PART I

GREEK ASTRONOMY TO ARISTARCHUS OF SAMOS

I

SOURCES OF THE HISTORY

THE history of Greek astronomy in its beginnings is part of the history of Greek philosophy, for it was the first philosophers, Ionian, Eleatic, Pythagorean, who were the first astronomers. Now only very few of the works of the great original thinkers of Greece have survived. We possess the whole of Plato and, say, half of Aristotle, namely, those of his writings which were intended for the use of his school, but not those which, mainly composed in the form of dialogues, were in a more popular style. But the whole of the pre-Socratic philosophy is one single expanse of ruins;[1] so is the Socratic philosophy itself, except for what we can learn of it from Plato and Xenophon.

But accounts of the life and doctrine of philosophers begin to appear quite early in ancient Greek literature (cf. Xenophon, who was born between 430 and 425 B.C.); and very valuable are the allusions in Plato and Aristotle to the doctrines of earlier philosophers; those in Plato are not very numerous, but he had the power of entering into the thoughts of other men and, in stating the views of early philosophers, he does not, as a rule, read into their words meanings which they do not convey. Aristotle, on the other hand, while making historical surveys of the doctrines of his predecessors a regular preliminary to the statement of his own, discusses them too much from the point of view of his own system; often even misrepresenting them for the purpose of making a controversial point or finding support for some particular thesis.

From Aristotle's time a whole literature on the subject of the older philosophy sprang up, partly critical, partly historical. This

[1] Gomperz, *Griechische Denker*, i[3], p. 419.

again has perished except for a large number of fragments. Most important for our purpose are the notices in the *Doxographi Graeci*, collected and edited by Diels.[1] The main source from which these retailers of the opinions of philosophers drew, directly or indirectly, was the great work of Theophrastus, the successor of Aristotle, entitled *Physical Opinions* (*Φυσικῶν δοξῶν* $\overline{\iota\eta}$). It would appear that it was Theophrastus's plan to trace the progress of physics from Thales to Plato in separate chapters dealing severally with the leading topics. First the leading views were set forth on broad lines, in groups, according to the affinity of the doctrine, after which the differences between individual philosophers within the same group were carefully noted. In the First Book, however, dealing with the Principles, Theophrastus adopted the order of the various schools, Ionians, Eleatics, Atomists, &c., down to Plato, although he did not hesitate to connect Diogenes of Apollonia and Archelaus with the earlier physicists, out of their chronological order; chronological order was indeed, throughout, less regarded than the connexion and due arrangement of subjects. This work of Theophrastus was naturally the chief hunting-ground for those who collected the 'opinions' of philosophers. There was, however, another main stream of tradition besides the doxographic; this was in the different form of biographies of the philosophers. The first to write a book of 'successions' (*διαδοχαί*) of the philosophers was Sotion (towards the end of the third century B. C.); others who wrote 'successions' were a certain Antisthenes (probably Antisthenes of Rhodes, second century B. C.), Sosicrates, and Alexander Polyhistor. These works gave little in the way of doxography, but were made readable by the incorporation of anecdotes and apophthegms, mostly unauthentic. The work of Sotion and the 'Lives of Famous Men' by Satyrus (about 160 B. C.) were epitomized by Heraclides Lembus. Another writer of biographies was the Peripatetic Hermippus of Smyrna, known as the Callimachean, who wrote about Pythagoras in at least two Books, and is quoted by Josephus as a careful student of all history.[2] Our chief storehouse of biographical details derived from these and all other available sources is the great compilation which goes by the

[1] *Doxographi Graeci*, ed. Diels, Berlin, G. Reimer, 1879.
[2] *Doxographi Graeci* (henceforth generally quoted as *D. G.*), p. 151.

name of Diogenes Laertius (more properly Laertius Diogenes). It is a compilation made in the most haphazard way, without the exercise of any historical sense or critical faculty. But its value for us is enormous because the compiler had access to the whole collection of biographies which accumulated from Sotion's time to the first third of the third century A.D. (when Diogenes wrote), and consequently we have in him the whole residuum of this literature which reached such dimensions in the period.

