CLEOSTRATUS.

I do not know of any book or published paper devoted to Cleostratus. In the indexes to most histories of astronomy you will seek his name in vain, and, where you do find it, you are referred to a few jejune paragraphs or more often to a single sentence. Boll in his *Sphaera* (1903) honours him with three pages (191–194), based on a passage in Pliny and a scholium on Euripides, but he misinterprets both passages and holds one of them to be based on a misunderstanding of some older writer. Nearly all the passages bearing on him are to be found with notes of varying value in Diels, *Fragmente der Vorsokratiker*[3], ii. (1912), pp. 197, 198, where they occupy rather more than a page. Some valuable comments and one reference which is not in Diels will be found in Breithaupt's treatise *De Parmenisco Grammatico* (1915). And yet, for all this neglect, there are attributed to Cleostratus two capital contributions to Greek astronomy, *viz.* the introduction of the signs of the zodiac and the authorship of the eight years' cycle of intercalations.

The following is, so far as I know, a complete list of passages bearing on Cleostratus.

(1) From a life of Aratus, excerpted in E. Maass's *Commentariorum in Aratum reliquiae* (1898), p. 324:—

Βόηθος δὲ ὁ Σιδώνιος ἐν τῷ α′ περὶ αὐτοῦ [sc. *'Αράτου*] *φησιν οὐχ 'Ησιόδου ἀλλ' 'Ομήρου ζηλωτὴν γεγονέναι· τὸ γὰρ πλάσμα τῆς ποιήσεως μεῖζον ἢ κατὰ 'Ησίοδον· πολλοὶ γὰρ καὶ ἄλλοι Φαινόμενα ἔγραψαν καὶ Κλεόστρατος καὶ Σμίνθης καὶ 'Αλέξανδρος ὁ Αἰτωλὸς καὶ 'Αλέξανδρος ὁ 'Εφέσιος καὶ 'Αλέξανδρος ὁ Λυκαΐτης καὶ 'Ανακρέων καὶ 'Αρτεμίδωρος καὶ Ἵππαρχος καὶ ἄλλοι πολλοί. ἀλλ' ὅμως πάντων λαμπρότερον ὁ Ἄρατος ἔγραψεν.*

In this passage *Κλεόστρατος* is a correction made by Bergk and published by Meineke, *Zeitschrift für die Alterthumswissenschaft* (1843), p. 23, for the MS. reading *Κλεοπάτρης*.

The writer does not make it clear whether he gives this list on his own authority or cites it from Boethus, but the inclusion of Alexander of Ephesus shows that the list cannot have been compiled till after the time of Boethus.

(2) From a catalogue of writers on Aratus, edited by Maass in A. Kiessling's *Philologische Untersuchungen*, xii. (1892), p. 121, reprinted by Breithaupt, *loc. cit.* pp. 49, 50:—

οἱ περὶ τοῦ ποιητοῦ συνταξάμενοι.

Ἄτταλος Ῥόδιος. Ἀρίσταρχος Σάμιος. Ἀπολλώνιος γεωμέτρης. Ἀντίγονος γραμματικός. Ἀγησιάναξ. Ἀρίστυλλοι δύο γεωμέτραι. Βόηθος. Γεμῖνος. Διόδοτος. Δίδυμος Κνίδιος. Ἐρατοσθένης. Ἕρμιππος. Εὐαίνετος. Ζήνων. Ἡλιόδωρος στωικός. Θαλῆς. Ἵππαρχος Βιθυνός. Κράτης. Πύρρος Μάγνης. Παρμενίσκος γραμματικός. Σμίνθης. Τιμόθεος.

Εὐαίνετος ἕτερος. Ἕρμιππος περιπατητικός. Καλλίμαχος Κυρηναῖος. Κλεόστρατος Τενέδιος. Νουμήνιος γραμματικός. Παρμενίδης.

Ἀπολλώνιος γραμματικός. Ἀρίστυλλος μέγας. Ἀρίστυλλος μικρός. Ἀρίσταρχος γραμματικός. Ἀριστοφάνης. Ἀλέξανδρος Αἰτωλός. Ἀλέξανδρος Ἐφέσιος. Δίδυμος πονηρός.

A similar but shorter list which does not include the name of Cleostratus is found at the close of a MS. of Geminus's Εἰσαγωγὴ εἰς τὰ Φαινόμενα, printed with apparatus by Maass in *Hermes*, xvi. (1881), p. 388. But in this case the word πόλου takes the place of ποιητοῦ in the title, and there can be no doubt that Von Wilamowitz-Möllendorff (A. Kiessling's *Philologische Untersuchungen*, iv. [1881], p. 339) is right in reading πόλου in the longer list also. Maass has shown (A Kiessling's *Philologische Untersuchungen*, xii. pp. 123–139) that in this instance πόλος is used in the sense of 'sky.' Here again Κλεόστρατος is the result of a correction. The MS. reading is Καλλίστρατος, corrected by Meineke, *Philol. exercit. in Athen.* i. (1843), p. 23, cited by Maass.

(3) Theophrastus, περὶ σημείων, i. 4, ed. Wimmer (Paris, 1866), p. 389. *διὸ καὶ ἀγαθοὶ γεγένηνται κατὰ τόπους τινὰς ἀστρονόμοι ἔνιοι οἷον* Ματρικέτας *ἐν* Μηθύμνῃ *ἀπὸ τοῦ* Λεπετύμνου, *καὶ* Κλεόστρατος *ἐν* Τενέδῳ *ἀπὸ τῆς* Ἴδης, *καὶ* Φαεινὸς Ἀθήνησιν *ἀπὸ τοῦ* Λυκαβηττοῦ *τὰ περὶ τὰς τροπὰς συνεῖδε, παρ' οὗ* Μέτων *ἀκούσας τὸν τοῦ ἑνὸς δέοντα εἴκοσιν ἐνιαυτὸν συνέταξεν. ἦν δὲ ὁ μὲν* Φαεινὸς *μέτοικος* Ἀθήνησιν *ὁ δὲ* Μέτων Ἀθηναῖος. *καὶ ἄλλοι δὲ τὸν τρόπον τοῦτον ἠστρολόγησαν.*

(4) Scylax 78, ed. Fabricius (1878), p. 27 :—

Καὶ νῆσος κατὰ ταῦτα κεῖται Τένεδος *καὶ λιμήν, ὅθεν* Κλεόστρατος *ὁ ἀστρόλογός ἐστί.*

(5) Athenaeus, vii. 278 A (ed. Kaibel, ii. [1887], p. 115) :—

ὁ δὲ ὀψοδαίδαλος Ἀρχέστρατος *ἐν τῇ* Γαστρολογίᾳ *(οὕτως γὰρ ἐπιγράφεσθαί φησι* Λυκόφρων *ἐν τοῖς περὶ* Κωμῳδίας, *ὡς τὴν* Κλεοστράτου *τοῦ* Τενεδίου Ἀστρολογίαν) *περὶ τῆς ἀμίας φησὶν οὕτως.*

Here Ἀστρολογίαν is a correction by Heringa for Γαστρολογίαν.

(6) *Chron. pasch.* ed. Dindorf in Migne's *Patrologia Graeca*, 92 (1865), col. 301 :—

τούτῳ τῷ ἔτει Θαλῆς *ὁ* Μιλήσιος *φιλόσοφος ἐν* Τενέδῳ *ἀπέθανεν.*

(7) 'Leo Grammaticus,' ed. Bekker, *Corpus Scriptorum Hist. Byz.* xxvi. (1842), p. 36:—

κατὰ τούτους τοὺς χρόνους Θαλῆς Μιλήσιος ἐν Τενέδῳ ἀπέθανε καὶ Σίβυλλα Ἐρυθραία ἐγνωρίζετο.

(8) Pliny, *Nat. Hist.* ii. 8 (6), 30.

