On Greek Stellar and Zodiacal Date-Reckoning

Alexander Jones

As is well known, the calendars employed in Greek communities for civil and cult purposes before the Roman period were lunisolar, and subject to much variation from place to place in the naming of months and days and in the season in which the year's beginning was approximately fixed. The evidence for how these calendars were administered is extremely uneven in both quantity and quality.[1] Even in the case of the Athenian calendar, for which we have by far the most extensive documentation, consensus still cannot be reached on whether—and if so, when—a fixed cycle of intercalations was adopted, nor can attested dates be synchronized with our Julian chronography with anything approaching the precision (generally plus or minus one day at most) possible for contemporary Babylonian and Egyptian dates.[2] Lunisolar intercalation cycles are associated in ancient Greco-Roman texts with various astronomers, including Meton (late 5th century BC, 19 years = 235 months), Eudoxus (early 4th century BC, 8 years = 99 months), Callippus (late 4th century BC, 76 years = 940 months = 27759 days), and Hipparchus (late 2nd century BC, 304 years = 3760 months = 111035 days).

Of these cycles, the Callippic 76-year cycle is the only one around which we can confidently say that a full-blown and widely used calendar was constructed, possibly by Callippus himself.[3] This Callippic calendar employed the month names and midsummer epoch of the Athenian calendar, but the years are designated simply by year number within a serially numbered 76-year period (e.g. "according to Callippus period 3, year 14") without reference to the conventions for naming years in any specific locality, such as names of magistrates or regnal years. All the attestations of Callippic dates, which range from the early 3rd century BC to the middle of the 1st century AD, are in the context of astronomical observation reports or predicted astronomical data, so that it is legitimate to speak of the Callippic calendar not merely as an astronomical calendar but as an *astronomers'* calendar, which nevertheless retained and regularized the key features of the Greek local calendars on which laymen (i.e. nonastronomers) depended.

The Egyptian calendar, in its pre-Roman unintercalated form, can also be regarded as an astronomers' calendar when it appears in astronomical and astrological texts and tables, though in this instance we are not dealing with a calendar structure expressly devised for astronomical purposes on the model of lay calendars, but rather an actual civil calendar that astronomers, apparently as early as Timocharis in the 3rd century BC., found convenient, and that thus survived in this specialized context long after laymen had abandoned it. In one important respect, however, the astronomers' version of the Egyptian calendar was not simply taken over from common usage. Hipparchus, who unlike his predecessor Timocharis and his successor Ptolemy did not work in Egypt, numbered specific Egyptian calendar years not by Ptolemaic reigns but by an era count from the death of Alexander, while Ptolemy (perhaps following a Hipparchian precedent) adapted a Babylonian king list for the designation of Egyptian years for the interval from the mid 8th century BC to the death of Alexander. These are conventions that would have had no application outside astronomy.

One last astronomers' calendar is known from a set of observation reports in Ptolemy's *Almagest*. This calendar "according to Dionysius" had, so far as we know, a shorter and more localized career than the Callippic and the astronomical Egyptian calendars, since all the attestations fall within a few decades during the 3rd century BC and appear to originate in a small group of astronomers probably working in Egypt. The Dionysian calendar stands out among the Greek astronomers' calendars in that it appears not to be an adaptation of an already existing kind of calendar: its years are solar, and subdivided into months correlated with the sun's passage through the zodiacal signs, with no reference to the moon. Nevertheless the Dionysian calendar has antecedents in Greek practices of time reckoning, most immediately in a technical astronomical application but ultimately in broader contexts of intellectual life – but these antecedents were not calendars. The present paper is an attempt to sketch the relations and development of these practices, in which the determining elements are the sun, stars, and later on the zodiac.

1. Lay Dating by Annual Astronomical Phenomena

> After the Pleiades, there was good weather with clouds and mists. [Sick people had] crises [i.e. critical stages of illness] on the fifth day and sixth day and seventh day and also at greater intervals. The fevers were characterized by relapses, wandering about to some extent, loss of appetite, and bile. And there were dysenteries accompanied by loss of appetite and fever. Around the setting of the Pleiades, the southerly winds blew strongly. There were hemorrhages and tertian fevers and agues. The fellow in the cobbler's shop had a hemorrhage; a little violent excretion; he reached crisis on the seventh day with shivering. The boy living by the last shop had an abundant hemorrhage on the fourth day; at once he began to babble; the belly was constipated; the abdomen was painful and hard; a suppository on the sixth day brought nasty yellow stuff; early on the seventh day, tossing about, much shouting, pulsation of the blood vessels by the navel...
>
> At the winter solstice, a meteor, and not a small one; on the fifth and sixth days after, earthquake. When we got to Perinthos, [we saw] the asthmatic woman, the wife of Antigenes, who did not know if she was pregnant, manifesting red discharges from time to time; small belly, at other times big, for example when she went for too fast a walk (for she had a cough). It was her eighth month. She settled down after first having a fever. [pseudo-Hippocrates, *Epidemics* 4.20]

