Studies in the Greek Astronomers

George Huxley

I

Eudoxian Topics

IT IS OBVIOUS THAT EUDOXUS OF CNIDUS occupies a distinguished position in the intellectual life of Greece in the fourth century B.C.: he was a mathematician, an astronomer, a lawgiver, and a geographer, and the interests of this astonishing man reached into medicine and philosophy. As an associate of Plato and a friend of Aristotle, Eudoxus repays examination by Platonists and Aristotelians, but he is hardly less interesting for himself and his own work. He still awaits a biographer, but the range of his interests was so great and the evidence for his work is so fragmentary that it is doubtful whether a definitive biography could be written. In this essay we consider a few only of the outstanding problems concerning his life and work.

The Chronology of Eudoxus' Life

The attempt to determine the dates of his birth has given rise to a number of estimates ranging from 420 to about 390 B.C.[1] All make use of the statement of Apollodorus[2] that Eudoxus died in his fifty-third year and flourished in the 103rd Olympiad (368 to 365 B.C.). If Apollodorus placed his *floruit* in his fortieth year then he lived from *ca.* 408 B.C. to *ca.* 355 B.C., and these dates are given for his lifespan in many textbooks. However, we do not know that Apollodorus assumed that Eudoxus was forty in 368 B.C., and if Eudoxus died in 355 then he predeceased Plato; but a passage in Pliny shows clearly that Eudoxus

[1] Among the dates suggested for his birth have been: 390, Fr. Susemihl, *RhM* 53 (1898) 626ff; 395, P. Merlan, *Studies in Epicurus and Aristotle* (Wiesbaden 1960) 98; *ca.* 409, R. Helm, *Hermes* 29 (1894) 167ff; 420/19, G. F. Unger, *Philologus* 50 (1891) 191ff. Compare also G. de Santillana, *Isis* 32 (1949) 248–262 with H. Cherniss, *Lustrum* 4 (1959) 42 n.1.

[2] *FGrHist* 244 F 76.

actually mentioned the death of Plato in his writings,[3] from which it is plain that Eudoxus died after 347, the year of Plato's death. Hence, if he lived about fifty-three years, he cannot have been born before 400 B.C., and may in fact have been born sometime after that year.

The sources named by Diogenes in his life of Eudoxus are a mixed bag—"Nicomachus" (Aristotle), Callimachus, Eratosthenes, Sotion, Hermippus, Apollodorus and Favorinus are mentioned—but most of the details look sound, and they do enable us to reconstruct his life and travels at least in outline. At the age of about twenty-three he came to Athens with Theomedon the physician, who provided for him. He lived at Piraeus and went up every day to lectures in Athens. After two months he returned to Cnidus and then, it seems soon afterwards, supported by the generosity of his friends, went on to Egypt in the company of Chrysippus, a physician. Since he was not born before 400, and was already twenty-three when he went to Athens, the journey to Egypt cannot have been made before 377.

To Egypt he took letters of introduction to king Nectanebes (or Nectanabis) which had been given to him by Agesilaus of Sparta. Since Diogenes places the visit in an early period of the life of Eudoxus, we infer that this Nectanebes is Nectanebes I, who reigned from about 381/0 to 364/3.[4] According to Diogenes Eudoxus stayed in Egypt with the priests for a year and four months. There is unlikely to be any truth in another story that he was there in the company of Plato, and the tale reported by Strabo that the two men were there together for thirteen years is obviously absurd.[5] How the number thirteen was arrived at is not clear: it may be the interval between the date of Plato's supposed visit to Egypt and that of Eudoxus. The Epitome of Strabo has the two men spend *three* years together in Egypt.

From Egypt he went to Cyzicus and the Propontis and gave lectures. Next he visited the court of Mausolus, who had become dynast of Caria in 377/6. And from there, reports Diogenes, he came again to Athens.

Now the Vita Marciana of Aristotle states that Aristotle joined the Academy in Athens "in the time of Eudoxus," an expression which

[3] Pliny, *NH* 30.3.

[4] P. Sattler, *Studien aus dem Gebiet der alten Geschichte* (Wiesbaden 1962) 46–47: *cf.* Beloch, *GG* III.2², 122ff.

[5] Strabo 17.806.

seems to mean that Eudoxus was then in charge of the Academy.[6] Aristotle first came to Athens in 368/7, and about that time Eudoxus may well have been in charge of the Academy, for Plato was then absent in Sicily on his second visit to the West. The order of events in the life of Eudoxus by Diogenes suggests that the visits to Egypt, to Cyzicus, and to Mausolus all took place before the second visit to Athens, and so all before 368/7. We have already seen that the first visit to Athens and the journey to Egypt cannot have happened before 377, and therefore Eudoxus went from Cnidus to Athens, back to Cnidus, to Egypt, thence to Cyzicus, to the court of Mausolus, and to Athens again all within the course of a decade. If a story in Aelian[7] is to be trusted, Eudoxus was in the West after Plato's visit to Dionysus II about 361. That he was in the West sometime is confirmed by the report that Archytas of Tarentum was his teacher in geometry,[8] but he can hardly have been "taught" geometry by Archytas so late in life as 361; a visit to Tarentum by Eudoxus as a young man, about the time of the first visit to Athens, is a possibility.

He later returned to Cnidus,[9] where he was received with great honor, evidence for which was a decree concerning him, and he became famous throughout Greece for his legislation at Cnidus. So much for the bare chronology of his life: we can now add some detail.

The Visit to Egypt

The tradition of the stay of Eudoxus in Egypt is surrounded by legend; but he undoubtedly went there, and in Strabo's day the observatory in which he worked at Kerkesoura could still be seen, while his school at Heliopolis was still pointed out.[10]

There is no evidence whatsoever that the Egyptians of the fourth century B.C. were better astronomers than the Greeks. Eudoxus went to Heliopolis not to learn planetary theory from the priests, but to make observations, especially of those stars which were not visible in the latitude of Cnidus, and to study the calendar and the priestly lore. Most of his study of Egyptian religion seems to have been incorporated in his geographical work *The Tour of the Earth*, several fragments of which turn up in Plutarch's quaint work *On Isis and Osiris*.

[6] *Cf.* W. Jaeger, *Aristotle*², tr. R. Robinson (Oxford 1948) 16 n.2.

[7] *VH* 7.17.

[8] Callimachus fr. 429 Pfeiffer (Diog. Laert. 8.86).

[9] Diog. Laert. 8.88 (implied but not stated).

[10] Strabo 17.806.

