dependence of the tides on the sign in which the moon was situated had been observed by "Seleukus of the Erythrean sea." The latter included the Persian Gulf, so that no doubt the same man is referred to. Seleukus was the originator of the idea, adopted by Hipparchus (Strabo, pp. 5-6), that the Indian Ocean was surrounded by land on all sides. As he was quoted by Hipparchus and wrote against Krates of Mallus, he must have lived in the middle of the second century B.C. About him see a little monograph: "Der Chaldäer Seleukos. Eine kritische Untersuchung aus der Geschichte der Geographie, von Sophus Ruge." Dresden, 1865, 23 pp. 8°.

² Immediately after this comes the passage already quoted in Chapter III. that Plato in his old age is said to have regretted that he had placed the earth in the centre of the world. This, however, does not prove that Plutarch here speaks of Aristarchus and Seleukus as having taught the orbital motion of the earth, and as nobody else attributes this doctrine to Seleukus, we shall hardly be justified in concluding from Plutarch that he held it, as Schiaparelli does (*I Precursori*, p. 36).

³ Aet. III. 17; Stob. I. 38, Diels, p. 383.

"Seleukus the mathematician, writing against Krates¹, and himself letting the earth be in motion, says that the revolution of the moon is opposed to its (i.e. the earth's) rotation, but the air between the two bodies being drawn forward falls upon the Atlantic Ocean, and the sea is disturbed in proportion." Evidently Seleukus supposed the atmosphere to reach to the moon if not further; from another passage we learn that he considered the universe to be infinite².

These are the only allusions found in classical writings to the last philosophers of Greek antiquity who taught that the earth had any motion, except an allusion to the doctrine of the earth's rotation by Seneca, who however does not mention any names in connection with it³. But scanty though they are, these allusions leave no doubt that Aristarchus taught the annual motion of the earth round the sun, and that both he and Seleukus taught the diurnal rotation of the earth. When we consider that seventeen hundred years were to elapse before the orbital motion of the earth was again taught by anybody, we cannot help wondering how Aristarchus can have been led to so daring and lofty an idea.

After Kalippus and Aristotle the homocentric system never received any further development or improvement, simply because, as Simplicius tells us⁴, the great changes in the brightness of the planets, especially Venus and Mars, rendered the idea of each planet being always at the same distance from the earth utterly untenable. According to him, Autolykus of Pitane (about 300 B.C.), writing against Aristotherus (teacher of the poet Aratus and probably an adherent of Kalippus⁵),

¹ Krates had also written on the cause of the tides, as stated by Stobæus a few lines above.

² Act. II. 1; Stob. I. 21, Diels, p. 328. Stobæus has: "Seleukus the Erythrean and Herakleides of Pontus say that the world is infinite."

³ Seneca, *Quæst. Nat.* VII. 2: "Illo quoque pertinebit hoc exeuississe, ut sciamus, utrum mundus terra stante circumbeat, an mundo stante terra vertatur. Fuerunt enim qui dicerent, nos esse, quos rerum natura nescientes ferat, nec cœli motu fieri ortus et occasus, sed ipsos oriri et occidere. Digna res est contemplatione, ut sciamus in quo rerum statu simus: pigerrimam sortiti an velocissimam sedem: circa nos Deus omnia, an nos agat."

⁴ *De Cælo*, p. 504 (Heib.).

⁵ Susemihl, l. c. I. pp. 286 and 703.

tried in vain to explain this. "For the star called after Aphrodite as well as that called after Ares appears in the midst of the retrograde movement many times brighter, so that that of Aphrodite on moonless nights causes bodies to throw shadows." He adds that it is also easy to see that the moon does not always keep at the same distance from us, as observations show that sometimes a disc of eleven inches and sometimes one of twelve inches, held at the same distance from the eye, is required to hide it. Simplicius further alludes to the fact that central eclipses are sometimes total and sometimes annular, which confirms the observation of the varying distance of the moon; and although he here manifestly follows Sosigenes, who lived towards the end of the second century A.D.¹, still we cannot doubt that the generation after Aristotle found the great variation of distances a very awkward fact to deal with, since Simplicius also refers to Polemarchus of Kyzikus as having known it, though the difficulty is said not to have troubled him much, as he all the same adhered to the homocentric spheres. Simplicius even adds² that Aristotle himself in his "Physical Problems" was not perfectly satisfied with the hypotheses of astronomers on account of the variation of brightness; but as this book is lost we have unfortunately no way of testing this statement, which certainly is not confirmed by anything in the writings of Aristotle still existing³.