> The majority of fishes breed during the three months Mounychiôn, Thargêliôn, and Skirrophoriôn. A few do so in the autumn; for example the *salpê*, the *sargos*, and others of that sort [breed] a little before the autumnal equinox, and the *narkê* and *rhinê*. A few breed in either winter or summer, as was said earlier; for example the *labrax*, the *kestreus* in winter, the *belonê* in summer around [the month] Hekatombaiôn, and the *thynnis* around the summer solstice. [Aristotle, *Historia Animalium* 5.11]

> Before [the time of] Antigenides, when they used to play the *aulos* [i.e. shawm] in an unsophisticated manner, [people say that] the season for cutting [the reeds] was at [the rising of] Arcturus in the month Boêdromiôn; [a reed] cut thus becomes usable quite a few years afterwards and needs a lot of preliminary blowing, but the gap between the tongues is closed up, which is useful for [*text corrupt*]. But when they went over to the sophisticated manner, the [practice of] cutting was also changed. They now cut it in Skirrophoriôn and Hekatombaiôn, as it were a little before the [summer] solstice or at the solstice; they say that it is usable when three years old and needs [only] brief blowing, and that the tongues withstand rough vibrations, which is necessary when people play the *aulos* in the sophisticated manner. [Theophrastus, *Historia Plantarum* 4.11.3]

Histories of Greek astronomy often take Hesiod's didactic poem, *Works and Days* (composed around 700 BC) as their effective starting point.[4] Hesiod delineates an agricultural year in terms of a cycle of natural "signal" events, many of which (though not all) are astronomical: the morning risings and settings of Orion and the Pleiades, the morning and evening risings of Arcturus, the morning rising of Sirius, and the two solstices. He also states intervals in days for the times from the evening setting to the morning rising of the Pleiades (40 days) and from the winter solstice to the evening rising of Arcturus (60 days) but not a complete scheme connecting all the dates of the phenomena; proper times are fundamentally determined by observations, not by counting days. Just once Hesiod mentions a lunar calendar month, Lênaiôn, a time of harsh wintry weather when activities are to be avoided. (Interestingly, Lênaiôn is not a month of the Boeotian calendar, which would have been local to Hesiod and his immediate audience, but Ionian.) Thus he presumes that a lunar calendar will receive intercalary months with sufficient regularity to keep a particular month around a particular stage of the natural year; but in general he seems intent on not relating the agricultural year to a lunar calendar.

It is less commonly recognized that this method of astronomical dating independent of lunar calendars was practiced also in the classical Greece of the fifth and fourth centuries BC. The passages quoted at the beginning of this section are illustrations of the two chief contexts in which such datings occur. The first is a specimen of the case notes recorded by an itinerant Greek physician who probably lived in the late fifth or early fourth century BC, and preserved as Book 4 of the *Epidemics* in the Hippocratic corpus. The seven books of *Epidemics*, which appear to derive from the work of several such physicians working in many places in the Greek world about this period, contain numerous statements of the times of year when certain patterns of weather were observed and individuals and groups of people fell sick.[5] Although these were records of specific historical occurrences, not generalized patterns, the authors eschew any identification of the year or other absolute chronological data, and they never employ the local calendars of the localities where they were working. Instead, they either refer simply to the meteorological season (*eär* = spring, *theros* = summer, *phthinopôron* = autumn, *kheimôn* = winter) or, more precisely, to one of a cycle of seven annual astronomical events:

winter solstice
vernal equinox
summer solstice
morning rising of Sirius (about 30 days after summer solstice)
morning rising of Arcturus (about 80 days after summer solstice)
autumnal equinox
morning setting of Pleiades (about 50 days after autumnal equinox)

Nowhere in the *Epidemics* do we find an explanation of why the medical histories were dated with reference to astronomical phenomena, and to these phenomena in particular. Galen (2nd century AD) was confident that he knew the reason:

> If all nations had the same [months], Hippocrates would not have referred to Arcturus and the Pleiades and Sirius and the equinoxes and solstices, but he would have been content to state that such and such conditions occurred in the makeup of the environment at the beginning of [the month] Dios, naming [the month]

> according to the Macedonians if that was the state of affairs [i.e. if all nations used Macedonian months]. But since in fact a reference to Dios is clear only to the Macedonians, but not to the Athenians and the rest of mankind, whereas Hippocrates intended to be of service to people from all nations, it was better for him to record just the equinox without mentioning in which month. For the equinox is a universal matter, while the months are local to each nation. Now anyone who is ignorant of astronomy should really know that he is not obeying Hippocrates' exhortation to [learn] this [science] for the sake of using the aforesaid [phenomena]. [Galen, *In Hippocratis librum primum epidemiarum commentarii iii*, 19]

In other words the only thing that prevented Hippocrates—for Galen believed that the historical Hippocrates was the author of Books 1 and 3 of the *Epidemics*, while at least three of the others were by his son Thessalus—from dating everything according to a conventional civil calendar was that no single calendar would have been familiar to all of his intended readership.