In order to show at a glance the conclusions of Diels as to the relation of the various representatives of the doxographic and biographic traditions to one another and to the original sources I append a genealogical table[1]:

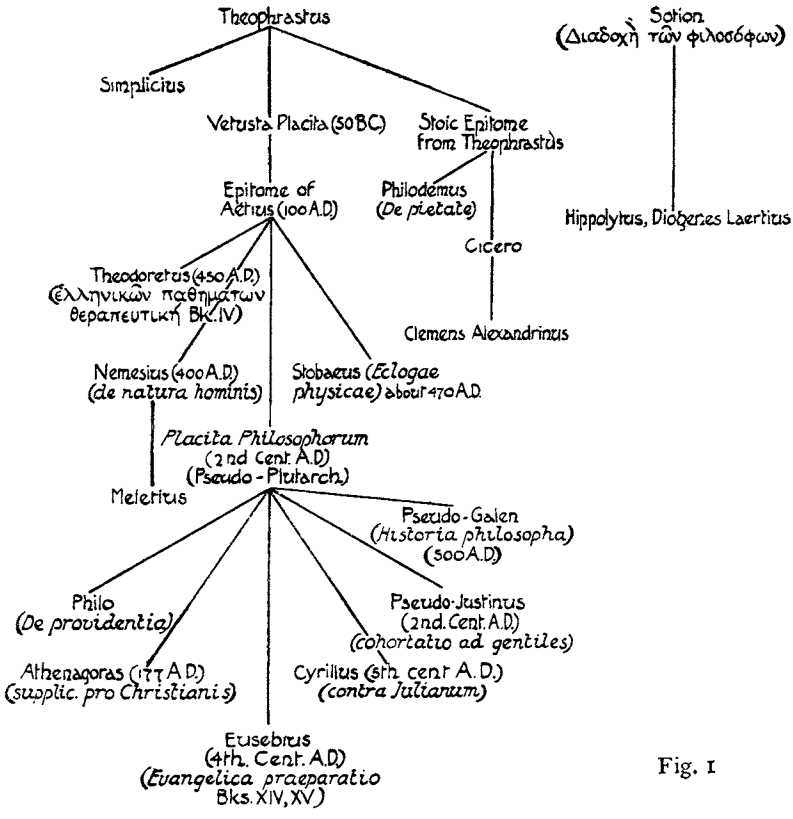

Fig. 1

[1] Cf. Günther in Windelband, *Gesch. der alten Philosophie* (Iwan von Müller's *Handbuch der klassischen Altertumswissenschaft*, Band v. 1), 1894, p. 275.

Only a few remarks need be added. 'Vetusta Placita' is the name given by Diels to a collection which has disappeared, but may be inferred to have existed. It adhered very closely to Theophrastus, though it was not quite free from admixture of other elements. It was probably divided into the following main sections: I. De principiis; II. De mundo; III. De sublimibus; IV. De terrestribus; V. De anima; VI. De corpore. The date is inferred from the facts that the latest philosophers mentioned in it were Posidonius and Asclepiades, and that Varro used it. The existence of the collection of Aëtius (*De placitis*, *περὶ ἀρεσκόντων*) is attested by Theodoretus (Bishop of Cyrus), who mentions it as accessible, and who certainly used it, since his extracts are more complete and trustworthy than those of the *Placita Philosophorum* and Stobaeus. The compiler of the *Placita* was not Plutarch, but an insignificant writer of about the middle of the second century A. D., who palmed them off as Plutarch. Diels prints the *Placita* in parallel columns with the corresponding parts of the *Eclogae*, under the title of *Aëtii Placita*; quotations from the other writers who give extracts are added in notes at the foot of the page. So far as Cicero deals with the earliest Greek philosophy, he must be classed with the doxographers; both he and Philodemus (*De pietate*, *περὶ εὐσεβείας*, fragments of which were discovered on a roll at Herculaneum) seem alike to have used a common source which went back to a Stoic epitome of Theophrastus, now lost.

The greater part of the fragment of the Pseudo-Plutarchian *στρωματεῖς* given by Eusebius in Book I. 8 of the *Praeparatio Evangelica* comes from an epitome of Theophrastus, arranged according to philosophers. The author of the *Stromateis*, who probably belonged to the same period as the author of the *Placita*, that is, about the middle of the second century A. D., confined himself mostly to the sections *de principio*, *de mundo*, *de astris*; hence some things are here better preserved than elsewhere; cf. especially the notice about Anaximander.