The astronomical observations he included in his works *The Mirror* (*Enoptron*) and the *Phaenomena*.

According to Diogenes Laertius, some people believed that Eudoxus composed a work on the Octaeteris or eight-year lunar and solar cycle when he was in Egypt. It is true that he was interested in the Egyptian calendar, and he may have attempted to determine the length of the Octaeteris when he was in Egypt and later, but it is unlikely that he devoted a special book to the subject. Eratosthenes[11] denied that a work on the Octaeteris current in his own time was by Eudoxus, and there was a treatise on the cycle by Dositheus of Pelusium which went under the name of Eudoxus.[12] Other Alexandrian interest in the astronomy of Eudoxus is indicated by the papyrus fragment that goes under the name *Ars Eudoxi* (ed. F. Blass, Programm Kiel [1887]), though how much genuinely Eudoxian doctrine this puzzling work of the early second century B.C. contains is problematical. Some of this Hellenistic "Eudoxian" literature may also survive in Plutarch's book *On Isis and Osiris*.

The teacher of Eudoxus was Chonouphis. The name is fairly common, being found in the forms of Chonouphis, Ichonouphis, Konouphis, and Chenouphis.[13] It is probable that Eudoxus studied under a priest called Chonouphis or the like, but he certainly did not take lessons in theoretical astronomy. What he first learned was the Egyptian language. He is said to have translated into Greek from Egyptian the so-called *Dogs' Dialogues*, and he may well have been good enough after more than a year in Egypt to undertake a translation. Diogenes does say, however, that according to Eratosthenes, Eudoxus composed the dialogues himself. Of their content we are ignorant. The dog-faced god Anubis may have appeared in them, and we know that Egyptian priests were interested in dogs and related species. Herodotus mentioned that "wolves" conducted a priest to the temple of Demeter (Isis),[14] and that wolves were bred with dogs in Egypt is shown by Aristotle.[15]

Eudoxus was not the only Greek with whom Chonouphis had dealings. King Agesilaus, who had given letters of introduction to

[11] Achilles, *Isag.* p. 139E Petau. See E. Maass, "Aratea," *Phil. Unt.* 12 (Berlin 1892) 18.

[12] Censorinus, *De Die Nat.* 18.5. Crito of Naxos also wrote on the Octaeteris a book said to be Eudoxus': Sud. *s.v.* *κρίτων*.

[13] F. W. von Bissing, *Forschungen und Fortschritte* 25 (1949) 226.

[14] 2.122.3.

[15] *Hist. Anim.* 607a2. J. B. Hainsworth, *G&R* N.S. 8 (1961) 124.

Eudoxus to bear to Nectanebes I,[16] had a long correspondence with the Egyptian king. His earliest letter to Egypt may have been sent about 380 B.C., for, sometime after the Spartan capture of the Cadmeia at Thebes, Agesilaus sent to Egypt for interpretation a copy of a bronze inscription found in the supposed tomb of Alcmena.[17] Plutarch (*Mor.* 578F) says that the priest who interpreted the inscription was Chonouphis, and remarks that the text was taken to Egypt by Agetoridas the Spartiate; we are not told that Eudoxus went with him, and if the two men did travel together, the journey cannot have been made before 377, the earliest possible date for the visit of Eudoxus to Egypt. If Agetoridas (and perhaps Eudoxus with him) did carry a Mycenaean text to Egypt, it must have made a very striking and original letter of credence to Nectanebes.

In his study of Egyptian religion Eudoxus remarked that the body of Osiris lay at Bousiris, because that was his own city;[18] he also reported an Egyptian myth about a god whom he identified with Zeus. The god's legs grew together until he was unable to walk; in shame he lived in the desert, until Isis separated his legs and enabled him to walk.[19] Isis, Eudoxus reported, presided over sexual matters.[20] He also denied the concepts of Dionysus as ruler of the dead and bringer of the Nile flood.[21] His piety led Eratosthenes to call him "god-fearing,"[22] and in return for it he enjoyed the favor of the gods, for, the tale went, the Apis bull licked his cloak: this led the priests to predict that he would be famous but short lived, according to Favorinus.[23] The legend was perhaps started by Chonouphis in Memphis, where Apis was thought to have lived and where his bull was kept.

The most striking phenomenon in the Egyptian year is the Nile flood. Since Eudoxus was in Egypt for more than a year, he witnessed the flood at least once, and several fragments show that he studied it. He noticed that pigs were not sacrificed, but were kept to tread the grain into the sodden soil after the flood, so as to stop the birds from eating it.[24] As for the cause of the flood, he reported that according

[16] Diog. Laert. 8.87.
[17] Plut., *Mor.* 577 EF.
[18] *De Is. et Osir.* 359C.
[19] *De Is. et Osir.* 376C.
[20] *De Is. et Osir.* 372E.
[21] *De Is. et Osir.* 377A.
[22] Fr. 35, 9 Powell. *Cf.* Wilamowitz, *KS* 2 (1941) 60.
[23] Diog. Laert. 8.90.
[24] Aelian, *HA* 10.16. Compare Herodotus 2.14.

to the priests the Egyptian summer corresponds to winter on the other side of the earth, and that the Nile flood is due to heavy rain far to the south of Egypt, there being ceaseless rain in Aethiopia in summer.[25]

We come now to his astronomical work in Egypt. From his observatory he watched the star Canobus, though he did not call it by that name but wrote of "the star that is observed from Egypt."[26] The name Canobus seems to have been introduced in the third century B.C., when Apollonius Rhodius wrote a poem of that name in choliambics about the steersman of Menelaus.[27] Eudoxus also paid attention to the date of the visible rising of Sirius, and later when he came to compose his parapegma or seasonal calendar, he began his year with the rising of that star, which the Egyptians called Sothis.

Since the Egyptian year was 365 days long, their calendar year began about a day earlier in the natural year every four years. Hence the rising of Sirius happened a day later by the calendar every four years, and the star rose heliacally on the same day in the calendar after an interval of about 1460 years. This was the Sothic period.[28] None of the fragments of Eudoxus discusses the period, but he is likely to have heard about it from the priests, and in the extant Greek parapegmata Eudoxus and "the Egyptians" are several times named together. The Egyptian calendar year consisted of twelve months of three ten-day weeks each, and was divided into three seasons of four months each. There followed five epagomenal days, called "the days upon the year." One of the questions Eudoxus will have discussed with Chonouphis is, how much longer than 365 days is the sidereal year? He was by no means the first Greek to have studied the problem. About sixty years earlier Meton and Euctemon had already taken the length of the year to $365\frac{5}{19}$ days.