A little further down in the same commentary, Galen observes rather casually that it is only possible to assign fixed dates for the solstices, equinoxes, and stellar phenomena in a calendar based on solar years:

> Of course the months must not be counted according to the moon as they are in most of the Greek cities at present and in all of them in olden days, but according to the sun as they are counted among many nations and in particular among the Romans... [Galen, *In Hippocratis librum primum epidemiarum commentarii iii*, 21]

Hence if "Hippocrates" had dated the events recorded in the *Epidemics* with reference to the months of, say, the calendar of Cos, even a reader from Cos would not have been getting exactly the same information as is conveyed by the astronomical datings, since in even the most uniformly intercalated lunar calendar an annual astronomical phenomenon can fall anywhere within an interval of approximately thirty calendar days in different years. This might or might not be a strong motive for avoiding civil calendars, depending on whether the authors of the *Epidemics* meant the correlation of medical phenomena with recurring stages of the natural year to be rough or precise.

In another roughly contemporary text in the Hippocratic corpus, *Airs, Waters, Places*, we are warned to avoid performing therapeutic actions close to changes of the seasons:

> Especially one ought to watch out for the most important changes of the seasons and neither administer a drug, if one has the choice, nor apply any cautery or cutting to the bowels before ten days have passed or even more. The greatest and most dangerous are these four: both the solstices and especially the summer solstice, and both the [dates] regarded as equinoxes and especially the autumnal equinox. One ought also to watch out for the risings of the stars and above all that of Sirius, and thereafter that of Arcturus, and moreover the setting of the Pleiades. For illnesses have their crises especially on these days; some cause death, others cease, and all the rest change into another form and another condition. [pseudo-Hippocrates, *Airs, Waters, Places*, 11]

The list of medically significant astronomical events exactly corresponds to the ones cited in the *Epidemics*. The last quoted sentence is surely the key to understanding the astronomical dates in the *Epidemics*: they are not a substitute for the civil calendars, but an expression of a theory tying together astral phenomena, the meteorological environment, and patterns of illness.

In still another Hippocratic text, *Regimen* Book 3, the appropriate diet and routine for maintaining good health through the course of the year is indexed according to the following cycle of astronomical phenomena:

	Morning setting of Pleiades = beginning of winter
44 days	Winter solstice
59 days	Evening rising of Arcturus
32 days	Vernal equinox = beginning of spring
48 days	Morning rising of Pleiades = beginning of summer
[*lost interval*]	Summer solstice
93 days	Morning rising of Arcturus = autumnal equinox = beginning of autumn
48 days	Morning setting of Pleiades

Though similar to the cycle of phenomena in the *Epidemics*, this cycle omits Sirius but has two (out of a possible four) phenomena for both Arcturus and the Pleiades. The other noteworthy element here is the more or less complete scheme of time intervals between the phenomena, which can be seen as a step towards eliminating the need for observing the phenomena.

Neither the Hesiodean farmer nor the Hippocratic physician could by any reasonable definition be called an astronomer, but their time-reckoning practices presume some astronomical knowledge. One should not exaggerate the degree of this knowledge, however. For the stellar phenomena one would have to be able to pick out three or four very bright or easily recognized stars or star groups—admittedly close to sunrise or sunset, when most of the background of dimmer stars would be invisible. Solstices present no difficulties so long as one is not attempting to determine the exact day, and there is nothing in these texts to suggest anything more sophisticated than watching for when the sun's rising or setting point on the horizon appears to remain unchanged for several successive days. The equinoxes are not quite as trivial to observe even crudely, so it is interesting to find them routinely cited in the *Epidemics*. The author of *Airs, Waters, Places* acknowledges that the physician must to some extent take these dates on trust when he refers to them as the dates "regarded as" (*nomizomenai*) equinoxes. I imagine that this means that one did not attempt to observe the equinoxes directly by, e.g., watching the sun's rising or setting points, but instead one counted a certain number of days from the preceding solstice or from one of the stellar dates.

When Aristotle and Theophrastus wanted to indicate the times in the natural year pertaining to the life cycles of animals and planets (and to human activities connected with them), their practice was less consistent than that of the Hippocratic writers. Instead, they sometimes refer to months of the Athenian calendar (e.g. Hekatombaiôn, Boêdromiôn, Mounychiôn, Thargêliôn, and Skirrophoriôn in the passages quoted), sometimes to solar and stellar phenomena, and often, redundantly, to both. The cited phenomena include all the solstices and equinoxes, the morning rising of Sirius, the morning rising and setting of the Pleiades, and the morning rising and evening setting of Arcturus. Both authors seem to have expected their readers to be familiar with the approximate correlation of the astronomical events and the calendar months. In general it is difficult to see the reason why one mode of dating or the other is being used. On one occasion (*Historia Animalium* 5.22) Aristotle asserts that bees deposit honey primarily at the dates of risings of constellations, but in general neither Aristotle nor Theophrastus suggests that the astronomical phenomena are more than convenient ways of marking stages of the year.