Circulorum quoque caeli ratio in terrae mentione aptius dicetur, quando ad eam tota pertinet, signiferi modo inuentoribus non dilatis. obliquitatem eius intellexisse, hoc est rerum fores aperuisse, Anaximander Milesius traditur primus Olympiade quinquagesima octaua, signa deinde in eo Cleostratus, et prima arietis ac sagittarii, sphaeram ipsam ante multo Atlas.

(9) Euripides, *Rhesus*, 527–537 (ed. Murray, 1909).

τίνος ἁ φυλακά; τίς ἀμείβει
τὰν ἐμάν; πρῶτα
δύεται σημεῖα καὶ ἑπτάποροι
Πλειάδες αἰθέριαι· μέσα δ' αἰετὸς οὐρανοῦ ποτᾶται.
ἔγρεσθε, τί μέλλετε; κοιτᾶν
ἔγρεσθε πρὸς φυλακάν.
οὐ λεύσσετε μηνάδος αἴγλαν;
ἀὼς δὴ πέλας, ἀὼς
γίγνεται, καί τις προδρόμων
ὅδε γ' ἐστὶν ἀστήρ.

Scholium (Schwartz, *Scholia in Euripidem*, ii. [1891], p. 340). (I have for the most part rejected Schwartz's conjectural emendations.)

Κράτης ἀγνοεῖν φησι τὸν Εὐριπίδην τὴν περὶ τὰ μετέωρα θεωρίαν διὰ τὸ νέον ἔτι εἶναι ὅτε τὸν Ῥῆσον ἐδίδασκε. μὴ γὰρ δύνασθαι Πλειάδων καταδυομένων <*τοὺς*>[1] *τοῦ ἀετοῦ μεσουρανεῖν. ὑπὸ γῆν γάρ ἐστι τότε ὁ αἰγόκερως, ἐφ' οὗ ὁ ἀετὸς ἵδρυται, καὶ ἔτι Πλειάδων δυομένων ὑπὲρ μὲν γῆς εἰσὶ ζῴδια τάδε, ταῦρος δίδυμοι καρκίνος λέων παρθένος ζυγός· ὑπὸ γῆν δὲ τάδε, σκορπίος τοξότης αἰγόκερως ὑδροχόος ἰχθύς κριός. καὶ ταῦτα μὲν ὁ Κράτης. ἔοικε δὲ ὑπὸ τῆς φράσεως ἀμφιβόλου* <*οὔσης*> *κεκρατῆσθαι. τὰ γὰρ πρῶτα σημεῖα καὶ τὰς Πλειάδας ᾠήθη καταδύεσθαι λέγειν τὸν Εὐριπίδην. τὸ δὲ οὐχ οὕτως ἔχει, ἀλλὰ τὰ μὲν πρῶτα σημεῖα τῆς φυλακῆς φησι δύεσθαι, τὰς δὲ Πλειάδας ἀνατέλλειν. πῶς γὰρ ἐπὶ καταδυομένων εἶπεν αἰθερίας αὐτάς; ὥστε τριχόθεν τὸν καιρὸν ὑπὸ* <*τῶν*> *φυλάκων δηλοῦσθαι, ἀπὸ τῆς δύσεως, ἀνατολῆς καὶ μεσουρανήματος. ὁ μὲν οὖν Παρμενίσκος π ρ ῶ τ α σ η μ ε ῖ α 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 τρίτον ἦμαρ ἐπ' ὀγδώκοντα μένησι,
σκορπίου εἰς ἅλα πίπτει ἅμ' ἠοῖ φαινομένηφι . . .

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[1] So Breithaupt, *op. cit.* p. 31.

τοῦτο δὲ παραδείξας ὁ Παρμενίσκος ὅτι καταδύεται τὰ πρῶτα σημεῖα τοῦ σκορπίου, καὶ τὰ περὶ τῆς Πλειάδος ἐπιτολῆς ἐπέξεισιν· 'ὅταν γάρ,' φησίν, 'Εὐριπίδης λέγῃ καὶ ἑπτάποροι Πλειάδες αἰθέριαι, οὐ δύεσθαι τότε αὐτάς, ἀλλ' ἔμπαλιν ἀνατέλλειν ἐκ τοῦ ὑπὸ <γῆν> τμήματος εἰς τὸ ὑπὲρ <τὸν> ὁρίζοντα ἀνιούσας· καὶ τοῦτο εἶναι τὸ καὶ ἑπτάποροι Πλειάδες, οἷον· εἰς τὸν ὡς πρὸς ἡμᾶς οὐρανὸν ἀφικνούμενοι. ταῦτα δὲ κασταστησάμενος, ὁμολογεῖ,' φησί, 'τοῖς Εὐριπίδου τὰ φαινόμενα. τὰ μὲν πρῶτα σημεῖα τῆς ὥρας εἰς δύσιν κεχώρηκεν, ἡ δὲ Πλειὰς ἀνατέλλει, ὁ δὲ ἀετὸς πρὸς τὸ μέσον κεχώρηκε.'

Compare Theon Alexandrinus on Aratus, *Phaenomena*, 719, in Maass, *Commentariorum in Aratum Reliquiae*, p. 470 :—

Ὅτε λοφιή τε καὶ οὐρή· καὶ καθ' ὃν καιρὸν συμβέβηκε τοῦ Κήτους τήν τε λοφιὰν καὶ τὴν οὐρὰν ἐκ τῶν νοτίων μερῶν ἀνατέλλειν, τότε δὴ καὶ ὁ Ἀρκτοφύλαξ ἄρχεται μετὰ τοῦ πρώτου ζῳδίου, τουτέστι τοῦ Σκορπίου, δύνειν, ὅς ἐστι κατὰ διάμετρον τῷ Ταύρῳ.

(10) Hyginus, *Poeticon Astronomicon*, ii. 13, ed. Chatelain and Legendre, *Bibliothèque de l'École des hautes études*, 180 (1909), p. 27, fully cited by Breithaupt, *De Parmenisco Grammatico* (1915), p. 47 :—

Hos autem hedos Cleostratus Tenedius dicitur primus inter sidera ostendisse.

(11) Censorinus, *De die natali*, xviii. 4–6 :—

Hoc quoque tempus [*i.e.* quadriennium], quod ad solis modo cursum nec ad lunae congruere uidebatur, duplicatum est et octaeteris facta, quae tunc enneaeteris uocitata, quia primus eius annus nono quoque anno redibat. hunc circuitum uere annum magnum esse pleraque Graecia existimauit, quod ex annis uertentibus solidis constaret, ut proprie in anno magno fieri par est. nam dies sunt solidi . . . uno minus centum, annique uertentes solidi octo. hanc octaeteridam uulgo creditum est ab Eudoxo Cnidio institutam, sed hanc (alii *Jahn*) Cleostratum Tenedium primum ferunt conposuisse et postea alios aliter, qui mensibus uarie intercalandis suas octaeteridas protulerunt, ut fecit Harpalus, Nauteles, Menestratus, item alii, in quis Dositheus, cuius maxime octaeteris Eudoxi inscribitur. ob hoc in Graecia multae religiones hoc interuallo temporis summa caerimonia coluntur, Delphis quoque ludi qui uocantur Pythia post annum octauum olim conficiebantur.