The most important of the biographical doxographies is that of Hippolytus in Book I of the *Refutation of all Heresies* (the sub-title of the particular Book is *φιλοσοφούμενα*), probably written between 223 and 235 A.D. It is derived from two sources. The

one was a biographical compendium of the διαδοχή type, shorter and even more untrustworthy than Diogenes Laertius, but containing excerpts from Aristoxenus, Sotion, Heraclides Lembus, and Apollodorus. The other was an epitome of Theophrastus. Hippolytus's plan was to take the philosophers in order and then to pick out from the successive sections of the epitome of Theophrastus the views of each philosopher on each topic, and insert them in their order under the particular philosopher. So carefully was this done that the divisions of the work of Theophrastus can practically be restored.[1] Hippolytus began with the idea of dealing with the chief philosophers only, as Thales, Pythagoras, Empedocles, Heraclitus. For these he had available only the inferior (biographical) source. The second source, the epitome of Theophrastus, then came into his hands, and, beginning with Anaximander, he proceeded to make a most precious collection of opinions.

Another of our authorities is Achilles (not Tatius), who wrote an Introduction to the *Phaenomena* of Aratus.[2] Achilles' date is uncertain, but he probably lived not earlier than the end of the second century A.D., and not much later. The foundation of Achilles' commentary was a Stoic compendium of astronomy, probably by Eudorus, which in its turn was extracted from a work by Diodorus of Alexandria, a pupil of Posidonius. But Achilles drew from other sources as well, including the Pseudo-Plutarchian *Placita*; he did not hesitate to alter his extracts from the latter, and to mix alien matter with them.

The opinions noted by the *Doxographi* are largely incorporated in Diels' later work *Die Fragmente der Vorsokratiker*.[3]

For the earlier period from Thales to Empedocles, Tannery gives a translation of the doxographic data and the fragments in his work *Pour l'histoire de la science hellène, de Thalès à Empédocle*, Paris, 1887; taking account as it does of all the material, this work is the best and most suggestive of the modern studies of the astronomy of the period. Equally based on the *Doxographi*, Max Sartorius's dissertation *Die Entwicklung der Astronomie bei den Griechen bis*

[1] Diels, *Doxographi Graeci*, p. 153.
[2] Excerpts from this are preserved in Cod. Laurentian. xxviii. 44, and are included in the *Uranologium* of Petavius, 1630, pp. 121–64, &c.
[3] Second edition in two vols. (the second in two parts), Berlin, 1906–10.

Anaxagoras und Empedokles (Halle, 1883) is a very concise and useful account. Naturally all or nearly all the material is also to be found in the monumental work of Zeller and in Professor Burnet's *Early Greek Philosophy* (second edition, 1908); and picturesque, if sometimes too highly coloured, references to the astronomy of the ancient philosophers are a feature of vol. i of Gomperz's *Griechische Denker* (third edition, 1911).

Eudemus of Rhodes (about 330 B.C.), a pupil of Aristotle, wrote a History of Astronomy (as he did a History of Geometry), which is lost, but was the source of a number of notices in other writers. In particular, the very valuable account of Eudoxus's and Callippus's systems of concentric spheres which Simplicius gives in his Commentary on Aristotle's *De caelo* is taken from Eudemus through Sosigenes as intermediary. A few notices from Eudemus's work are also found in the astronomical portion of Theon of Smyrna's *Expositio rerum mathematicarum ad legendum Platonem utilium*,[1] which also draws on two other sources, Dercyllides and Adrastus. The former was a Platonist with Pythagorean leanings, who wrote a book on Plato's philosophy. His date was earlier than the time of Tiberius, perhaps earlier than Varro's. Adrastus, a Peripatetic of about the middle of the second century A.D., wrote historical and lexicographical essays on Aristotle; he also wrote a commentary on the *Timaeus* of Plato, which is quoted by Proclus as well as by Theon of Smyrna.

[1] Edited by E. Hiller (Teubner, 1878).

II

HOMER AND HESIOD

WE take as our starting-point the conceptions of the structure of the world which are to be found in the earliest literary monuments of Greece, that is to say, the Homeric poems and the works of Hesiod. In their fundamental conceptions Homer and Hesiod agree. The earth is a flat circular disc; this is not stated in so many words, but only on this assumption could Poseidon from the mountains of Solym in Pisidia see Odysseus at Scheria on the further side of Greece, or Helios at his rising and setting descry his cattle on the island of Thrinakia. Round this flat disc, on the horizon, runs the river Oceanus, encircling the earth and flowing back into itself (*ἀψόρροος*); from this all other waters take their rise, that is, the waters of Oceanus pass through subterranean channels and appear as the springs and sources of other rivers. Over the flat earth is the vault of heaven, like a sort of hemispherical dome exactly covering it; hence it is that the Aethiopians dwelling in the extreme east and west are burnt black by the sun. Below the earth is Tartarus, covered by the earth and forming a sort of vault symmetrical with the heaven; Hades is supposed to be beneath the surface of the earth, as far from the height of the heaven above as from the depth of Tartarus below, i.e. presumably in the hollow of the earth's disc. The dimensions of the heaven and earth are only indirectly indicated; Hephaestus cast down from Olympus falls for a whole day till sundown; on the other hand, according to Hesiod, an iron anvil would take nine days to pass from the heaven to the earth, and again nine days from the earth to Tartarus. The vault of heaven remains for ever in one position, unmoved; the sun, moon, and stars move round under it, rising from Oceanus in the east and plunging into it again in the west. We are not told what happens to the heavenly bodies