While the Hippocratics and the Peripatetics shared a concern with naturally occurring phenomena that suggests an obvious motivation for astronomical dating, one might not expect to find this kind of dating in historiographical writing; yet there are a small number of instances in Thucydides: two references to events taking place "around" the winter solstice (7.16 and 8.39), and one to an event "around" the morning rising of Arcturus (2.78). Thucydides generally organizes time by broader references to the seasons, and in fact employs Athenian calendar months every bit as rarely as the astronomical markers (2.15, 4.118, 5.19).

The high degree of consistency in the choice of phenomena exploited for "natural" dating by Hesiod, the Hippocratic authors, the Peripatetics, and Thucydides deserves comment. One finds always the same few stellar objects (Sirius, Arcturus, the Pleiades, Orion only in Hesiod), the solstices, and—except in Hesiod—the equinoxes. A further indication that one was dealing with an extremely restricted list of familiar events is the elliptical manner in which they are often specified: it was enough to say "after Arcturus" (*met' Arktouron*) if one intended the days following the star's morning rising.

2. The Parapegmatists

> And I have recorded the episêmasiai belonging to these [stars] and set them down according to the Egyptians and Dositheus, Philippus, Callippus, Euctemon, Meton, Conon, Metrodorus, Eudoxus, Caesar, Democritus, [and] Hipparchus. Of these, the Egyptians observed here, Dositheus in Cos, Philippus in the Peloponnese and Locris and Phocis, Callippus on the Hellespont, Meton and Euctemon at Athens and the Cyclades and Macedonia and Thrace, Conon and Metrodorus in Italy and Sicily, Eudoxus in Asia and Sicily and Italy, Caesar in Italy, Hipparchus in Bithynia, Democritus in Macedonia and Thrace. [Ptolemy, Phaseis ed. Heiberg 66–67.]

> Why does the *notos* wind blow at the [rising of] Sirius, and this occurs as regularly as anything else? Is it because the region below is hot because the sun is <not> far away, so that the vapour is abundant? They would actually blow often were it not for the Etesian winds; but as things are, [the Etesians] prevent them. Or is it because a sign occurs [*sêmainei*] at all the settings and risings of the stars, and not least at this one? Obviously there are winds especially at this [the rising of Sirius] and after it. When it is stifling, winds, and indeed the hottest ones, are set in motion at this [rising]; and the *notos* wind is hot. But since there is a tendency especially for changes to occur from opposites to opposites, and the *prodromoi* winds, which are *boreai* winds, blow before [the rising of] Sirius, it makes sense that *notos* blows after [the rising of] Sirius, since an *episêmasia* occurs [*episêmainei*], and for stars making their rising "an *episêmasia* occurs" means causing a change in the air; and all winds change into the winds that are opposed or to their right. [pseudo-Aristotle, *Problemata* 26.12, 941b.]

The restricted choice of astronomical phenomena used by the lay writers is the more remarkable because by the time when Aristotle and Theophrastus wrote (the third quarter of the fourth century), a tradition of astrometeorology making use of a considerably larger repertoire of stars and constellations had been in existence for about a hundred years if not longer.[6] Our evidence for this tradition is from Hellenistic and Roman period documents that are now conventionally referred to as *parapegmata*, in which solar and stellar phenomena as well as presumed annual repetitions of weather changes are assigned to specific days within an idealized solar year. Two of these documents are especially important because they contain numerous dates of phenomena attributed to past authorities: the so-called "Geminus" parapegma that is preserved immediately following the abrupt (and perhaps mutilated) end of Geminus' *Isagoge*, and Ptolemy's *Phaseis*. The "Geminus" parapegma, which probably has no connection with Geminus himself, cites no authority later than the third century BC, whereas Ptolemy used sources as late as Julius Caesar. Unfortunately Ptolemy chose to include only the weather dates from his authorities, preferring his own calculations for the astronomical phenomena.

The earliest persons associated with parapegmatic data are Meton, Euctemon, and the Presocratic atomist Democritus, all of whom were active in the late fifth century BC; the authenticity of the reports associated with Democritus is, however, highly questionable, and anyway most of them pertain to weather and only a few to astronomical phenomena. Several of the ancient references to Meton and Euctemon link their names as if they were colleagues, but the nature of their collaboration—if that is what it was—is unclear, and the parapegmatic data are always attributed to just one man or the other. As it happens, only a single astronomical event, the morning rising of Sirius, has an extant parapegmatic entry ascribed to Meton.