The Four- and Eight-Year Cycles

According to Pliny[29] Eudoxus proposed a Tetraeteris or four-year cycle, beginning with the rising of the Dog Star, and in each cycle the

[25] *Placit. Philosoph.* 4.1.7 (Diels, *Doxographi Graeci* [Berlin 1879] 386) and Schol. *Od.* 4.477 (Eudoxus fr. 65, p. 37 Gisinger).

[26] Hipparchus, *Comment.* 1.11.6, p. 114, 18 Manitius.

[27] Maass, "Aratea," p. 364.

[28] Geminus, *Elem. Astron.* 8.24. For the origin of the Sothic cycle see O. Neugebauer, *Acta Orientalia* 17 (1939) 169–195.

[29] *NH* 2.47.130.

first was an intercalary year: thus the cycle consisted of $(4 \times 365) + 1 =$ 1461 days. A great deal was made of this passage by Boeckh in his classic study of Eudoxian astronomy;[30] it may be that by "intercalary year" Pliny meant the Julian leap year, but Pliny's words do not entail that the Julian and Eudoxian leap years were the same, and we cannot be certain of the year in which Eudoxus started his first four-year period. He may have started the cycle when he observed Sirius in Egypt, but we do not know that he did. The natural meaning of Pliny's words is that Eudoxus proposed a four-year cycle which began with the rising of Sirius, and that the first year of the cycle was 366 days long: thus his Tetraeteris had the same length, but not necessarily the same leap years, as the Julian cycle. It would have been pointless for Eudoxus to make his Octaeteris[31] exactly twice the Tetraeteris or 2922 days, but a period of 2921 days for his eight-year cycle is possible: this will have consisted of 49 hollow months of 29 days each and 50 full months of 30 days each, giving 99 synodic months in eight years.

Astronomy at Cyzicus

When Eudoxus was at Cyzicus with his school, he made astronomical observations. This is shown by the excerpts of Hipparchus from the *Phaenomena* and the *Enoptron*. The former work gives the ratio of the longest to the shortest day as 5:3, which fits a latitude about 40° 40′.[32] The *Enoptron* seems to have been set even further to the north, for in it Eudoxus took the ratio 12:7, giving a latitude of 42° 15′. This parallel passes through the Black Sea, and it is thus probable that the observations set out in the *Enoptron* were made in some Greek city on the shores of that sea, which as several fragments of the *Tour of the Earth* show were well known to Eudoxus.[33]

To the school at Cyzicus belonged the mathematicians Menaechmus, Dinostratus, and Athenaeus.[34] Another member was probably

[30] A. Boeckh, *Ueber die vierjährige Sonnenkreise der Alten* (Berlin 1863) 123–134.

[31] This cycle can be traced back to the time of Cleostratus of Tenedos in the sixth century B.C. It still found favor in some quarters in late Byzantine times; see O. Schissel, *Hermes* 72 (1937) 317–333.

[32] *Cf.* Maass, "Aratea," pp. 287–289. This ratio recurs in Cleomedes (1.6 p. 50 Ziegler) and in Ptolemy, *Almagest* 2.8 (Vol. I, p. 138 Heiberg). See also O. Neugebauer, *TAPS* 32 (1942) 257.

[33] See the fragments in F. Gisinger, *Die Erdbeschreibung des Eudoxos von Knidos* (Berlin 1921).

[34] Procl. in *Element.* 1, p. 67 Friedlein.

the astronomer Helicon of Cyzicus. Polemarchus of Cyzicus, a pupil of Eudoxus, worked with Callippus, who improved the Eudoxian theory of homocentric spheres, but it is not certain that Callippus, who worked with Aristotle in Athens, was born early enough to have been a pupil of Eudoxus in Cyzicus.[35]

The Seasonal Calendar and the PHAENOMENA

We come now to the seasonal calendar of Eudoxus. The *Ars Eudoxi* states "From the autumnal equinox to the winter solstice according to Eudoxus are 92 days. From the winter solstice to the spring equinox according to Eudoxus and Democritus are 91 days." The number of days between the summer solstice and autumnal equinox is missing in the papyrus, but supposing the motion of the sun to be as uniform as possible, the calendar of Eudoxus can be reconstructed.

1. From autumnal equinox to winter solstice	92 days
2. From winter solstice to spring equinox	91 days
3. From spring equinox to summer solstice	⟨91 days⟩
4. From summer solstice to autumnal equinox	⟨91 days⟩

In a leap year there will have been 92 days from spring equinox to summer solstice. Since Eudoxus made the quarters of the year as equal to each other as possible, it is a little surprising to find that he did not make the tropical and equinoctial points at right angles to each other. That he did not is clear from quotations by Hipparchus,[36] which show that whereas the equinoxes lay on the same circle, two *different* circles, one drawn through the middle of Cancer, the other through the middle of Capricorn, passed respectively through the summer and winter solstitial points. Eudoxus may have adopted this arrangement because even with his schematic calendar the quarters of the years were still not exactly equal to each other. His equinoctial circle passed through the middle of Aries and of Chelae.

Hipparchus' quotations show that Eudoxus had a fairly well defined zodiac circle. Eudoxus indeed may have been the first Greek to employ Babylonian zodiacal signs each equal to one twelfth of the ecliptic circle. Euctemon in the time of Pericles may have known zodiacal constellations only, and the zodiacal dates given in the calendar[37] preserved in his name may have been added in the fourth

[35] Boeckh, *Sonnenkreise* 152; T. L. Heath, *Aristarchus of Samos* (Oxford 1913) 212.
[36] *Comment.* 2.1.20. p. 132, 11–18 Manitius.
[37] W. K. Pritchett/B. L. Van der Waerden, *BCH* 85 (1961) 32–37.

century B.C. or later. We do not know where Eudoxus heard of the signs of the zodiac as they were defined in Babylonia. He may have found out about them in Egypt, or from a Persian source in Cnidus or Cyzicus, or possibly in Athens, for at one time there had been a Chaldaean in the Academy.[38] Whatever the source of his knowledge, it is clear that when he undertook the composition of his seasonal calendar, the final version of which was perhaps produced during his legislation at Cnidus, for new laws and festivals needed a new calendar, he divided the year into twelve equal parts, one for each of the zodiacal signs through which the sun passes. Since the quarters were of 92 or 91 days, each quarter had three months of 31+30+31 or 30+31+30 days.