All that we know of Cleostratus is deduced from these eleven passages. The first seven need not detain us long. We learn from them that he belonged to Tenedos, and it will be observed that according to the Paschal Chronicle and 'Leo Grammaticus' Thales died at Tenedos, from which Von Wilamowitz-Möllendorff (cited by Diels, *Fragmente der V.* i. p. 8) has inferred with great probability that there was a school tradition which regarded Cleostratus as the successor of Thales. As the traditional date for the death of Thales is 545 B.C., this would place the floruit of Cleostratus in the latter half of the sixth century B.C. This conclusion is confirmed by the passage cited from Pliny, which places Anaximander's discovery of the obliquity of the ecliptic in the 58th Olympiad, *i.e.* in 548–544 B.C., and Cleostratus's work on the signs of the zodiac at a later date, while further confirmation is obtained from the passage cited from Censorinus, according to which Cleostratus produced his octaeteris before Harpalus, who is described in the *Laterculi Alexandrini* (ed. Diels, *Abhandlungen der königlich. preussischen Akademie der Wissenschaften* [1904], pp. 8, 9) as the engineer of Xerxes' bridge over the Hellespont (481–0 B.C.).[2]

We also learn that Cleostratus wrote a poem called Ἀστρολογία, from which the hexameter verses cited by Parmeniscus are presumably derived. We do not know whether he left any other writings. It would appear that this work dealt with φαινόμενα, that is, with the successive risings and settings of different stars and groups of stars. This part at least of the work may well have been based on his own observations, for observations made in a different latitude would not hold for Tenedos. Moreover, there would appear to have been little written in Greece on this subject before Cleostratus, and the passage from Theophrastus shows that Cleostratus left a reputation as an observer. Like Hesiod he doubtless introduced solstices, if not equinoxes, into his series of phenomena, and his method of observation is at least a sign of the care with which he attempted to obtain accurate results. The determination of the exact date of a solstice remained a difficulty throughout the whole course of ancient astronomy. Even Ptolemy deduced from his own observation a date 38 hours later than the true date for the summer solstice. What Theophrastus probably means is that Cleostratus watched morning by morning the exact spot on Mount Ida where the winter sun rose, and tried to determine on which day the sunrise point lay furthest west. The importance of the mountain would then lie in the fact that it gave a clearly defined and rapidly varying horizon, which made it easier to compare the sunrise point of one day with the sunrise point of the next. The day on which the sun rose furthest to the west would of course be the day of the winter solstice. But, since for some days on either side of the solstice there is very little variation in the sunrise point, it would be impossible to determine the solstice with complete accuracy by this method. I owe this explanation to Redlich, *Der Astronom Meton und sein Zyklus* (1854), p. 34, cited by Ginzel, *Handbuch der mathematischen und technischen Chronologie*, ii. (1911), p. 375. It will be noted that all the observers named by Theophrastus

[2] Diels, *Fragmente der Vorsokratiker*, ii. 198, argues that several octaeterides must have passed before the necessary corrections could be discovered, and, therefore proposes to place Cleostratus about 520 B.C. The date is reasonable enough, but the argument implies that Cleostratus's octaeteris was used in practice and Harpalus's corrections were based on experience. There is no ground for either assumption. As will be seen later, the octaeteris remained an astronomical conceit, and there is every reason to believe that the succession of octaeterides and other cycles produced by the astronomers of the fifth century B.C. did not owe their origin to defects in earlier systems proved by experience, but were exercises in the art of combining days, months, and years, of which the relative mean durations had been learned from Babylon.

used mountains to the south-east or north-east available for the observation of sunrise at one or other solstice.

I come now to my eighth excerpt, the passage from Pliny, which has caused great trouble to the commentators. It will be observed that Pliny states that he will not postpone mention of the inventors or discoverers of the zodiac or 'signifer' though he will postpone the discussion of the circles of the stars. From this we may infer that Anaximander and Cleostratus mentioned in the next sentence are to be regarded as 'signiferi inuentores.' The meaning of the next sentence down to 'quinquagesima octaua' is clear enough. 'Anaximander of Miletus is said to have first recognised the obliquity of the zodiac, that is to have opened the door of the subject, in the 58th Olympiad.' In the next clause with 'Cleostratus' as subject we have to supply the verb and also the noun qualified by 'prima.' If we treat the sentence from a purely grammatical point of view without regard to the sense, we should naturally supply 'intellexisse traditur' from the previous clause as the verb, while 'prima' should either qualify 'signa' supplied from the first half of the clause, or should mean first things or first points without a noun understood. This clause would then mean 'Afterwards Cleostratus is said to have recognized the signs in it, *i.e.* in the zodiac, and the first points or first signs of Aries and Sagittarius.' The fact that no commentator has yet taken the passage in this literal way is, doubtless, due to their failure to find a sense for it. One translation that has found currency makes *signa* 'some of the signs' and then understands that Aries and Sagittarius were the first signs that Cleostratus introduced. Boll, *loc. cit.*, recognizes that the passage must mean that Cleostratus introduced all the signs, but fails to find a reasonable sense for the second half of the clause, and supposes that Pliny's authority had stated that Cleostratus had been the first to introduce Aries and Sagittarius into the zodiac. No commentator has grasped that 'prima signa' was a technical term, being the Latin translation of πρῶτα σημεῖα, which occurs in the passage from the *Rhesus* of Euripides and the scholium upon it, which make up my ninth excerpt. I take it then that what Pliny asserts is that Cleostratus is said to have recognized the signs in the zodiac and the πρῶτα σημεῖα of Aries and Sagittarius.

What, then, is the meaning of πρῶτα σημεῖα ?

An answer is supplied in the ninth excerpt by Parmeniscus. He says that Euripides gives this name to the first degrees of Scorpio because they are so named by the ἀρχαῖοι, and adds that Bootes sets simultaneously with these. He then proceeds to cite Cleostratus of Tenedos ἀρχαῖος, 'But when the third day beyond eighty remains,' or 'But when it or he remains the third day beyond eighty, something of Scorpio falls into the brine at the time of the appearing of dawn.' Doubtless the missing phrase on which the genitive Σκορπίου depends is πρῶτα σημεῖα or σημήϊα πρῶτα or words to that effect; otherwise there is no point in Parmeniscus's citation of these lines as illustrative of the meaning of πρῶτα σημεῖα. It would follow then that the phrase πρῶτα σημεῖα was used by Cleostratus with the genitive of the name of the sign, just as 'prima [signa]' is by Pliny and as *πρῶτα σημεῖα* is again by the scholiast in the sentence immediately following. It may be observed that the scholiast also uses the phrase *πρῶτα σημεῖα τῆς φυλακῆς* and seems to cite from Parmeniscus the phrase *πρῶτα σημεῖα τῆς ὥρας*. It is true that in both these instances critics have bracketed the mysterious genitives, but that hardly seems a fair way of getting rid of them. If there were other *πρῶτα σημεῖα* beside those of Scorpio the meaning would be clearer. The *πρῶτα σημεῖα* of Scorpio are the *πρῶτα σημεῖα* of this particular watch (*φυλακή*) or season of the year or night (*ὥρα*). And we see that Pliny knows *πρῶτα σημεῖα* of two different signs.

It is sad to see what terrible havoc has been made of this passage by the innocent little phrase *καὶ ὅτι ταύταις ὁ Βοώτης ἅμα ἄρχεται καταδύεσθαι.* Grammar and trigonometry conspire to render impossible that these words can represent any statement by Cleostratus. But Schwartz and Boll, Diels and Von Wilamowitz-Möllendorff, have decreed that they do. Ignoring trigonometry and having in textual emendation a sovereign spell before which all grammatical difficulties vanish, they have dragged this phrase or words to like effect either into the text or into the exposition of the lines from Cleostratus. Poor Cleostratus! we have only two lines from him. Could not the editors have let them alone?

Let us attend for a moment to the construction. Down to the second *λέγεσθαι* the sentence is clear enough. 'Parmeniscus says that the first degrees of Scorpio are called *πρῶτα σημεῖα* because they are so called by the *ἀρχαῖοι*, and that,' etc. Surely the phrase introduced by 'and that' (*καὶ ὅτι*) can depend on *φησι* and *φησι* only. 'Parmeniscus says . . . .' So the statement about Bootes is made by Parmeniscus on his own authority. It could not have been made by Cleostratus, for at Tenedos in the time of Cleostratus, Bootes did not begin to set with the first degrees of Scorpio; on the contrary it did not begin to set till Scorpio had wholly sunk below the horizon.