For Euctemon, however, the "Geminus" parapegma preserves for us what seems to be a large fraction of the complete set of astronomical phenomena that he recorded.[7] In addition to the solstices and equinoxes, Euctemon's list of phenomena included morning or evening risings or settings of fifteen bright stars and constellations; in many instances "Geminus" has all four possible phenomena, and it seems likely that this was originally true for more of them before some entries dropped out in the transmission (either between Euctemon and "Geminus" or in the manuscript tradition of the "Geminus" parapegma itself). Table 1 is a list of Euctemon's stars and constellations, roughly in order of decreasing brightness. For the constellations we identify the brightest star or stars, since these were probably the ones whose appearances or disappearances determined the dates of risings and settings for the constellations as a whole.

It is a curious list, containing almost all the stars visible at the latitude of, say, Athens down to magnitude 1 (Procyon and Spica are the exceptions), omitting practically all stars with magnitudes between 1 and 2 (e.g. Pollux, Fomalhaut, Deneb, Regulus, Adhara, Castor, to name only the brightest), but then including several distinctly less bright groups. Some of these dimmer groups are fairly compact and hence recognizable asterisms, but Pegasus covers such a wide area as to make it doubtful which stars Euctemon had in mind. Euctemon's significant stars and constellations are fairly well spread in right ascension, and too scattered in declination to constitute a continuous belt. There does not seem to be any close relation between his choice of stars and any of the known Mesopotamian lists.

The "Geminus" parapegma also attributes to Euctemon many statements of weather changes (for which the technical term was *episêmasiai*, "significations"). Like all the data in this parapegma, these events are dated according to a rigid count of days that begins with the summer solstice. A second source for weather changes, but not astronomical phenomena, attributed to Euctemon is Ptolemy's *Phaseis*, in which all events are dated according to the Alexandrian (reformed Egyptian) calendar, which had a four-year cycle of 365-day and 366-day years like the Julian calendar and thus remains approximately fixed in relation to the solar year.

The relationships among these three sets of dates is easiest to see if we plot them along a scale of days counted from the summer solstice as day 1 (figure 1). First of all, nearly every

Star/Constellation	Brightest stars	Magnitude
Sirius	(α CMa)	–1.46
Arcturus	(α Boo)	–0.04
Lyra	Vega (α Lyr)	0.03
Capella	(α Aur)	0.08
Orion	Rigel (β Ori)	0.12
	Betelgeuse (α Ori)	0.50
Aquila	Altair (α Aqu)	0.77
Hyades	Aldebaran (α Tau)	0.85*
Scorpius	Antares (α Sco)	0.96
	Shaula (λ Sco)	1.63
Corona Borealis	Aphekka (α CrB)	2.23
Pegasus	Enif (ε Peg)	2.39
	Scheat (β Peg)	2.42
	Markab (α Peg)	2.49
	Algenib (γ Peg)	2.83
Vindemiatrix	(ε Vir)	2.83
Pleiades	Alcyone (η Tau)	2.87
Sagitta	(γ Sge)	3.47
Delphinus	Rotanev (β Del)	3.63
Haedi	(ζ Aur)	3.75

* According to later conventions Aldebaran was not counted among the Hyades, but the visibility dates assigned to the Hyades in the parapegmata seem to require the inclusion of this bright star.

TABLE 1. Euctemon's stars and constellations

date for which there is an astronomical event also has a weather change in the "Geminus" parapegma, and *vice versa*. This implies that for Euctemon, the astronomical events were not just a tool for tracking the progress of the natural year, as Geminus claimed in his factitious account of how the parapegmatic tradition began (quoted at the head of the next section below), but immediate signs, possibly even causes, of the weather changes.[8]

Secondly, while it is not possible to line up Ptolemy's Alexandrian calendar dates with the "Geminus" parapegma's day count from summer solstice in such a way as to make the two sets of weather phenomena exactly match, we can get nearly two thirds of the parapegma's dates to match dates from Ptolemy—21 coincidences out of 35 dates in "Geminus" and 55 in Ptolemy—if we equate Euctemon's summer solstice with Ptolemy's Epeiph 2 (equivalent to June 26 in any Julian calendar year). In most of these instances of coinciding dates the specifics of the weather changes are substantially the same in both sources. This is certainly the alignment that Ptolemy made, but it is not clear why he did it in just this way. In agreement with his solar theory, he set the summer solstice for his own period, the mid second century A.D., as occurring on Epeiph 1 (June 25). According to *Almagest* 3.1 the length of