Hipparchus shows that Eudoxus placed the points of the year in the middle of the signs Capricorn, Aries, Cancer, and Libra, not at the beginnings of the signs where he himself placed them. Columella adds that Eudoxus (and Meton!) put the points in the eighth degree of the signs,[39] and this may well have been true of the equinoxes; but the solstices, as we saw above, were not placed exactly opposite to each other, so that both of them cannot have been in the eighth degree of their respective signs. The vernal point at Aries 8° may have been borrowed from the Babylonians: it appears later in astrological texts and in System B of the Babylonian lunar theory. Finally we must bear in mind that if Hipparchus means that Eudoxus placed the points of the year in the very center of the signs, then Eudoxus at one time adopted a vernal point at Aries 15°.

No planets are discussed in the commentary of Hipparchus on Aratus, an omission which suggests that Eudoxus cannot have discussed them at length in the *Phaenomena*. He did, however, attempt to determine the synodic and sidereal times of the planets, and his reported results are, apart from the times given to Mars which may be corrupt, fairly accurate.[40] The planetary periods will have been discussed in his book *On Speeds*.

The *Phaenomena* was composed partly to help in finding the time at night, partly as an aid to navigation. As a systematic survey of the entire heaven it was a bold and pioneering treatise, and a great

[38] *Academicorum Index* p. 13 Mekler. *Cf.* J. Kerschensteiner, *Plato und der Orient* (Stuttgart 1945) 195.

[39] *RR* 9.14.12.

[40] T. L. Heath, *op.cit.* 208.

advance on the earlier lists of risings and settings. But it did not achieve the accuracy of Hipparchus, who criticized it thoroughly but always fairly. Thus Eudoxus took β of the Little Bear to be the pole of the world, but Hipparchus was at pains to point out that at the true pole there is no star.

We do not know whether Eudoxus ever published his observations made in Italy and Sicily;[41] but Posidonius, who saw his observatory above the other houses at Cnidus, knew that Eudoxus had observed Canobus from there.[42] This may have been a local tradition at Cnidus, or possibly Eudoxus published a book on his observations at Cnidus in addition to the *Phaenomena* and the *Enoptron*, which contained observations made at Cyzicus and further north.

Zoroaster, the Magi, and the Chaldaeans

It is well known that Eudoxus discussed the Magi and Zoroaster in his *Tour of the Earth*, but how accurate his knowledge was is not clear. If Pliny[43] is to be trusted, Eudoxus went so far as to date the life of Zoroaster six thousand years before the death of Plato, and if the number is not corrupt, it seems that Eudoxus confused the era of Zoroaster with an epoch in the Persian great world period, in which three-thousand-year periods of good and evil alternated. Eudoxus certainly discussed these cycles of good and evil, as a fragment in Diogenes Laertius[44] shows: "Aristotle says...that the Magi are older than the Egyptians, and that there are with them two principles, a good spirit and an evil spirit. The one is called Zeus and Oromasdes, the other Hades and Areimanios. Hermippus also says this in the first book *On the Magi* and Eudoxus in the *Tour of the Earth* and Theopompus in the eighth book of the *Philippica*." A fragment of Xanthus of Lydia[45] states that there were six thousand years from the expedition of Xerxes to the time of Zoroaster, but two manuscripts have six hundred years. If the fragment is genuine, then Greek knowledge of Zoroaster goes back earlier than Plato and Eudoxus to the fifth century, but it is surprising that Herodotus nowhere mentions Zoroaster.

[41] Ptolemy, *De Apparentiis* 93E mentions them.
[42] Strabo 2.119.
[43] Pliny *NH* 30.3 (Eudoxus fr. 59 Gisinger).
[44] Diog. Laert, 1.8. *Cf.* A. V. W. Jackson, *JAOS* 17 (1896) 3.
[45] *FGrHist* 765 F 32.

Astral determinism was becoming fashionable in Babylonia in the fourth century B.C., and some knowledge of it seems to have reached Eudoxus, for Cicero[46] states that he criticized the claim of the Chaldaeans to be able to predict the course of men's lives from the day of their birth. On the other hand, Eudoxus may have viewed favorably the meteorological omens of the Babylonians, for there are close similarities between the seasonal weather predictions associated with his name and cuneiform texts concerning thunder, clouds and other phenomena.[47] There is still no evidence, however, that either Eudoxus or the Babylonians of his time had a developed horoscopic astrology such as is found in Hellenistic times.

The Lawgiving at Cnidus

Our last topic is the lawgiving in Cnidus, for which he was greatly honored by his fellow citizens. The early constitutional history of Cnidus is obscure. Since the city was a Laconian foundation, the name of a Cnidian official, the *Aphester*, may be connected with the *Apostateres* of the Lycurgan Rhetra at Sparta, as Grote first suggested. In his fourth Greek Question Plutarch asks "Who are the Amnemones at Cnidus, and who is the Aphester?" Answer: "They appointed for life sixty men chosen from the aristocracy as overseers to take the preliminary decisions about the most important things. They were called Amnemones...The man who called upon them for their decisions was the Aphester."

In the *Politics*[48] Aristotle states that Cnidus was a closed oligarchy, which was overthrown when the nobles fought with each other because only a few of them had a share of power. A father and his son could not hold office at the same time, and of brothers only the eldest could do so. The people used these dissensions to overthrow the aristocratic factions, and taking a champion from amongst the nobles attacked them and gained power.

[46] *De Div.* 2.42.87.

[47] See C. Bezold/F. Boll, *SB Heidelberg* 1911, No. 7 (Phil.-Hist. Kl.) pp. 8–9. It is just possible that Eudoxus learnt about Babylonian astrology in Egypt, since an astrological document, dating probably from the time of the Persian conquest, has now been found in Egypt. The scheme of the papyrus is of Babylonian origin; all astrology in Egypt shows Greek or Babylonian influence. See R. A. Parker, *A Vienna Demotic Papyrus on Eclipse- and Lunar-Omina* [Brown Egyptological Studies 2 (Providence 1959)].

[48] 1305b12-18; 1306b5.

Prostates, champion, like *Amnemon*, is a technical term. It is found in Cnidian inscriptions of the fourth century B.C.,[49] and at some time during that century, before the writing of the *Politics*, a champion from amongst the nobles at Cnidus set up a democracy there. It is possible, though not provable, that the champion was Eudoxus, whose fellow citizens honored him greatly and from whom they received new laws.

Sometime in the fourth century B.C. the Cnidians moved from old Cnidus (Datça) to new Cnidus (Tekir),[50] and the move may well be linked with the establishment of the democracy amongst them; the new city needed new laws, and these were perhaps the laws that Eudoxus gave, if the move occurred in his lifetime.