The necessity of grappling with this difficulty led gradually to the complete abandonment of the system of Eudoxus, although, as we shall see, the word "sphere" continued from time to time to make its appearance. There can be no doubt that it was this very difficulty which gave rise to new systems; in fact Simplicius states this distinctly a page further on⁴,

¹ Comp. Proklus, *Hypotyposes*, ed. Halma, p. 111, where he quotes the book of Sosigenes *Περὶ τῶν ἀνελιπτουσῶν*, using almost the same words as Simplicius about solar eclipses.

² p. 505.

³ Though it is evident from the way in which Aristotle expresses himself, *De Cælo*, II. 12, p. 292 a, about the great distances of the stars and the few starting points we have, that he did not consider the problems of the planets finally solved.

⁴ p. 507, l. 14-20.

where he says that "astronomers therefore introduced the hypothesis of excentric circles and epicycles in the place of the homocentric spheres, if the hypothesis of excentrics was not already invented by the Pythagoreans, as some people say, among whom Nikomachus and on his authority Iamblichus." These two late authorities¹ are not to be relied on, since the Neo-Pythagorean school was always ready to attribute everything of value to the early Pythagoreans, and their statement has probably been copied by Proklus, who in his account of Ptolemy's planetary theory² says that "History teaches us that by the Pythagoreans have the excentrics and epicycles been invented as a sufficient means and the simplest of all." Geminus evidently means the same thing when he says that the Pythagoreans first assumed circular and uniform motion and put this question: how under this assumption the phenomena could be accounted for³? But Geminus lived in the first century B.C., at the very time when the first attempts were made to palm off as handed down from Pythagoras a system of philosophy which shows strong signs of having been influenced by much later, especially Stoic doctrines⁴, and his testimony cannot therefore be depended on. There were no doubt at the time of Aristotle some philosophers who still tried to explain the heavenly phenomena after the manner of the Pythagoreans⁵, but the Pythagorean school seems to have become finally extinct about the time of the death of Aristotle, and nothing indicates that its last members were distinguished as mathematicians. We must therefore reject as utterly unsupported by reliable testimony the statement of the later worshippers of Pythagoras, that the theory of excentric motion was started at the time when his school was at the point of extinction.

The statement of Nikomachus, that the excentric circles

¹ Nikomachus lived about A.D. 100, and Iamblichus early in the fourth century.

² *Hypotyp.* ed. Halma, pp. 70-71.

³ *Gemini Elementa Astron.* ed. Manitius, p. 11.

⁴ Alexander Polyhistor in *Diog. Laert.* viii. 24 sq.; compare Zeller, *Ph. d. Gr.* iii. b, p. 88 (3rd ed.).

⁵ *De Cælo*, p. 293 a; comp. above Chapter iii. p. 83.

were invented before the epicycles seems, however, correct (as we shall see in the next chapter), and combined with that of Sosigenes about the great variation of distances, it indicates the manner in which the way was cleared for the bold conception of Aristarchus¹. It was remarked that Mars was always brightest when it culminated at midnight and therefore was in opposition to the sun, while the planet gradually became fainter and fainter as it approached the sun. To the Greek mind a heavenly body could not possibly move in any other curve than a circle, and it followed therefore that Mars must move on a circle which was excentric to the earth, and furthermore that the centre of this circle lay somewhere on the straight line through the earth and the sun, since Mars evidently was nearest to the earth when opposite the sun. Obviously this was not a fixed line but one which turned round one of its extremities in a year; consequently the centre of the orbit of Mars described a circle round the earth in a year. This explained the fact that the oppositions of Mars do not take place in one particular point of the zodiac, but may occur at any point of it; and all that was necessary was to assume that Mars moved round the excentric circle in a period equal to its synodic revolution (i.e. the interval between two successive oppositions or two years and fifty days), while the centre of the excentric moved round the sun in a year. By a suitable selection of the ratio of the radii of the two circles it became possible completely to account for the length of the retrograde motion of Mars at opposition, a problem which had baffled the ingenuity of Eudoxus and Kalippus.