Why then did Parmeniscus drag in this otiose comment? It must be remembered that Parmeniscus was not merely a commentator on Euripides. He was also the author of a work on the sky, three fragments of which are preserved to us. (Numbers 18, 19, 20 in Breithaupt, *op. cit.*) He, doubtless, knew his Aratus and the controversies that raged round him. The author of a polemic against Crates was not likely to miss an opportunity of expressing his opinion on a debated question of astronomy. Hipparchus (ii. 2, ed. Manitius [1894], pp. 140–150) discusses at great length with what sign Bootes begins to set and in opposition to Aratus, Eudoxus, and Attalus holds that Scorpio is the sign in question. It is clear from the passage which he cites from Attalus that he was not the first to hold this opinion, and it is interesting to find his view endorsed by Parmeniscus.

When Parmeniscus explains that *πρῶτα σημεῖα* means the 'first degrees' of Scorpio, we must not take him too literally. Parmeniscus and his contemporaries were doubtless in the habit of specifying the degrees of the invisible ecliptic that rose and set with different stars. Hipparchus notices such degrees for every constellation and possessed instruments for observing them. But we may rest assured that Cleostratus did nothing of the kind, much less did Euripides or whoever wrote the *Rhesus* imagine that a Trojan guard measured the movements of the invisible ecliptic. The *πρῶτα σημεῖα* are, doubtless, not the first degrees of the sign of Scorpio on the ecliptic, but the first stars of Scorpio to set. The Greek *σημεῖον*, unlike the Latin 'signum,' is never a zodiacal or other constellation, but either a mathematical 'point,' such as the first degree of Scorpio and the solstitial and equinoctial points on the ecliptic, or else an 'indication,' such as the rising or setting of a star or group of stars which might indicate the time of year or the time of night. It is clear that the word is here used in the latter sense, except that it is not the abstract setting of the star but the concrete star setting that is called *σημεῖον*. And, thus interpreted, the setting of the *πρῶτα σημεῖα* tallies exactly with the meridian passage of Altair, the central and brightest star of Aquila, if we make the computation either for Athens or for Troy, and for the middle of the fifth century B.C.

I wish we could as easily save our author's credit in the matter of the Pleiades. I cannot with Crates believe him to have been so ignorant of astronomy as to have referred to the setting of the Pleiades. The Pleiades that are *αἰθέριαι* are the Pleiades that have risen from the stream of ocean and reached the upper air. But no Pleiades should have been in the sky when the Eagle was in midheaven. They should have been about 10° below the horizon at that time. Assuming that they could be seen when their central and brightest star Alcyone was at a true altitude of 2°, I find that Altair would have passed the meridian by an hour and three minutes if we compute for Troy, by an hour and six minutes if we compute for Athens. So far from being on the meridian, it would be in azimuth 27° or roughly south-south-west at Troy, or in azimuth 29°, roughly south-west by south, at Athens. The *πρῶτα σημεῖα* would have set long ago, but other stars in Scorpio would still be visible, for Scorpio should have taken an hour and twenty-six minutes to set at Troy, an hour and seventeen minutes at Athens. It is obvious that if the meridian and setting stars could not be defined more exactly than this, they would be of no use for timing the watch. So there was something in Crates' objection after all. The author of the *Rhesus* does show an imperfect acquaintance with astronomy. It is true that the Pleiades would disappear rather more than half an hour before Scorpio began to appear on the eastern horizon, and our author might infer that the Pleiades would rise an equal interval before Scorpio began to disappear in the west and thus be *αἰθέριαι* or up in heaven when that phenomenon occurred. But the problem is not so simple.

Breithaupt has expressed the opinion that *πρῶτα σημεῖα* means the first of the two signs of Scorpio, the first sign being what we call Libra, but what many of the Greeks regarded as the Scorpion's claws and named *χηλαί*. It is certain, however, that this is not what Parmeniscus understood by the first degrees of Scorpio, and, as we have seen, the signs of the zodiac are never called σημεῖα. Moreover, Scorpio at Tenedos in the time of Cleostratus would begin to set before Libra.

The reference to the *ἀρχαῖοι* is interesting. Of course an emendator—on this occasion Dindorf—has proposed to make Cleostratus *ἀστρολόγον* instead of *ἀρχαῖον*. I do not think it has ever been noticed that *οἱ ἀρχαῖοι* in Hipparchus and Geminus when not qualifying a noun regularly means the early astronomers, beginning with Thales and descending as far as the third century B.C.[3] Had this fact been realised, chronologists would not with one consent have mistaken the astronomical calendars described in the eighth chapter of Geminus for successive official calendars of Athens. The use of the same term by Parmeniscus suggests that it had acquired something of a technical meaning.

I confess that I am unable to identify either the phenomenon from which Cleostratus reckoned his 83 days or the *προδρόμων ἀστήρ* of the *Rhesus*.

We may now sum up the references to *πρῶτα σημεῖα* and see what they have in common. We have seen that both in the passage cited from Cleostratus and in the *Rhesus* the reference is to certain stars in Scorpio, presumably the first to set, and we may further notice that in both passages the setting is either at the appearance of dawn or when dawn is at hand. In other words the reference is to a morning setting, or to give it its technical name, a cosmical setting, and this raises the question whether the name *πρῶτα σημεῖα* was applied to these stars in relation to their cosmical setting only. I have no doubt that it was so. If we turn to Geminus's Calendar, we shall find Euctemon cited (Geminus, ed. Manitius 1898, p. 228) for *τοῦ Σκορπίου οἱ πρῶτοι ἀστέρες δύνουσιν*, where the reference is to the cosmical setting of the first stars in Scorpio. Euctemon we know was an *ἀρχαῖος* and a contemporary of Euripides. The adjective *πρῶτος* applied as here to particular stars is, so far as I know, unique in the Greek calendars. It is certainly unique in the calendars cited by Geminus. I take it then that Euctemon's setting of the *πρῶτοι ἀστέρες* of Scorpio is the same as the setting of the *πρῶτα σημεῖα*. With this we may compare further the passage that I have excerpted from Theon. Here the setting Scorpio is described as *τὸ πρῶτον ζῳδίον*, though in this case there is nothing to differentiate the cosmical setting from any other setting.

That the phrase *πρῶτα σημεῖα* could not be used of the first stars of any and every constellation is proved not only by the absence of evidence for its use in respect of the constellations generally, but also by the use of the phrase in the *Rhesus*, where no constellation is named but Scorpio is clearly intended; from which it may be inferred that Scorpio was either the only constellation of which it could ever be said *πρῶτα δύεται σημεῖα* or else the only constellation to which the phrase would apply near the particular time of the night.

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[3] Cleanthes is included among the ἀρχαῖοι in Geminus, xvi. 2. From the way in which the ἀρχαῖοι are habitually criticised by Hipparchus, it would appear that they were differentiated from the more modern astronomers by the inferiority of their mathematical methods.

Now in what sense are the first stars of Scorpio to set cosmically entitled to be called πρῶτα as distinct from other stars? To this there is a simple answer. If we arrange the different zodiacal constellations in the order in which they began their cosmical settings at Tenedos about 520 B.C. we shall find that Scorpio comes first after the vernal equinox. The vernal equinox was the starting-point of the Babylonian year and of the Babylonian zodiac. Cleostratus, as we shall see, derived his zodiac from Babylon, and therefore Scorpio took the first place among the cosmical settings.

If then we have πρῶτα σημεῖα of Scorpio in respect of cosmical settings, is there any other series that we might expect? The morning setting would naturally be matched by the morning rising, and the zodiacal constellation which first began to rise heliacally after the vernal equinox was Aries. And, sure enough, Aries is one of the constellations of which Pliny tells us that Cleostratus recognised the 'prima signa.' But I have sought in vain for any similar explanation of the 'prima signa' of Sagittarius. The presence of Sagittarius and the absence of Scorpio are equally striking in the Pliny passage. If Breithaupt is right in supposing (*op. cit.* p. 33) that Pliny drew his information from Varro, and Varro his from Parmeniscus, there is no room for the theory of a rival tradition here. The πρῶτα σημεῖα of Scorpio are abundantly attested, and not least by Parmeniscus's evidence; and I incline to the opinion that either Varro or Pliny has erroneously substituted Sagittarius for Scorpio. This seems easier than to suppose that Scorpio has been erroneously omitted and that Sagittarius was inserted for some valid reason which has hitherto escaped detection.