There are two periods in which democracy may have been set up in Cnidus. The later is after Alexander's victory at the Granicus, when democracies were established in several cities of Asia Minor. This date has a little support from the archaeological remains at new Cnidus,[51] which do not seem to be earlier than the last quarter of the fourth century B.C. This is not conclusive, however, and there are several arguments for dating the move to new Cnidus earlier than the battle of the Granicus, to the middle of the fourth century and so to the lifetime of Eudoxus. First, all the examples in the *Politics* date from before Alexander's conquest of Asia Minor—Alexander is not even mentioned in the work and there is no particular reason why the Cnidian example should be later than the others. Secondly, the Aphrodite of Praxiteles was sold to the Cnidians, and such a work is unlikely to have remained unsold in the workshop for long. The traditional *floruit* of Praxiteles is 364/1; the date may be that of his best-known work, the Cnidian Aphrodite, which was set up in a sanctuary at new Cnidus. The Aphrodite was first offered to Cos, the occasion for the offer being perhaps the founding of new Cos in 366/5. Thus it is very likely that the sanctuaries of new Cnidus were being built when the Aphrodite of Praxiteles was new,[52] and the statue would then have been set up in new Cnidus not later than the fifties of the fourth century. Now there is an inscription of the Prostatai of new Cnidus, which mentions a Hermes being set beside an

[49] J. M. Cook/G. E. Bean, *BSA* 47 (1952) 206, with bibliography and discussion.

[50] *Ibid.* 171–204.

[51] *Cf. ibid.* 210.

[52] *Ibid.* 211.

Aphrodite, and the Aphrodite may well be the Praxitelean statue bought for the sanctuary in the new city very soon after the foundation.[53] Thus the inscription, and with it the founding of the new city of Cnidus, should perhaps be dated not later than the fifties of the fourth century B.C.

A third argument for connecting Eudoxus with the move to new Cnidus concerns Mausolus. Eudoxus visited Mausolus,[54] who favored new foundations on the Carian coast, and new Cnidus is like Myndus, a Mausolan foundation, in plan. It is quite possible that the institution of a Cnidian democracy and the building of a new city at Tekir had the approval of Mausolus, in which case the changes will have occurred before his death in 352 B.C.

The inscription mentioning the Prostatai of the new city fits well the middle of the fourth century. In it the "Prostatai of the new citizens" are the leaders of the people in the new city. Plutarch says nothing about Prostatai in his fourth Greek Question, and it is likely that the Prostatai of Cnidus were introduced when the oligarchy of the Amnemones was overthrown, but the office of Aphester did continue in use at Cnidus until Roman times.[55] In his legislation therefore the reformer (be he Eudoxus or another) may well have preserved some parts of the ancient constitution.

Finally, Strabo's account[56] of the observatory of Eudoxus implies that it was at new Cnidus, the Cnidus of Posidonius' day: this is another argument for dating the move to new Cnidus in the lifetime of Eudoxus, and another hint that his legislation may have been linked with the move and with the establishment of the democracy.

Epilogue

The topics studied in this paper are a part only of the great range of problems opened up by the life and thought of Eudoxus. We have said nothing about his work in pure mathematics, little about his planetary theory and his geography, and have barely touched upon his relations with Plato and Aristotle, all fruitful fields for further

[53] *Ibid.* 206.
[54] Diog. Laert. 8.87.
[55] *SGDI* 3.i, No. 3505.
[56] 2.119.

research. His ethics and his theory of knowledge also demand attention, as do his astronomical instruments, his relations with the later Pythagoreans, and his knowledge of Presocratic philosophy. But I hope that this paper has made a small contribution to the study of this most learned and original thinker.

THE QUEEN'S UNIVERSITY, BELFAST
February, 1963

II

A Fragment of Cleostratus of Tenedos

THERE ARE in the Scholia to Euripides two verses of an astronomical poem by Cleostratus of Tenedos:
Schol. [Eur.] *Rhesus* 528[1]

> *ἀλλ' ὁπόταν τρίτον ἦμαρ ἐπ' ὀγδώκοντα μένησι*
> *σκορπίου εἰς ἅλα πίπτει ἅμ' ἠοῖ φαινομένηφι.*

ὀγδώκοντα Dindorf, *ὀγδοήκοντα* ms. *μένησι* ms, *πέλησι* Schwartz.

The verses, which are incomplete, are introduced by a quotation from Parmeniscus as follows:

> *ὁ μὲν οὖν Παρμενίσκος 'πρῶτα σημεῖα' φησὶ λέγεσθαι τὰς τοῦ σκορπίου πρώτας μοίρας διὰ τὸ ὑπὸ τῶν ἀρχαίων οὕτως αὐτὰς λέγεσθαι, καὶ ὅτι ταύταις ὁ Βοώτης ἅμα ἄρχεται καταδύεσθαι. Κλεόστρατον γοῦν τὸν Τενέδιον ἀρχαῖον οὕτως· ἀλλ' ὁπόταν κτλ.*

καὶ ὅτι ms, *διότι* Schwartz. *ἀρχαῖον* ⟨ *ὄντα ἀστρολόγον εἰπεῖν* ⟩ *οὕτως* Diels, (after Schwartz) *Vorsokr.* 6 B 1. *σκορπίος* Meineke.

The missing words on which Cleostratus' genitive *σκορπίου* depends are doubtless *πρῶτα σημεῖα*, for Parmeniscus quoted from Cleostratus to illustrate their use in the passage of *Rhesus* on which he was commenting. In the hexameters of Cleostratus the first stars or points of the Scorpion would, then, be called *σημήϊα πρῶτα*. They are the first stars of the constellation to set.

Now Diels (*Vorsokr.*[9] 6 B 1) proposed to supplement the verses of Cleostratus as follows:

> *ἀλλ' ὁπόταν τρίτον ἦμαρ ἐπ' ὀγδώκοντα μένησι*
> ⟨*Ἀρκτοφύλαξ φαίνων, τότε δὴ σημήϊα πρῶτα*⟩
> *σκορπίου εἰς ἅλα πίπτει ἅμ' ἠοῖ φαινομένηφι.*

[1] See J. K. Fotheringham, *JHS* 39 (1919) 166.