The complete planetary system according to the excentric circle theory was therefore as follows. In the centre of the universe the earth, round which moved the moon in 27 days, and the sun in a year, probably in concentric circles. Mercury and Venus moved on circles, the centres of which were always

¹ The importance of the movable excentrics in the development of the system of Aristarchus has been especially insisted on by Schiaparelli; see his "Vorläufer des Copernicus im Alterthum," *Altpreuss. Monatsschrift*, xiii. p. 113 (not in the Italian original), and especially his second paper, "Origine del sistema eliocentrico." Also by Tannery, *Recherches sur l'astronomie ancienne*, p. 256 ff.

on the straight line from the earth to the sun¹, so that the earth was always *outside* these circles, for which reason the two planets are always within a certain limited angular distance of the sun, from which the ratio of the radius of the excentric to the distance of its centre from the earth could easily be determined for either planet. Similarly the three outer planets moved on excentric circles, the centres of which lay somewhere on the line from the earth to the sun, but these circles were so large as always to surround both the sun and the earth.

This system of "movable excentrics" was known to and employed by Apollonius in the middle of the third century B.C., and as he is not by any writer said to have invented it, it was most probably already known to Aristarchus, who was only about thirty or forty years senior to Apollonius. The part of the system which refers to Mercury and Venus had indeed, as we have seen, been found by Herakleides, who had even gone further and let the centres of the orbits of these two planets coincide with the sun. But is it likely that he or anyone else went another step further and let the centres of the orbits of Mars, Jupiter, and Saturn fall in the sun? This elegant system, which eighteen hundred years later was actually proposed by Tycho Brahe, is not mentioned or hinted at by any writer of antiquity. It is obvious that it presents the same advantages as the system of movable excentrics, of which it is a special and simple case, all the five planetary orbit-centres falling in one point. Very probably Aristarchus may first have been led from the general idea of movable excentrics to this simple case of it, and then his mathematical mind cannot have failed to be struck by the fact, that the phenomena would be precisely the same if he went one step further and made the earth go round the sun instead of the sun round the earth, leaving everything else unaltered. In fact there is no other way in which he can have been led to the heliocentric system, unless the epicyclic theory had already at that time been fully developed. But there is absolutely nothing to indicate that any other thinker either before or after Aristarchus has proposed this "Tychonic

¹ This is the first of the two suggestions of Theon referred to above, p. 127. There are many allusions to the movable excentrics in Theon's book.

system," and it is difficult to see why this system if once proposed should have been needlessly complicated by substituting excentrics with different centres for the beautifully simple Tychonic idea of all the orbits having one centre, the sun. All the same, Schiaparelli insists on the necessity of assuming that this system was a stepping-stone from the old geocentric to the heliocentric (or Copernican) system of Aristarchus, not only in the mind of Aristarchus, but separately deduced long before his time. Schiaparelli urges especially, that the idea of any celestial body moving in a circle round a mere mathematical point must at first have been repugnant, and that the conception of motion round a material body must have preceded it. But he would seem to have overlooked the fact that in the first place it was in the eyes of the Greeks perfectly natural for a celestial body to move in a circle and for a terrestrial one to move in a straight line up and down; and secondly, that no philosophical system previous to the time of Aristarchus had supposed a powerful influence to emanate from the centre, with the one exception of the system of Philolaus. The central fire had been created first, and so to say held the world together, although it may be doubted whether the statements of Stobæus and Simplicius to this effect are not strongly influenced by notions of much later date, as the phraseology seems to show¹. In the system of Plato the soul of the world permeated the whole universe and there was no thought of the centre exerting a ruling power over the celestial motions. According to Aristotle all influences in a sphere or a circle emanated from the circumference and proceeded towards the centre and not *vice versâ*², and we shall see in the next chapter that the Stoics practically were of the same opinion. But let us for the sake of argument accept it