If Parmeniscus, as would appear, took the πρῶτα σημεῖα to mean the first degrees of the sign measured on the invisible ecliptic; if, like Hipparchus, he began his series of signs with the actual spring equinox, and if he observed at Alexandria, he would find that the setting of the πρῶτα σημεῖα of Scorpio followed the rising of the πρῶτα σημεῖα of Aries by an hour and thirty-one minutes. On the same assumption there might be about a month between the heliacal rising of the one and the cosmical setting of the other. If these assumptions are not all correct, we must amend these figures, but there can be little doubt that to him there was a perceptible interval between the two phenomena, which would account for the phrases τὰ πρῶτα σημεῖα τῆς φυλακῆς and τὰ πρῶτα σημεῖα τῆς ὥρας.

Pliny's statement, then, as interpreted and corrected in the light of the passages cited, means that Cleostratus introduced the signs of the zodiac and the πρῶτα σημεῖα of Aries and Scorpio. The statement about the signs of the zodiac is perfectly consistent with what we know from other sources. Homer and Hesiod give us no zodiacal stars except the Hyades and Pleiades and give us no zodiacal constellation at all. The same applies to the fragments of Musaeus, Thales, Phocus, and Anaximander, and with one possible exception to the fragments of the ἀστρονομία which passed under the name of Hesiod. The one exception is the reference to the Scorpion in fragment 182 (ed. Rzach, [1913], p. 202). It is true that Franz, *Leipziger*

Studien zur classischen Philologie, xii. (1890), p. 357, followed by Von Wilamowitz-Möllendorff, *Nachrichten von der königl. Gesellschaft der Wissenschaften zu Göttingen, Hist. phil. Klasse* (1895), p. 232, has held that this fragment may come from some other part of Hesiodic literature, while Rehm (*Mythographische Untersuchungen über griechische Sternsagen* [1896], p. 47) has on this ground alone placed the Ἀστρονομία later than Cleostratus. There is also a school, represented powerfully by Maass (Kiessling's *Philologische Untersuchungen*, xii. pp. 268–272), who place the poem later than Aratus. But it must be confessed that the view that at present holds the field is that the fragment in question belongs to the *ἀστρονομία* and that the *ἀστρονομία* is older than Cleostratus. The writer who has done most to establish the early date for the Hesiodic *ἀστρονομία* is Nilsson in *Rheinisches Museum*, lx. (1905), p. 180 ff. After citing two passages (Hesiod, fragments 263 and 38), where Aratus may conceivably be held to be imitating Hesiod, though there is nothing to show that the fragments of Hesiod come from the *ἀστρονομία*, he applies an argument which has carried weight with Diels (*Fragmente der Vorsokratiker*, ii. p. 195) and Rzach (article 'Hesiodos' in Pauly-Wissowa, viii. [1913], 1223), based on Pliny, *N.H.* xviii. 25 (57), 213. Pliny there cites as an example of the discrepancies of different writers on the dates of annual astronomical phenomena: 'occasum matutinum uergiliarum Hesiodus—nam huius quoque nomine exstat astrologia—tradidit fieri, cum aequinoctium autumni conficeretur, Thales XXV. die ab aequinoctio, Anaximander XXXI. (?), Euctemon XLVIII.' I may here put in a word of caution. It is improbable that all our authorities stated the actual interval between the equinox and the cosmical setting of the Pleiades. It is more likely that a compiler has in some cases calculated the interval from other correlations which his authority had asserted of one or both phenomena. Anyhow, Nilsson argues that of these discrepant statements that attributed to Hesiod is the most erroneous, from which he infers that it is the most ancient, holding that it is inconceivable that a late writer with trustworthy books before him would deliberately insert an erroneous astronomical statement in order to give his book an air of antiquity. Exactly the same argument had been used by Franz, *op. cit.*, p. 356, and I do not know why Nilsson should get special credit for it. It is to be feared, however, that if astronomical errors are to be made a criterion of antiquity, much literature that passes as modern will have to be relegated to a remote age; and anyone who cares to check the dates of celestial phenomena given in the calendars collected in Wachsmuth's edition of Lydus, *De Ostentis*, will find numerous instances of errors as great as that attributed to Hesiod. On the whole I consider that the antiquity of the Hesiodic *ἀστρονομία* is not proved. If a work dealing with the legends of the constellations belonged to the sixth century B.C., it neither set nor followed a fashion, whereas, if it belonged to the Alexandrine age it was well in the fashion. But, when we find Franz doubting whether the work did deal with the legends of the constellations, we can only reply that if his view is right we have practically no evidence left by which to date the book, nor does the date matter to us, for it is only in a legend of the constellations that Scorpio is named.

If, however, the mention of Scorpio is not older than Cleostratus, a mention of Capricorn follows close on his heels. See Epimenides, fragment 24 in Diels, *Fragmente der Vorsokratiker*, ii. 193.

It would appear then that with the doubtful, to my mind very doubtful, exception of Scorpio, there is no trace of the mention of a zodiacal constellation in Greek literature before Cleostratus, though a knowledge of the zodiac spread rapidly after his time. The next question is whence he derived his knowledge of the zodiac, and the answer lies ready to hand—from Babylon. An excellent account of the Babylonian zodiac by Jeremias is to be found in the article 'Sterne' in Roscher, 68 Lieferung (1914), 1446–1470. From this it is clear that the twelve signs of the zodiac were already planned out and in common use long before the time of Cleostratus.[4] We are now learning that the Ionian school of philosophy did not consist of pioneers of original investigation or speculation. On the contrary they in large measure assimilated the products of Babylonian science. Dr. Langdon in his paper, 'The Babylonian Conception of the Logos,' *Journal of the Royal Asiatic Society* (1918), pp. 433–449, has shown very conclusively that the natural philosophy of Thales was of Babylonian origin and has given reasons, on which I do not venture to offer an opinion, for thinking that Babylonian influences were at work on Heraclitus. It has long been recognized that Thales could have learned the art of predicting eclipses from none but Babylonian sources, and there can be no reasonable doubt that all through the sixth century B.C. the thought of Babylonia along with its material civilization was streaming into Greece through Ionia. I do not know of any Babylonian influence on Greek thought before the reign of Nebuchadrezzar, and the influence would appear to have been seriously impaired by the outbreak of the Persian war, after which Greece, and more particularly European Greece, entered on the most original and most brilliant period of its history. The conquests of Alexander reopened the way to Babylonian influences, but the Greece that received them was far superior to Babylon in its philosophic and mathematical conceptions. It could still learn scientific facts, or astrological fancies from Babylon; it had nothing to learn in the way of abstract conceptions. Of sixth century Greece with its mind open to the barbarian later Greece was ashamed. Barely an admission is to be found in Greek sources of anything in science or philosophy learned from the Chaldaeans,[5] the enemies in the golden age. What Thales learned abroad he was said to have learned from the Egyptians. Even Herodotus, who, as became an Asiatic Greek, still cherished in the fifth century B.C. an admiration for the civilization of the East, is accused by Plutarch of being *φιλοβάρβαρος* (*De Herodoti Malignitate*, 857 A, ed. Bernardakis, v.

[4] I am assured by Dr. Langdon that the evidence in the case of Cancer is unsatisfactory.

[5] Herodotus acknowledges the sun-dial, the gnomon, and the twelve hours of the day.

[1893], p. 214). And even to-day the history of the Ionian school is worked up for us by some of our leading scholars, with barely a hint that either its philosophy or its astronomy was of eastern origin. Democritus is an exception. It was admitted that he travelled in Babylon and other eastern countries and learned much of Babylonian lore. I shall have more to say of this Babylonian influence when I come to deal with the lunar cycle.