Similarly Boll's interpretation (*Sphaera* p. 192–193 note 1) also introduced Bootes: "Wenn der Bootes mit seinem Spätaufgang 83 Tage am Nachthimmel verweilt, so geht der Anfang des Skorpions in der Morgendämmerung unter, gleichzeitig mit den ersten Sternen des Bootes." However, the addition of Bootes to the fragment was rejected by Fotheringham (*JHS* 39, 170); for the words following *καὶ ὅτι* in the scholium are comment by Parmeniscus. They do not show that Cleostratus mentioned Bootes at this point in the poem, and the change to *διότι* by Schwartz is needless.

Parmeniscus, then, quoted the following words only from Cleostratus:

> ἀλλ' ὁπόταν τρίτον ἦμαρ ἐπ' ὀγδώκοντα μένῃσι
> . . . ⟨σημήϊα πρῶτα⟩
> σκορπίου εἰς ἅλα πίπτει ἅμ' ἠοῖ φαινομένηφι.

They may be translated "But when ⟨he⟩ awaits the third and eightieth day,...the first points of the Scorpion fall into the sea with the appearance of dawn." Presumably Cleostratus here refers to an astronomer watching the stars sinking into the sea westwards from the island of Tenedos.

The question to be answered, then, is "What happened eighty-three days before the apparent morning setting of the first points of the Scorpion?" Of this Fotheringham wrote (*JHS* 39, 172) that he was unable to identify the phenomenon from which Cleostratus reckoned his eighty-three days.

One of the few facts we know about this Tenedian astronomer of the late sixth century B.C.[2] is that he observed solstices. Theophrastus or one of his followers states that Matricetas in Methymna in Lesbos observed solstices as the sun rose behind mount Lepetymnos, Cleostratus in Tenedos watched them on Mount Ida, and Phaenus, a metic, at Athens on Lycabettus (*De Signis* 4). We are not told from what point in Athens Phaenus watched the sun rise over Lycabettus, and

[2] Pliny (*NH* 2.31) makes him later than Anaximander, who flourished in the middle of the sixth century B.C., and Censorinus (*De Die Nat.* 18.5) implies that Cleostratus was earlier than Harpalus. This Harpalus is perhaps the builder of the bridge over the Hellespont for Xerxes (*Laterc. Alex.* 8.8 [*Abh.d.Berl.Akad.* 1904] p. 8). There seems also to have been a school tradition which regarded Cleostratus as a successor of Thales in astronomy, for Thales is reported to have died in Tenedos (see Wilamowitz, *ap. Vorsokr.*[9] 11 A 8 and Fotheringham, *JHS* 39, 167). For other discussions of the work of Cleostratus, see E. J. Webb, *JHS* 41 (1921) 70–85 and the reply by J. K. Fotheringham, *JHS* 45 (1925) 78–83. Compare also W. Kroll, *RE* Supp. 4, 912; E. Bethe, *Rhein.Mus.* 55 (1910) 414ff; Schmidt-Stählin, I.1.323 n. 5; M. Breithaupt, *De Parmenisco Grammatico*, 34.

so we do not know which solstice he attempted to determine; but his pupil Meton observed the summer solstice from the Pnyx. It is clear that Matricetas in Methymna observed the winter solstice, for the clearly defined ridge of Mount Lepetymnos is south of east from that city. Cleostratus also observed the winter solstice, for the ridges of Ida lie on the horizon southeast from Tenedos.[3] Since the sun seems to rise at almost the same point on the horizon for several days before and after the true solstice, it is unlikely that Cleostratus determined the solstice correctly to the nearest day, but if he halved the interval during which the sun seemed to rise at the same point on Ida, he may not have been far wrong. That point was the most southerly at which the sun rose in the course of the year.

The poetical fragment of Cleostratus shows that he composed a poetical calendar of risings and settings of stars and groups of stars. After determining the winter solstice he could relate the risings and settings to a fixed point in the year, as had already been attempted by Hesiod long before. The Boeotian poet had placed the acronychal rising of Arcturus sixty days after the winter solstice (*Op.* 564–567). The interval of eight-three days given by Cleostratus may well be then the interval between the winter solstice, which we know he attempted to determine, and the morning setting of the first stars of the Scorpion. A century later Euctemon who observed, not in Tenedos, but in Athens and in Thrace, estimated the interval to be eighty-nine days in his seasonal calendar.[4]

We suggest, then, that the interval of eighty-three days in the fragment of Cleostratus is his estimate of the interval between the winter solstice and the setting of the first stars of the Scorpion at dawn, as seen from Tenedos towards the end of the sixth century B.C. In such patient observations of celestial phenomena in Greece and in Babylonia, as well as in the cosmogonical speculations of the Presocratics, is the origin of the exact sciences to be discerned.[5]

THE QUEEN'S UNIVERSITY, BELFAST
February, 1963

[3] *Cf.* K. Redlich, *Der Astronom Meton und sein Kyklos* (Hamburg 1854) 20–25, quoted by F. K. Ginzel, *Handbuch der Chronologie* 2 (Leipzig 1911) 375, n. 1.

[4] Geminus, *Elementa* ed. C. Manitius, pp. 210–233; and W. K. Pritchett/B. L. Van der Waerden, *BCH* 85 (1961) 32–37.

[5] I thank W. M. Calder III and C. H. Kahn for their comments on a draft of this paper.

III

Friends and Contemporaries of Apollonius of Perge

APOLLONIUS OF PERGE in Pamphylia was born in the reign of Ptolemy Euergetes (246–221 B.C.).[1] He went to Alexandria[2] and stayed there a long time studying with the disciples of Euclid, and he became famous as an astronomer in the time of Ptolemy Philopator (221–205 B.C.) according to a quotation by Photius from Ptolemy Chennus.[3]

Apollonius, Eudemus, and Philonides

Some more evidence for his life comes from the prefaces to his great work, the *Conics*.[4] In the preface to Book I he mentions a visit to Pergamum, where Eudemus had asked him for an account of his work in conics. The same preface shows that Apollonius undertook the investigation of conics at the request of the geometer Naucrates, who had come to Alexandria and stayed with him there. Apollonius worked out the subject in eight books without revising them thoroughly, as Naucrates was about to sail. He later set to work publishing from time to time a corrected version of each part of the treatise. Apollonius adds that other persons who had been with him had also obtained uncorrected versions of the first and second books.[5]

Book II was brought to Eudemus at Pergamum by the author's son, who was also called Apollonius. The preface requests Eudemus to communicate the work to all who are fit to study it, "and if Philonides the geometer, whom I introduced to you in Ephesus, ever