¹ Stobæus (Diels, p. 332 b) even uses the Stoic expression ἡγεμονικὸν of the central fire, and Simplicius, p. 512, calls it τὴν δημιουργικὴν δύναμιν. Zeller, i. pp. 412 and 416, from a comparison of all references comes, however, to the result that the world owed its origin to the central fire and continued to be ruled by it.

² Compare above, Chapter v. pp. 110 and 115. See also Aristotle's *Physics*, p. 267 b, where he shows that the swiftest motion belongs to that which is nearest to the moving cause.

as an indisputable fact, that the adherents of Philolaus had been in the habit of thinking of the power of the central fire "not only mathematically and mechanically, but also dynamically" (as Zeller says), and that this might still influence the mathematicians who designed the system of excentric circles. The centres of these travelled round a very material body, the earth, and one would think that this circumstance would satisfy even a mind filled with the then obsolete Pythagorean notions as to the seat of power, though it was only indirectly that the planets moved round the body in the centre. The conception of motion round a mathematical point (which in its turn moved round the earth) need therefore not have had any difficulties to contend with. No doubt a great mathematician like Apollonius must have noticed how simple the system of movable excentrics would become by letting all the centres fall in the sun, but for some reason or other he must have considered this hypothesis inadmissible; at any rate there is no sign of his having proposed it. A system in which the planets moved round the sun would have been just the sort of thing which later writers would have mentioned among the "opinions of philosophers"; and in the total absence of any mention of the Tychonic system by any writer we can only conclude, that it was never proposed as a way of "saving the phenomena," though Aristarchus may have been first led to it, and then immediately afterwards may have been struck by the still greater simplicity and beauty of the heliocentric system, which alone he therefore considered worth proposing publicly.

The very few and scanty references to the system of Aristarchus by classical authors prove that it can never have been favourably received. Although the time was long past, when a philosopher might be judicially called to account for proposing startling astronomical theories, as Anaxagoras had once been, and though the accusation of "impiety" (if it was really brought forward) can hardly have done the theory much harm, still the novel proposal of Aristarchus was too much opposed to the general views about the universe of Platonists and Aristoteleans, as well as to those of the dominant school

of the Stoics, to obtain a hearing. Possibly it seemed to superficial observers a mere reminiscence of the old and discredited Philolaic system, and we know from Theon¹ that the old idea (quoted by Plato) of the earth being "the house of the gods" had not been forgotten, while those who taught that it moved were by Derkyllides declared worthy of execration as subverting the principles of divination, an Eastern pseudo-science which now had commenced to take a firm hold of the human mind in Europe and to develop into an important branch of knowledge.

But beyond a doubt the principal reason why the heliocentric idea fell perfectly flat, was the rapid rise of practical astronomy, which had commenced from the time when the Alexandrian Museum became a centre of learning in the Hellenistic world. Aristarchus had no other phenomena to "save" except the stationary points and retrograde motions of the planets as well as their change of brilliancy; he may even have neglected the inequality of the sun's apparent motion originally discovered by Euktemon and recognized by Kalippus. But when similar and much more marked inequalities began to be perceived in the motions of the other planets, the hopelessness of trying to account for them by the beautifully simple idea of Aristarchus must have given the deathblow to his system, which thereby even among mathematicians lost its only claim to acceptance, that of being able to "save the phenomena." Most likely, as we have already said, these new inequalities had already more or less dimly commenced to make themselves felt in the days of Apollonius (about B.C. 230), and in that case we can understand why he did not feel disposed to simplify the system of movable ex-centrics by gathering the reins of all the unruly planetary steeds into one mighty hand, that of Helios.

¹ *Theon. Smyrn.* ed. Martin, p. 328.