I need hardly mention that the statement that Cleostratus was the first to name the Kids is consistent with the absence of their name from earlier writers. If he was the first to write a systematic poem on the constellations, there must have been many names which the later Greeks found in him and in no earlier writer.

I take it then that Cleostratus imported the signs of the zodiac and perhaps some other constellations from Babylon. He probably combined these with names of stars and groups of stars already used in Greece, and found from his own observations the order of their risings and settings and how these stood in relation to the solstices—no small work if it had stood alone.

But there is also attributed to him the invention of the octaeteris, or the eight years' cycle of intercalations; at least Censorinus gives it as one of two accounts. The alternative view that regarded Eudoxus as the author of the first octaeteris is manifestly mistaken, and Censorinus was clearly right in preferring the view that he merely produced or obtained the credit for a perfected octaeteris.

The view that Cleostratus was the author of the first octaeteris is nowhere challenged in antiquity, but it is almost universally rejected by modern scholars. In some measure Censorinus is responsible for this result, for he holds that many eight-yearly religious rites in Greece, and notably the Pythian games, owe their period to the octaeteris. Now, of course, these eight-yearly festivals go back beyond Cleostratus. If, therefore, Censorinus was right in explaining the eight-yearly festivals by the octaeteris, he was wrong in attributing the first octaeteris to Cleostratus. But Censorinus's explanation of the eight-yearly festivals is seriously compromised by his explanation of the four-yearly festivals. These he regards as older than the eight-yearly, and he explains them by the four years' cycle, which equates an exact number of solar years with an exact number of days, our own leap-year period in fact. Now, it is impossible to believe that such a cycle was known or could have had any calendarial significance if it had been known in early Greece. We are driven, therefore, to the conclusion that Censorinus's connexion of the festival periods with periods of intercalation is not a valid historical tradition but the fancy of a later age. And in fact it is easier to explain the festival periods as mere powers of two. We have two-year festivals, and four-year festivals, and eight-year festivals.

But our scholars will not have it so. Greek legends have been ransacked for intervals of eight years or nine—for, of course, nine may mean eight reckoned inclusively, though in some passages cited it clearly means nothing of the sort. I shall not deal with these here. Those who care for such things will find them in plenty in the works of Otfried Müller, of Böckh, Sir James Frazer, and Mr. Cornford. Some discussion of them will be found in a posthumous work of the late Mr. W. H. Forbes on the Attic calendar and chronology of Thucydides, in which I was privileged to give him a little assistance, and which I am now editing. But I may venture on a reference to W. H. Roscher's two papers, 'Die Ennead. und Hebdomad. Fristen und Wochen,' *Abhandlungen der kön. sächs. Gesellschaft der Wissenschaften*, Band 48, *Philolog. Hist. Classe*, xxi. (1903), and 'Sieben- u. Neunzahl im Kultus u. Mythus d. Griechen,' *ibid.* Band 53, *Philolog. Hist. Classe*, xxiv. (1904), where it is shown what an important part all the early odd numbers 3, 5, 7, and 9 play in Greek legend and religion.

The attempt to find an octaeteris in the Olympic festival might seem more plausible to the unwary. We have a statement in Porphyry on *Iliad*, x. 252, ed. Schrader, p. 148, that the Olympic games were celebrated at intervals of 50 and 49 years *ἐναλλάξ*. These alternate periods are supposed by the moderns to make up the 99 months of the octaeteris. Now Porphyry's object is not to explain nicely the rules for fixing the time of the Olympic games but to illustrate the use of round numbers by the poets—in this case 50, while the unpoetic numeral 49 is ignored. It would be sufficient for his purpose if these two intervals normally alternated, as in fact they would in any well-regulated luni-solar calendar. I have thought it worth while to examine the Olympic years of the nineteenth century. Assuming that in modern, as in ancient, times the Olympic year is that following the Julian leap-year, and examining the date of Easter full moon in Olympic years, I find that from 1833 to 1909, the Easters of Olympic years fell alternately at intervals of 49 and 50 lunar months, yet it is known to everybody that our Easter full moons are regulated not by an 8 years' cycle, but by one of 19 years.

A scholiast on Pindar, *Ol.* iii. 35, says that the race was held sometimes after an interval of forty-nine months, sometimes after one of fifty, *ὅθεν καὶ ποτὲ μὲν τῷ Ἀπολλωνίῳ μηνί, ποτὲ δὲ τῷ Παρθενίῳ ἐπιτελεῖται.* Now *ὅθεν* is of course absurd. Even if the games had been always in the same calendar month, we should have expected this variation between forty-nine and fifty month periods, but the statement that the games were sometimes in Apollonius, sometimes in Parthenius, has been supposed to lend colour to the theory that they were governed by an octaeteris.

Another scholiast in two very corrupt scholia gives us the clue to this variation of calendar date, though I do not find that the explanation has ever been grasped. The passages are best studied in Drachmann's edition of the Pindar scholia, i. (1903), p. 114, and in Weniger's article in *Klio*, v. (1905), pp. 1 ff. I reproduce the passages, but do not vouch for the text:—

ἤ δ η γ ὰ ρ α ὐ τ ῷ· περὶ τοῦ χρόνου καθ' ὃν ἄγεται τὰ Ὀλύμπια καθ' ἑκάστην Ὀλυμπιάδα, καὶ Κώ<μαρχος> ὁ τὰ περὶ κλείων [*potius* Ἠλείων] *συγκατάξας φησὶν οὕτως· πρῶτον μὲν οὖν παντὸς περίοδον συνέθηκεν ἐν τῇ ἡμέρᾳ ἄρχειν νουμηνίαν μηνὸς ὃς Θωσυθιὰς ἐν Ἤλιδι ὀνομάζεται, περὶ ὃν τροπαὶ ἡλίου γίνονται χειμεριναί. καὶ π̄ᾱ Ὀλύμπια ἄγεται η' μηνί ἑνὸς δὲ* *ὄντος διαφέροντων τῇ ὥρᾳ, τὰ μὲν ἀρχομέν*[6] *τῆς ὀπώρας, τὰ δὲ ὑπ' αὐτὸν τὸν Ἀρκτοῦρον. ὅτι δὲ καὶ ἄγεται ὁ ἀγών, καὶ αὐτὸς ὁ Πίνδαρος μαρτυρεῖ.*

διχόμηνις· διχόμηνις περὶ τὴν ις' πανσελήνου οὔσης ἄγεται τὰ Ὀλύμπια, τουτέστι οὐμηνίᾳ [*διχομηνία*?] *Παρθενίου ἢ Ἀπολλωνίου μηνός, παρ' Αἰγυπτίοις Θὼθ ἢ Μεσωρίων.*

From the earlier of these passages I infer that the Elean month Thosythias fell about the time of the winter solstice, and that the Olympic festival was celebrated in the eighth month after Thosythias. Which month this would be would depend on whether an intercalary month had been inserted since Thosythias. This explanation assumes that the proper place for an Elean intercalary month was somewhere in the seven months following Thosythias, and it suggests that a vague coincidence of Thosythias with the winter solstice may have played the same part in the popular conception of the Elean calendar that the vague coincidence of Hecatombaeon with the summer solstice did in the popular conception of the Attic calendar. The reason for keeping the Olympic festival at a fixed interval from Thosythias irrespective of intercalations was, very possibly, that some of the feasts falling before the intercalation were of the nature of a preparation for the great festival, which had to follow them at a fixed interval. Moreover, if the Eleans intercalated at short notice, they may have thought it undesirable that the intercalation should affect the date of a pan-Hellenic festival like the Olympic games. It would appear then that the fact that the games were sometimes in Apollonius, sometimes in Parthenius, had nothing to do with the octaeteris. It merely meant that there was sometimes an intercalation between Thosythias and the games and sometimes not. And of course there is nothing to prove that the rule given by the scholiast is ancient. Comarchus, if it is Comarchus, may have lived in the fifth, fourth, or third century B.C. We can only date him from the fact that a scholium on Plato, *Phaedo* 89, names him along with Pherecydes of the fifth century and Istrus of the fourth century, B.C.