[1] Eutocius, *Comm. on Conics*, in *Apollonii Opera* 2, p. 168 Heiberg.
[2] Pappus 7.35, p. 678, 10–12 Hultsch.
[3] *Bibliotheca* 190, p. 151b, 18–21 Bekker (Berlin 1824).
[4] T. L. Heath, *Apollonius of Perga* (Cambridge 1896) lxix–lxxv.
[5] *Cf.* C. Hoeg, *Studi e Testi* 124, pp. 1–12.

visits the neighborhood of Pergamum," Apollonius orders, "communicate it to him." This Philonides is the Epicurean geometer from Laodicea-on-the-Sea in Syria, who is also mentioned in a fragmentary text from Herculaneum containing a biography of him.[6] The text names Eudemus his teacher, and probably Apollonius too.[7] Another teacher of Philonides was the mathematician Dionysodorus, son of Dionysodorus, of Caunus in Caria.[8] Now Philonides was of mature years by the time of Antiochus IV Epiphanes,[9] who reigned from 175 to 164 B.C., so that his education by Apollonius, Eudemus, and Dionysodorus is likely to have ceased by 170 B.C. at the latest. Thus we have for the lifespan of Apollonius the limits 246 B.C. to about 170 B.C.[10] The *Conics* cannot have been completed before about 200 B.C., because the preface to Book II shows that by the time the book was finished Apollonius had a grown son who was able to take it to Pergamum.

The first three books of the *Conics* were dedicated to Eudemus of Pergamum, but after his death the fourth, fifth, sixth, and seventh were sent to an Attalus, and in the preface to the seventh Apollonius promises to send Attalus the eighth as soon as possible. The prefaces do not show who this Attalus was; he may be, as has been assumed, King Attalus I, the patron of arts and sciences in Pergamum and vanquisher of the Gauls. If he is the person addressed, then Eudemus had died before 197 B.C., when Attalus I himself died; and it would follow that Philonides was old enough at that time to have been taught by Eudemus, and that the *Conics* was completed by 197 B.C.

The preface to Book IV states that Conon the Samian expounded to Thrasydaeus a problem in conics without showing proper mastery of the proofs, and so Nicoteles of Cyrene somehow fell foul of him. Apollonius does not say that he had met any of these men, but Conon is almost certainly the Samian astronomer of that name; he distinguished the lock of Berenice in the heavens, observed the heavens from Italy and Sicily, was a friend of Archimedes, and studied

[6] Roll No. 1044.

[7] *Βίος Φιλωνίδου* fr. 25, 5; 53, 1. R. Philippson, *RE* 20.1 (1941) 65. Note that in the *RE* entries *s.v.* Philonides, Philonides 7 is the same man as Philonides 5.

[8] Fr. 25, 6.

[9] U. Köhler, *SB Akad. der Wiss.* (Berlin 1900) 2, pp. 999f. H. Usener, *RhM* 56 (1901) 146–148.

[10] *Cf.* W. Crönert, *SB Akad. der Wiss.* (Berlin 1900) 2, p. 958.

geometry; Pappus states that he proposed a theorem about a spiral in the plane.[11]

Apollonius and Hypsicles

Hypsicles, the geometer and astronomer, is usually dated to the second century B.C.,[12] and his *Ἀναφορικός* is generally thought to be the earliest Greek astronomical work extant in which the division of the circle into 360 degrees is found. Hypsicles wrote the so-called fourteenth book of Euclid's *Elements*, and in the introduction to that book he states that at Alexandria Basilides of Tyre and Hypsicles' father looked into a tract by Apollonius concerning the ratio to each other of a dodecahedron and an icosahedron inscribed in the same sphere. They concluded that Apollonius' treatment was not correct, but later Hypsicles himself came across another book by Apollonius containing the demonstration elaborated more thoroughly.[13] As with the *Conics*, then, there seem to have been two stages of publication of this work.

Manitius in his edition of the *Ἀναφορικός*[14] inferred from the introduction to *Elements* XIV that Hypsicles' father was a contemporary of Apollonius and did not live to see the corrected demonstration published. This not very cogent reasoning was rejected by Dicks,[15] who preferred to date Hypsicles in the first or second century A.D. The astrology and the technical terms of the *Ἀναφορικός*, however, such as the degrees into which the ecliptic is divided (*μοῖραι τοπικαί*) and the degrees of revolution of the ecliptic (*μοῖραι χρονικαί*) do not rule out the earlier dating, about a generation after Apollonius; and there are other arguments for dating the work to the second century B.C.

The fourteenth book of the *Elements* is addressed to a Protarchus, who doubtless was interested in geometry. Now Protarchus of Bargylia was the tutor of Demetrius Laco according to Strabo,[16] and this Demetrius was an Epicurean who lived about the middle of the second century B.C. He is perhaps the author of the work entitled *Δημητρίου περὶ γεωμετρίας*,[17] and his tutor may well be the Protarchus

[11] 4.30, p. 234, 2 Hultsch.
[12] O. Neugebauer, *The Exact Sciences in Antiquity*² (Providence 1957) 183.
[13] See T. L. Heath, *The Thirteen Books of Euclid's Elements*, Vol. I, pp. 5–6.
[14] pp. iv–v (Dresden 1888).
[15] *The Geographical Fragments of Hipparchus* (London 1960) 148–149.
[16] 14.658.
[17] W. Scott, *Fragmenta Herculanensia* (Oxford 1885) 36–37.

addressed by Hypsicles.[18] This is made more probable by the fact that in the same sentence Hypsicles names a Basilides; for a famous Epicurean of the middle of the second century B.C. was Basilides, who for a time was in charge of the Garden in Athens.[19] There he was visited by Philonides, the friend of Apollonius of Perge.[20] It is very likely, then, that Hypsicles was connected with a group of Epicurean mathematicians of the mid-second century B.C. Apollonius too, through Eudemus and Philonides, had ties with these Epicureans, and it is even possible that the name of Hypsicles is to be read in the Herculaneum biography of Philonides.[21] Thus, while it cannot be proved that Hypsicles lived in the second century B.C., it is most probable that he lived in Alexandria not far in time from Apollonius.

Apollonius, Pergamum, and the Chaldaean Astronomers

Finally we consider the question of Babylonian influences upon the astronomy of Apollonius. In Ptolemy's *Almagest*[22] it is stated that the number of sidereal rotations of a planet added to the number of the synodic periods is equal to the number of years. As an example, in *Almagest* 12.1 Ptolemy states that Mars has 42 rotations in longitude and 37 synodic periods (conjunctions with the sun) in 79 years.[23] This part of Book 12 is, as Ptolemy himself states, taken from Apollonius.[24]

The relation that the number of sidereal rotations of an exterior planet added to the number of synodic periods is equal to the number of years was well known to the Babylonian astronomers of the Seleucid period. Thus for Mars they used an accurate period:

284 years = 133 occurrences of conjunction + 151 rotations

and two smaller approximate periods of 47 and 79 years with 22 and 37 synodic arcs respectively.[25] The last of these periods is the one known to Apollonius.