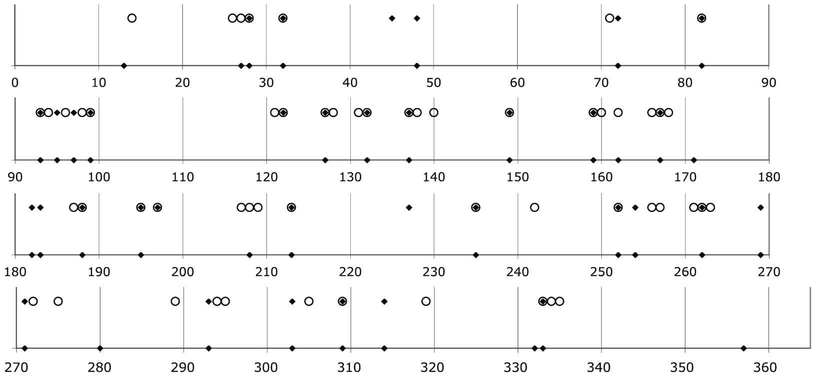

FIGURE 1. Concordance of parapegmatic dates attributed to Euctemon according to dates counted from summer solstice. Lower line: astronomical phenomena in the "Geminus" parapegma. Upper line: weather phenomena in the "Geminus" parapegma (solid) and in Ptolemy's Phaseis (circles).

the tropical year is 365 ¼ - 1/300 days. Hence since Euctemon worked nearly six hundred years before Ptolemy, his solstice should have fallen on Epeiph 3, not Epeiph 2.

The many divergences between the two sets of weather data, and in particular the fact that Ptolemy's list includes significantly more dates, some of which tend to cluster around the shared ones, surely point to interventions in the tradition that go beyond accidental dropping out of entries. But fundamentally the separate testimony of Ptolemy supports the hypothesis that what Euctemon compiled was in the first instance a collection of linkages between astronomical and weather events, all set at specific intervals of days. Thus the stellar events have a twofold function, serving both as indices of the stage of the solar year and as weather signs in their own right.

This linkage of the stellar events with contemporaneous weather changes seems on the face of it to have been absent, or nearly so, from the lay employment of such events as date markers discussed in the preceding section, except for parts of the Hippocratic tradition. Hesiod, it is true, speaks of Sirius as "parching the head and knees" (587), but one could plead that Sirius was a special case, supposing the expression must be taken literally. On the other hand, one of the pseudo-Aristotelian *Problemata* (1.3, 859a), reflecting notions circulating among the early Peripatetics of the late 4th or early 3rd century BC, asserts as a matter of fact that winds, waters, and good and bad weather are affected by "the seasons and the risings of stars such as Orion and Arcturus and the Pleiades and Sirius", which is precisely the traditional list of events. Another of the *Problemata* (26.12, quoted at the head of this section) goes so far as to assert a *causal* connection between stellar risings and weather changes, though typically for this genre the text offers an alternative theory that even a weather change coinciding with the rising of Sirius is really caused by the sun.

After Euctemon, the next parapegmatist for whom both "Geminus" and Ptolemy provide a large number of dates is Eudoxus. The first thing that strikes one on comparing the citations of Euctemon and Eudoxus is that Eudoxus used exactly the same set of stars and

Star/Constellation	Specific parts referred to	Magnitude of brightest star
Aries	beginning, entirety	2.00
Taurus	horns. head, tail, entirety	0.85
Gemini	beginning, middle	1.14
Cancer	beginning, entirety	3.52
Leo	beginning, middle, entirety	0.05
Virgo	shoulders, Spica, middle, entirety	0.98
"Claws" (Libra)	beginning	2.61
Scorpio	brow, bright star	0.96
Sagittarius	beginning, entirety	1.85
Capricorn	beginning	2.87
Aquarius	middle	2.91
Pisces	southern fish, node	3.62
Orion	entirety	0.12
Sirius		–1.46
Arcturus		–0.04
Pleiades		2.87 (Alcyone)

Table 2. Stars and constellations appearing in the Callipic entries of the "Geminus" parapegma.

constellations as his predecessor. Again the astronomical phenomena and the weather changes in the "Geminus" parapegma tend to fall on the same dates, though there are more exceptions than was the case for Euctemon (figure 2). And again there is a unique alignment of Ptolemy's weather dates with those of the "Geminus" parapegma such that we get a significant number of coincident dates with substantially the same statements about the weather; in this case one has to equate the summer solstice with Epeiph 1 (June 25), the same date that Ptolemy gave for the solstice in his own time. This alignment also brings a number of Ptolemy's weather dates in line with dates of astronomical phenomena in the "Geminus" parapegma for which there are no coincident weather statements in that document. But Ptolemy also has numerous weather dates that have no counterpart at all in "Geminus," and that cannot all have been tied directly to astronomical phenomena. It is not clear how Eudoxus would have specified such dates, whether as so many days before or after an astronomical phenomenon or in relation to a day count covering the entire solar year. There seems in any case to be a slight, but only a slight, diminution in the independent significance of the stellar dates as something beyond markers of the progress of the natural year.