I have already alluded to the eighth chapter of Geminus which describes the gradual growth and increasing perfection of lunar cycles, aiming at comprising an exact number of natural days, months, and years. I am convinced that this chapter has nothing to do with the calendars actually used in Greek cities, but only with the cycles propounded by astronomers, which may have influenced the cities, but would appear never to have been adopted by them. The early cycles are the work of *οἱ ἀρχαῖοι*, which, according to Geminus's usage, should mean the early astronomers. If anyone doubts, let him look at the attempts made to explain the Attic intercalations of the fifth and fourth centuries B.C. by either the eight years or the nineteen years cycle.[7] Every investigator has to find reasons why his scheme of intercala-

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[6] According to Drachmann this is the MS. reading, which he takes to represent ἀρχομένης. Weniger on the authority of Tycho Mommsen gives ἀρχόμενα.

[7] This subject will be more fully treated in Mr. Forbes's book on the Attic Calendar and Chronology of Thucydides.

tion does not fit the hard facts of the historical evidence. The simplest explanation is that the Athenians recognised no law of intercalation. The practical man treated the man of science with a contempt only one degree less profound than the contempt with which the man of science treated the rest of mankind.

What writers on the Greek calendar have never grasped, is that in the ancient world cycles of intercalation were all but unknown to civil calendars whether Greek or barbarian. Wherever we have evidence, it would appear that the number of months in the year was determined annually not by rule of thumb, but by some living authority, just as the number of weeks in each vacation is determined annually in the University of Oxford by Hebdomadal Council.

If the Greek cities had desired, like modern Christians or modern Jews, to maintain a common calendar, they would doubtless have found it most convenient to regulate their intercalation by calendar rule, but, while each city regulated its own calendar, it was found most convenient to determine the question of intercalation year by year, just as Hebdomadal Council annually arranges the academic year.

Let him who has further doubts on this subject turn to Father Kugler's *Sternkunde und Sterndienst in Babel*, Ergänzungen zum ersten und zweiten Buch (1913), p. 131, where the author shows that down to the year 528 B.C. intercalation at Babylon was irregular. The figure 528 appears to require revision, for the list of Babylonian intercalary years given in Ginzel, *Handbuch der mathematischen und technischen Chronologie*, i. (1906), p. 133, supplemented by ii. (1911), p. 499, is consistent with the use of an octaeteris from 533 to 503 B.C. For the earlier part of the sixth century B.C. we can by means of numerous contract-tablets, identify most of the intercalary years, and there can be no doubt that the intercalation was irregular. On the slowness with which cycles of intercalation came into use in antiquity, see Ginzel, *op. cit.* iii. (1914), pp. 366, 367. Intercalations were then unsystematic in Athens of the fifth and fourth centuries B.C. and in Babylon before 533 and after 503 B.C. The Jewish intercalation was still irregular, and was determined annually at the time represented by the Talmud. According to that work, regard might be had to the state of the roads, the bridges, and the passover-ovens, to the possibilities of pilgrims who had already started arriving in time for the passover, to the growth of the goats, lambs, and pigeons, of the corn and of the fruit, and to the number of days that had to elapse before the equinox. Intercalation according to some rabbis was to be avoided in a year of famine and in a sabbatical year, and a court might be influenced by the fact that the next year would be or the last had been a sabbatical year. In fact, almost anything might affect the decision except the place of the year in a cycle. (*Babl. Talmud, Synhedrin*, 10^b–13^b, ed. Lazarus Goldschmidt, vii. [1902], pp. 32–43.)

One may go further and say that from any cycle of intercalations it is possible to deduce mean lengths of the calendar month and calendar year, which in any calendar are intended to agree with the mean lengths of the true month and year. Whenever, therefore, a cycle of intercalations existed, there should be some exact value assigned to these periods. Hesiod, of course, suggests no such knowledge. He gives a few intervals between annual astronomical phenomena, so that you may know how the year is progressing, but he expects his husbandman to know the seasons, not by numbering the days, but by observing the sky. The Greek doxographers know of no astronomer before Thales. We have preserved to us the names of many literary men of older date, but of no astronomer, and the inference is that Greece had no astronomer before Thales, and no exact knowledge of the lengths of months and years.

This is important, because all our evidence goes to show that the very idea of a cycle is a product of exact astronomy, and we have no knowledge of the use of a lunar cycle anywhere in the world before the time of Thales. Probably the oldest lunar cycle is that of 223 lunar months or 6,585⅓ days, about 18 years and 11 days, which Suidas calls the *σάρος*, and Ptolemy (iv. 2, ed. Heiberg, i. [1898], p. 270) the *περιοδικὸς χρόνος*, or the same period multiplied by 3, *i.e.* 669 lunar months or 19,756 days, about 54 years and 33 days, which Geminus (chapter xviii.) and Ptolemy call the *ἐξελιγμός*. Ptolemy regards these as the discovery of *οἱ ἔτι παλαιότεροι* as distinguished from *οἱ παλαιοὶ μαθηματικοί*. He describes Hipparchus as having detected a small error in these periods, but does not suggest how far beyond the time of Hipparchus the knowledge of them went. These cycles were not used for intercalation, though it would appear from one Babylonian tablet of perhaps the fifth century B.C. that it was known at that time that the sun, moon, and fixed stars returned approximately to the same relative positions in 27 years. See Kugler, *ubi supra*. The cycles of 18 and 54 years were cycles of eclipses. Now, while no exact knowledge of astronomy and therefore no astronomical cycle was needed to determine when an intercalation was due, nobody could predict an eclipse without some exact astronomical science. In *Sternkunde und Sterndienst in Babel*, ii. (1909), pp. 58–77, Kugler argues forcibly that the Assyrian predictions of eclipses in the seventh century B.C. were not made by cycle, but were anticipations deduced from observations made a few days before the expected time of conjunction or opposition. But a prediction at a longer interval involves the use of a cycle, and, as Herodotus (i. 74) informs us that Thales predicted a change of day into night (*i.e.* a total eclipse of the sun) for a particular *ἐνιαυτός*, which I suppose means 'year,' he must have used a cycle. He doubtless learned the cycle from the Babylonians—though, as it happens, we have not yet run across an example of its use in Babylon before his time.

The first requisite for an exact determination of an astronomical period is a continuous measure of time. If you have no fixed rule to determine whether a particular month is to contain twenty-nine or thirty days, or a particular year twelve or thirteen months, it is of no use to know the year, month, day, and hour of an old observation, unless someone has been at the trouble to compile a list showing the length that has actually been assigned to each month and each year from the time of the old observation to the time of the new observation with which you wish to compare it. And, it the old observer has like most Babylonian observers down to the seventh century B.C. recorded only the month and day of the month with the vaguest indication of the time of day, leaving his successors ignorant of the year and the hour, even a canon of years, months and days, will be of little use. There was of course no such canon in Greece until the the self-regulating calendar of Meton was invented for the purpose of providing a continuous record of time, and it is interesting to observe that Ptolemy, who generally derives his observations from Hipparchus, cites no Greek observations before the time of Meton. Of what use would they have been without such a canon to correlate them with later observations? On the other hand Ptolemy cites an abundance of Babylonian observations going back nearly to the reign of Nabonassar, in which dates are expressed in Egyptian vague years, reckoned from Nabonassar's first year (747 B.C.). There is only one possible explanation of this fact, but it would appear that so far the explanation has been missed. Someone must have compiled a canon showing the number of days that had been included in each Babylonian month and the months included in each Babylonian year from the first year of Nabonassar onwards. Probably it was a great canon, containing not only the lengths of each month, but a dated list of observations made during it. The measure of accuracy in the eighth century observations cited by Ptolemy is, as Kugler remarks, about equal to that of the better defined observations preserved on cuneiform tablets of that age. Their chief value for subsequent astronomers lay in the fact that unlike most of the Babylonian observations of that age they were carefully dated. Now if such a canon of observations was brought down to a date when it could be compared with the Egyptian vague year, it was a simple matter to convert all the dates into the Egyptian calendar, and Hipparchus naturally preferred to express the dates in the Egyptian calendar, in which all months were thirty days long and all years 365 days long, a calendar in which calculation was easy and to which in all probability his own tables were accommodated. It will be observed that the significance of the era of Nabonassar lies simply in the fact that this canon began with the first year of his reign.