We cannot rule out an independent discovery of this period by

[18] *SB Akad. der Wiss.* (Berlin 1900) p. 999.

[19] Diog. Laert. 10.25, 26.

[20] *Βίος Φιλωνίδου* fr. 11, 1. (Philippson, *RE* 20.1 [1941] 67.)

[21] Fr. 1, 1. (Philippson, *op.cit.* 65 note.)

[22] 12.1 and 9.3.

[23] K. Manitius, *Des Claudius Ptolemäus Handbuch der Astronomie* 2 (Leipzig 1913) 271 and note *a*, 272.

[24] See also O. Neugebauer, *Communications on Pure and Applied Mathematics* 8 (1955) 642–643.

[25] O. Neugebauer, *Astronomical Cuneiform Texts* (Princeton/London 1955) pp. 302 and 381.

Apollonius, but there are grounds for thinking that he had it from a Babylonian source, and for suggesting who that source was. Apollonius was in Pergamum during or soon after the reign of Attalus I. When Attalus was king there came to Pergamum a Chaldaean, Sudines; this man was employed by Attalus and interpreted a sacrifice during the Celtic war of 239 to 236 B.C.[26] Sudines, together with Kidenas and Nabourianos, is called a μαθηματικός by Strabo,[27] and in a famous passage Vettius Valens remarks that he attempted to make a canon for himself of the sun and the moon in order to determine eclipses, but, as time was short, he decided to make use of "Hipparchus for the sun, Sudines, Kidenas, and Apollonius for the moon, and again Apollonius for both kinds of eclipses ... putting in their proper places the equinoxes and solstices at the eighth degree of the signs of the zodiac."[28] Thus Vettius Valens followed the lunar System B of the Babylonians in placing the vernal equinox at Aries 8°.

The name of Sudines has yet to be found in a Seleucid cuneiform astronomical text, but Nabourianos is found as Nabū-rimannu, and Kidenas probably as Kidin or Kidinnu.[29] Nabū-rimannu is associated in the texts with the lunar System A, Kidinnu with System B.

We next show that Sudines is to be associated with lunar System B. A list of *Kanonographoi* in a Vatican codex[30] attributes to certain astronomers different estimates for the length of the year. Euctemon, Philippus, and Apollinarius are stated to have given $365\frac{5}{19}$ days. The length attributed to Aristarchus is corrupt, and so is that of a "Babylonian" — a name seems to have fallen out here. Then comes

τξε′ δγ′ ε′ Σωδίνων. τξε′ δρ′ σ′[.

The δγ′ makes no sense as a fraction, but clearly the text is attributing to Sudines a length of the sidereal year slightly greater than τξε′ δ′

[26] Polyaenus 4.20.

[27] 16.739.

[28] 9.11, p. 354, 4–7 ed. Kroll. Vettius Valens will have added 8° to the tables of Hipparchus, who placed the vernal point at Aries 0°, not at Aries 8°. Van der Waerden (*Vierteljahrsschrift d. Naturforsch. Ges. in Zürich* 105 [1960] 136) infers from this passage of Vettius Valens that Apollonius also placed the equinox at 0° of longitude, but I am not sure that this is entailed by Valens' words: he may have needed to adjust by 8° the tables of Hipparchus alone.

[29] *ACT* I, p. 16. According to an anonymous commentator on Ptolemy, Kidenas made use of an ecliptic period of 251 lunations and 269 anomalistic revolutions. *Cat. Codd. Astr. Gr.* 8.2, p. 126. F. Cumont, *Astrology and Religion amongst the Greeks and Romans* (Dover reprint 1960) 36–37.

[30] E. Maass, "Aratea," *Phil. Unt.* 12 (Berlin 1892) 140 and *Hermes* 16 (1881) 389 n. 3.

($365\frac{1}{4}$) days. A similar list in Vettius Valens[31] gives to "the Babylonians" the length $\tau\xi\epsilon'$ δ' $\rho\mu\delta'$, that is $365+\frac{1}{4}+\frac{1}{144}$ days, and this shows how to restore the correct length beside the name Sudines in the Vatican text. Replace γ by ρ, and read $\tau\xi\epsilon'$ δ' $\rho\epsilon'$, that is $365+\frac{1}{4}+\frac{1}{105}$ days. We now write this number sexagesimally in the customary manner 6,5;15,34,17 ... This is strikingly close to the length of the sidereal year adopted in the Babylonian lunar theory of System B: 6,5;15,34, 18.[32] The two lengths are so nearly equal that it is clear that Sudines made use of System B for the moon.

The invention of System B cannot be traced back earlier than about the middle of the third century B.C., and Sudines was already in Pergamum at the time of the Celtic war of 239 to 236 B.C. Therefore he may well have lived close in time to the creation of System B, but it is not clear that either he or Kidenas was its inventor.

Ptolemy Chennus remarks that "Apollonius of Perga was called ϵ since the figure of ϵ is related to the figure of the moon which he investigated most accurately."[33] Since Sudines and Apollonius had both been in Pergamum and were both interested in lunar theory, it is a reasonable hypothesis that Apollonius, the younger of the two men, made use at Pergamum of Babylonian knowledge brought thither by Sudines. More than that cannot be suggested, but the present investigation perhaps helps to confirm the proposition that "the rapid development of Babylonian astronomy at the beginning of the third century B.C. is probably the main cause for the corresponding development in Greek astronomy."[34]

THE QUEEN'S UNIVERSITY, BELFAST
February, 1963

[31] 9.11, p. 353, 12–13 ed. Kroll.

[32] F. X. Kugler, *Babylonische Mondrechnung* (Freiburg 1900) 72 and 91. See also B. L. Van der Waerden, *Vierteljahrschr. d. Naturforsch. Ges. in Zürich* 100 (1955) 162.

[33] Photius, *Bibliotheca* 190, p. 151b, 18–21 Bekker (Berlin 1824).

[34] O. Neugebauer, "The Equivalence of Eccentric and Epicyclic Motion According to Apollonius," *Scripta Mathematica* 24 (1959) 9 n. 16.