The "Geminus" parapegma reports a large number of astronomical dates for only one other authority, Callippus. The list of stars and constellations appearing in the Callippic entries is strikingly different from those associated with Euctemon and Eudoxus (see table 2). Except for precisely the four objects found in Hesiod (and this overlap is surely significant), Callippus abandons Euctemon's list, and replaces it with the twelve zodiacal constellations. He manifestly has the constellations in view, not equal divisions of thirty degrees, as is apparent not only from the references to individual features of many of them but also from the irregular intervals separating the dates associated with the beginnings and completions of their risings and settings. It deserves to be remarked that several of the zodiacal constellations are quite as inconspicuous as the dimmest of the asterisms in Euctemon's list.

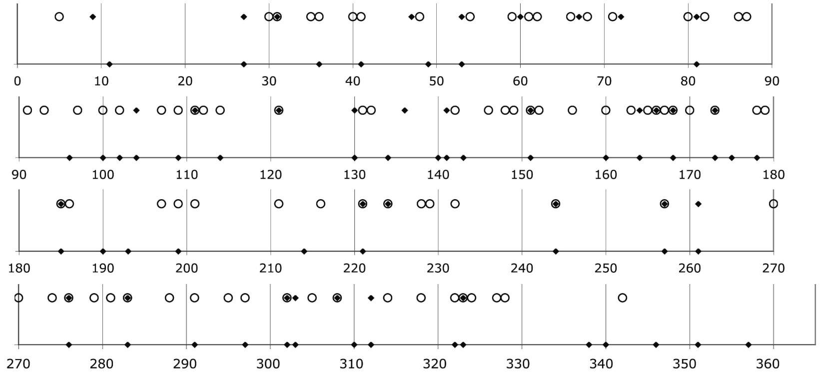

FIGURE 2. Concordance of parapegmatic dates attributed to Eudoxus according to dates counted from summer solstice. Layout as in figure 1.

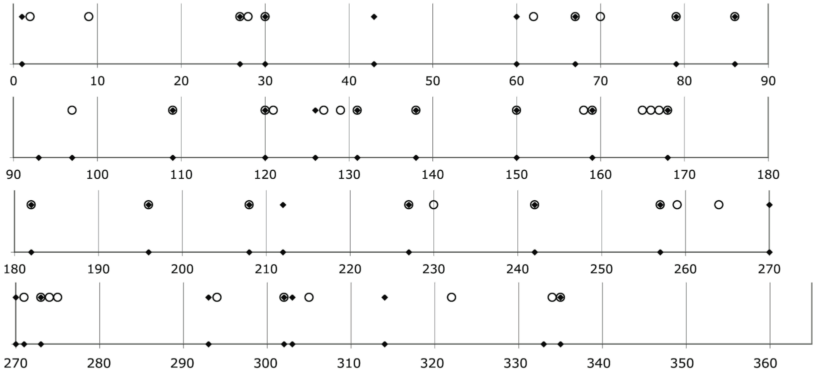

FIGURE 3. Concordance of parapegmatic dates attributed to Callippus according to dates counted from summer solstice. Layout as in figure. 1.

The optimal synchronization of Ptolemy's weather dates for Callippus with those in the "Geminus" parapegma requires an equation of the summer solstice with Epeiph 3 (figure 3). Ptolemy clearly had a very similar, and not much larger, data set for Callippus. The rate of coincidence of weather dates, from either source, with stellar dates in the "Geminus" parapegma is high, indeed higher than in the case of Eudoxus. It is tempting to hypothesize that Callippus was promoting a theory of weather changes according to which the signifying power was almost wholly restricted to the zodiacal belt.

3. Towards a Zodiacal Calendar

> [The parapegmatists] chose a beginning for the year, and took note of which zodiacal sign the sun was in at the year's beginning and at which degree, and they recorded the general changes of the air, winds, rains, and hail that occurred in each day and month, and they set them alongside the sun's positions by sign and degree. After observing this for a number of years, they recorded the changes that happened especially around the same places in the zodiac in the *parapegmata*.... But since they were unable to record a definite day or month or year in which any of these things was brought about because the beginnings of the years are not the same among all peoples and moreover the months do not have the same nomenclature and the days are not counted in the same way among all, they chose to define the changes of the air by means of certain fixed signs.... And just as a beacon is not itself responsible for a conditions of war but rather is a sign of an occasion for war, in the same way the risings of the stars are not themselves responsible for the changes in the air but are set out as signs of such conditions. [Geminus, *Isagoge* 17.7-11.]