between their setting and rising; they cannot pass round under the earth because Tartarus is never lit up by the sun; possibly they are supposed to float round Oceanus, past the north, to the points where they next rise in the east, but it is only later writers who represent Helios as sleeping and being carried round on the water on a golden bed or in a golden bowl.[1]

Coming now to the indications of actual knowledge of astronomical facts to be found in the poems, we observe in Hesiod a considerable advance as compared with Homer. 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, and which turns round on the same spot and watches Orion; it alone is without lot in Oceanus's bath'[2]),

[1] Athenaeus, *Deipnosoph.* xi. 38–9.

[2] It seems that some of the seven principal stars of the Great Bear do now set in the Mediterranean, e.g., in places further south in latitude than Rhodes (lat. 36°), γ, the hind foot, as well as η, the tip of the tail, and at Alexandria all the seven stars except α, the head. But this was not so in Homer's time. In proof of this, Sir George Greenhill (in a lecture delivered in 1910 to the Hellenic Travellers' Club) refers to calculations made by Dr. J. B. Pearson of the effect of Precession in the interval since 750 B.C., a date taken 'without prejudice' (*Proceedings of the Cambridge Philosophical Society*, 1877 and 1881), and to the results obtained in a paper by J. Gallenmüller, *Der Fixsternhimmel jetzt und in Homers Zeiten mit zwei Sternkarten* (Regensburg, 1884/85). Gallenmüller's charts are for the years 900 B.C. and A.D. 1855 respectively, and the chart for 900 B.C. shows that the N.P.D. of both β, the fore-foot, and η, the tip of the tail, was then about 25°. But we also find convincing evidence in the original writings of the Greek astronomers. Hipparchus (*In Arati et Eudoxi phaenomena commentariorum libri tres*, ed. Manitius, 1894, p. 114. 9–10) observes that Eudoxus [say, in 380 B.C., or 520 years later than the date to which Gallenmüller's chart refers] made the fore-foot (β) about 24°, and the hind-foot (γ) about 25°, distant from the north pole. This was perhaps not very accurate; for Hipparchus says (ibid., p. 30. 2–8), 'As regards the north pole, Eudoxus is in error in stating that "there is a certain star which always remains in the same spot, and this star is the pole of the universe"; for in reality there is no star at all at the pole, but there is an empty space there, with, however, three stars near to it [probably α and κ of Draco and β of the Little Bear], and the point at the pole makes with these three stars a figure which is very nearly square, as Pytheas of Massalia stated.' (Pytheas, the great explorer of the northern seas, was a contemporary of Aristotle, and perhaps some forty years later than Eudoxus.) But, as Hipparchus himself (writing in this case not later than 134 B.C.) makes the angular radius of the 'always-visible circle' 37° at Athens and 36° at Rhodes (ibid., pp. 112. 16 and 114. 24–6), it is evident that in Eudoxus's time the whole of the Great Bear remained well above the horizon. A passage of Proclus (*Hypotyposis*, c. 7, §§ 45–8, p. 234, ed. Manitius) is not without interest in this connexion. He is trying to controvert the theory of astronomers that the fixed stars themselves have a movement about the pole of the ecliptic (as distinct from the pole of the universe) of about 1° in 100 years