With such a canon before them it was no impossible task for the Babylonian astronomers first to map out the intervals between different eclipses and next to discover that they recurred in cycles such as have been mentioned above. The eclipse of Thales (585 B.C.) was 162 years later than the accession of Nabonassar, so that by his time the Babylonian astronomers had a long series of eclipse observations at known intervals. An eclipse, unlike a new moon, could be dated to an hour by direct observation, and it is reasonable to suppose that the indications of time were steadily made more exact as the idea of seeking or testing a cycle took shape.

A difficulty has been made in the interpretation of the prediction attributed to Thales on the ground that the 'saros' gives from two to five solar eclipses for each year and provides no means of determining which of these will be total or even visible at a particular place, while, when the 'saros' does give the date of an eclipse, it gives not only the year, but the month, day, and hour.[8] From this it would follow that a prediction of a solar eclipse for a particular year by means of the 'saros' is rather an absurdity, and it has been suggested by Tannery (*Pour l'histoire de la science hellène*, p. 60) that Thales picked up a number of predictions on his travels from an astrologer, and, after verifying some of them, ventured to assert one of the predictions on his own responsibility, and by a stroke of luck this prediction was fulfilled in the shape of a total eclipse of the sun visible in Asia Minor. Now it is true that a modern astronomer uses eclipse cycles merely for the purpose of discovering the dates of eclipses and, in the case of solar eclipses, of getting some vague indication of their magnitude on the earth generally. He discovers by more elaborate means whether a solar eclipse was visible at a particular place, and, if so, what its magnitude was.

But this does not mean that the 'saros' or ἐξελιγμός cannot be used to make predictions for a particular place. The opposite is the case. Each ἐξελιγμός brings an eclipse back to much the same hour of the day and to much the same track. A study of all the solar eclipses visible at Babylon from 700 B.C. to 556 B.C. shows that where the sun was above the horizon at the recurrence of the eclipse, the local magnitude was generally much the same as it had been fifty-four years previously. A total eclipse recurs as a total eclipse, but the belt of totality generally shifts steadily northwards or southwards. If the magnitudes of the ten largest eclipses visible at Babylon at their greatest phase between 700 and 610 B.C. inclusive are taken from Ginzel's *Spezieller Kanon der Finsternisse* (1899), it will be found that seven of the ten recurred after fifty-four years with the sun above the horizon. Measuring an eclipse by the proportion of the sun's diameter obscured, and reckoning the diameter according to astronomical usage in twelfth parts or digits, we shall find that four of these seven recurred at Babylon with a magnitude changed by less than one digit, and that two of the three others recurred with magnitudes changed by less than two digits. In the seventh instance the magnitude was changed by 4·8 digits, but in no case was the eclipse invisible at Babylon when the sun was above the horizon at the time of the recurrence of the eclipse. And, as the cycle tells us whether the sun will be above the horizon or not, it is really a very safe guide for the prediction of solar eclipses. It is true that the eclipse of 585 B.C. must have been foretold by means of that of 603 B.C. not that of 639 B.C., that is by the 'saros,' not by the ἐξελιγμός, but the fact that the time of the eclipse varies by eight hours from one 'saros' to the next, has the result that the sun is usually below the horizon at a recurrence after a 'saros' period, so that predictions by the 'saros' cycle would not be available so often as predictions by the ἐξελιγμός.

[8] Martin in *Revue Archéologique*, nouv. série, ix. (1864), pp. 170–199, makes much of these difficulties. Newcomb, *Researches on the Motion of the Moon*, Part I. (1878), pp. 28–30, rejected the prediction for the reason given in the text, but in Part II. of the same work (1912), p. 231, he stated 'There can be little doubt that Thales predicted this eclipse.'

Solar eclipses visible at a particular place do not occur every year. Once in four years is nearer the average. There is, therefore, nothing absurd in Thales having predicted a solar eclipse for a particular year by means of the 'saros.' He would appear from Herodotus's statement to have also predicted its totality. That of course he should have been able to do, so long as he did not venture to say where it was to be total. If, as the passage would seem to imply, he predicted the year, but not the month or day, the reason may have been that he did not know the precise date of the eclipse of 603 B.C., or that, if he knew it, he did not know how many intercalary months had been inserted since that date. He probably had not access to the Babylonian canon of years, months, and days.

If we acknowledge, then, that Thales was already in possession of a cycle of eclipses, the step to a cycle of intercalations is quite easy. A cycle of intercalations, as the Greeks understood it, has to satisfy three requirements; it must contain at once an exact number of days, of lunar months, and of solar years. The cycle of eclipses provided at once the number of days in a lunar month. The 'saros' contained 223 lunar months, amounting to $6585\frac{1}{3}$ days. This gives $29\frac{355}{669}$ days for each month, a number of days which exceeds the traditional lunation of $29\frac{1}{2}$ days by $\frac{1}{33}$ day almost exactly. This suggests a period containing some multiple of thirty-three months in order to obtain at once a whole number of days and a whole number of months. A period of ninety-nine months fulfils this requirement and is also very slightly in excess of eight solar years. Eight solar years were, according to the best science of the sixth century, B.C., 2,922 days long, while ninety-nine months of the length just determined amounted to $2{,}923\frac{1}{2}$ days. So an approximate cycle of eight years might be made to include 2,922 days or an approximate cycle of sixteen years to include 5,847 days. Here we have what Geminus regards as the first and second forms of the octaeteris. But, as has been seen, intercalation in Babylon had always been independent of cycles, and the octaeteris was certainly the result not of any civil necessity, but of a scientific appetite for a systematic rule. It does not appear that the Babylonians ever regarded it as part of their calendar system. We have seen that it was actually used from 533 to 503 B.C., and then set aside, but that may have been due to the influence of some influential astronomer, who favoured this cycle, and who ceased to advise or at all events to get his advice carried into effect after 503 B.C.

But those thirty years were just the age of Cleostratus. Then and then only could the octaeteris have been imported from Babylon to Greece, and, as in the case of the zodiac, it was Cleostratus who transplanted the idea into Greek science. His solstice observations may have had some relation to this cycle for harmonizing the periods of sun and moon, though they would be equally useful for the purpose of arranging in their proper order the annual phenomena which probably constituted the greater part of his poem.

It is curious that he should have left so slight a name and yet have exercised so great an influence. The name of Thales looms large through the tradition of Greek philosophy both among ancient and among modern writers.

His famous prediction seemed a marvellous feat of skill, but he did not transmit his science to succeeding generations, and the art of predicting eclipses had to be learned again from Babylon in the Macedonian period.

Cleostratus, like many of Earth's wisest, seems to have held no opinions and left no material for the doxographers. His poem, like many another astronomical poem, was rendered antiquated by Aratus. The signs of the zodiac survived, but others used the names and figures with greater skill. He started a fashion for making and perfecting luni-solar cycles, which provided plentiful exercise for the ingenuity of astronomers from his age down to Hipparchus, but the glory went not to him but to the authors of the cycles that were more widely current in a later age, Meton and Eudoxus. Had he not found a 'vates sacer' in Parmeniscus, we might have known nothing of his two great importations of Babylonian science, for which we have to thank him the more because they were made in that last generation before Greece lost the power and the will to absorb the learning of the East. Breithaupt (*op. cit.* p. 33) at least contends with great plausibility that the references to Cleostratus in Hyginus, Pliny, and Censorinus are all derived ultimately from Parmeniscus, as the reference in the Euripides scholium professedly is. On so small a thread has hung the fame, meagre at best, of one whose work has lived when its author has been forgotten.

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