Sirius ('the star which rises in late summer . . . which is called among men "Orion's dog"; bright it shines forth, yet is a baleful sign, for it brings to suffering mortals much fiery heat'), the 'late-setting Boötes' (the 'ploughman' driving the Wain, i.e. Arcturus, as Hesiod was the first to call it). Since the Great Bear is said to be the *only* constellation which never sets, we may perhaps assume that the stars and constellations above named are all that were definitely recognized at the time, or at least that the Bear was the only constellation recognized in the northern sky. There is little more that can be called astronomy in Homer. There are vague uses of astronomical phenomena for the purpose of fixing localities or marking times of day or night; as regards the day, the morning twilight, the rising and setting of the sun, midday, and the onset of night are distinguished; the night is divided into three thirds. Aristotle was inclined to explain Helios's seven herds of cattle and sheep respectively containing 50 head in each herd (i.e. 350 in all of each sort) as a rough representation of the number of days in a year. Calypso directed Odysseus to sail in such a way as to keep the Great Bear always on his left. One passage,[1] relating to the island called Syrie, 'which is above Ortygia where are the turnings (*τροπαί*) of the sun', is supposed by some to refer to the *solstices*, but there is no confirmation of this by any other passage, and it seems safer to take 'turning' to mean the turn which the sun takes at setting, when of course he begins his return journey (travelling round Oceanus or otherwise) to the place of his

(this is Ptolemy's estimate). 'How is it', says Proclus, 'that the Bears, which have always been visible above the horizon through countless ages, still remain so, if they move by one degree in 100 years about the pole of the zodiac, which is different from the world-pole; for, if they had moved so many degrees as this would imply, they should now no longer graze (*παραξέειν*) the horizon but should partly set'! This passage, written (say) 840 years after Eudoxus's location of β and γ of the Great Bear, shows that the Great Bear was then much nearer to setting than it was in Eudoxus's time, and the fact should have made Proclus speak with greater caution. [The star which Eudoxus took as marking the north pole has commonly been supposed to be β of the Little Bear; but Manitius (*Hipparchi in Arati et Eudoxi phaen. comment.*, 1894, p. 306), as the result of studying a 'Precession-globe' designed by Prof. Haas of Vienna, considers that it was certainly a different star, namely, 'Draconis 16,' which occupies a position determined as the intersection of (1) a perpendicular from our Polar Star to the straight line joining κ and λ of Draco and (2) the line joining γ and β of the Little Bear and produced beyond β.]

[1] *Odyssey* xv. 403–4.

rising, in which case the island would simply be situated on the western horizon where the sun *sets*.[1]

Hesiod mentions practically the same stars as Homer, the Pleiades, the Hyades, Orion, Sirius, and Arcturus. But, as might be expected, he makes much more use than Homer does of celestial phenomena for the purpose of determining times and seasons in the year. Thus, e. g., 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;[2] the time for harvest he fixed by the early rising of the Pleiades, which means the Julian 19th of May;[3] threshing-time he marked by the early rising of Orion (Julian 9th of July), vintage-time by the early rising of Arcturus (Julian 18th of September), and so on.[4] With Hesiod, Spring begins with the late rising of Arcturus; this would in his time and climate be the 24th February of the Julian calendar, or 57 days after the winter solstice, which in his time would be the 29th December. He himself makes Spring begin 60 days after the winter solstice; he may be intentionally stating a round figure, but, if he made an error of

[1] Martin has discussed the question at considerable length ('Comment Homère s'orientait' in *Mémoires de l'Académie des Inscriptions et Belles-Lettres*, xxix, Pt. 2, 1879, pp. 1–28). He strongly holds that τροπαὶ ἠελίοιο can only mean the *solstice*, that by this we must also understand the *summer* solstice, and that the expression ὅθι τροπαὶ ἠελίοιο must therefore be in the direction of the place on the horizon where the sun sets at the summer solstice, i.e. west-north-west. Martin's ground is his firm conviction that τροπαὶ ἠελίοιο has *never*, in any Greek poet or prose writer, any other than the technical meaning of 'solstice'. This is, however, an assumption not susceptible of proof; and Martin is not very successful in his search for confirmation of his view. Identifying Ortygia with Delos, and Syrie with Syra or Syros, he admits that the southern part of Syra is due west of the southern part of Delos; only the northern portion of Syra stretches further north than the northern portion of Delos; therefore, geographically, either west or west-north-west would describe the direction of Syra relatively to Ortygia well enough. Of the Greek commentators, Aristarchus of Samothrace and Herodian of Alexandria take τροπαί to mean 'setting' simply; Martin is driven therefore to make the most he can of Hesychius who (s.v. Ὀρτυγίη) gives as an explanation τοῦτο δέ ἐστιν ὅπου αἱ δύσεις ἄρχονται, 'This is where the settings commence', which Martin interprets as meaning 'where the sun sets *at the commencement of the Greek year*', which was about the time of the summer solstice; but this is a great deal to get out of 'commencement of setting'.

[2] Ideler, *Handbuch der mathematischen und technischen Chronologie*, 1825, i, pp. 242, 246.

[3] Ibid. p. 242.

[4] Ibid. pp. 246, 247.