> Dionysius named the twelve months, which had thirty days, by transference from the twelve zodiacal signs, and likewise (named) the days from the degrees at which the sun was approximately in mean motion. The first year of his Summer Solstices was in the 463rd year from Nabonassar. [Scholion to *Almagest* 11.3, text 2 in Jones (2003)]

The passage quoted above from Geminus' chapter on parapegmata is a patent fiction concocted to butress his argument that stellar risings and settings do not influence weather, and not the least implausible element of his story is his claim that the early parapegmatists initially correlated observations of weather with solar longitude rather than with stellar phenomena. Geminus' shortcomings as a historian of astronomy ought not to distract us from the fact that his book is a rather good mirror of the range of astronomical practice of his own time, the late Hellenistic period. In the present instance his account reflects what appears to have been the prevailing conventional organizational principle of Hellenistic parapegmata. The "Geminus" parapegma, for example—whose connection with the author Geminus is, as mentioned already, doubtful—does not simply count days from the summer solstice, but divides its year into twelve parts comprising stated numbers of days ranging from as few as 29 to as many as 32, during each of which the sun is stated to traverse one of the zodiacal signs. The near-uniformity of the time intervals, and the regularity of their distribution through the year, make it clear that the text is referring to equal signs of 30° rather than the homonymous constellations. One of a pair of fragmentary parapegma inscriptions from Miletus, dating from roughly 100 BC, was laid out in sections corresponding to the sun's passage through the twelve signs, with the number of days in each section recorded above the series of peg holes and inscribed texts that stand for the individual days and the associated phenomena.[9] Also from about 100 BC we have an artifact that corresponds still more closely to Geminus' story, namely the

Antikythera Mechanism, whose front dial had a revolving pointer displaying the sun's longitude along a dial graduated into zodiacal signs and degrees. Letters inscribed at irregular intervals along this scale served as indices to a list of stellar risings and settings.[10]

The earliest surviving parapegma is a papyrus, *P. Hibeh* 1.27, which can be dated on external and internal grounds to about 300 BC.[11] This text differs from the other Hellenistic parapegmata mentioned above in certain important respects: it organizes its data according to the Egyptian calendar rather than by a true solar year, and in addition to stellar dates and weather changes, it associates with specific dates computed values for the length of daylight in hours as well as numerous religious festivals. Although it does not use the sun's passage through the zodiacal signs to define the chronological framework, it does contain the following entries mentioning zodiacal signs:

> Tybi, in Aries, [day] 20, vernal equinox, the night 12 hours and day 12, and feast of Phitorois. [col. iv ll. 62–64]
>
> Mecheir 6, in Taurus, Hyades set acronychally, the night 11 ½ ⅒ 1⁄35 hours, the day 12 ⅓ 1⁄45. [iv 66–68]
>
> Phamenoth 4, in Gemini, [Capella] rises [in the morning], the night 11 1⁄45 hours, the day 12 ⅔ ¼ 1⁄20 1⁄90. [vi 88–90]
>
> Pharmuthi, in Cancer, 3, Sagitta sets acronychally, the night 10 ⅓ 1⁄30 1⁄90 hours, the day 13 ½ 1⁄90 [*sic for ⅒*] 1⁄45. [vii 107–109]
>
> Pachon 6, in Leo, Vindemiatrix rises, the night 10 ¼ 1⁄30 1⁄180 hours, the day 13 ⅔ 1⁄30 1⁄90. [ix 129–132]
>
> Payni [4], in Virgo, Sagitta sets in the morning, the night 10 ⅔ ⅕ 1⁄30 1⁄90 hours, the day 13 1⁄15 1⁄45. [x 137–140]
>
> Mesore 2, in Scorpio, Pleiades rise acronychally, the night 12 ⅕ hours, the day 11 ⅔ ⅒ 1⁄30, feast of Apollo. [xiii 181–186]

These entries have in common that each one is the first entry for its Egyptian month, and each is associated with some stellar phenomenon. The intervals between them, moreover, do not exhibit a regular pattern, although most are within a few days of 30 days (the exception is the first interval from Tybi 20 to Mecheir 6, which is only 16 days).[12] This irregularity is surely to be accounted for by the other facts just mentioned, that is, the stellar dates came first, and the zodiacal references have been attached to them at a secondary stage.[13] Hence I do not think that the interpretation that has been generally accepted since the first publication of *P. Hibeh* 1.27, that these are intended as dates when the sun crosses into the designated zodiacal sign—or alternatively its homonymous constellation—can be correct. Instead, I would suggest that their origin was in a list that simply stated, e.g., that the sun moves into Aries during the month Tybi, and Taurus during the month Mecheir, and so forth. This list was incorporated into the parapegma by the simple, if ignorant, expedient of inserting these statements as part of the first listed event for each month. If this is the correct explanation, then little can be said with certainty about when precisely the passages from one sign to the next were supposed to occur, and in particular whether the sun's passages into Aries, Cancer, Libra, and Capricorn were assumed to coincide with the equinoxes and solstices, as we find in the "Geminus" parapegma.[14] The balance of probability favours interpreting the entries in the Hibeh parapegma as referring to equal zodiacal signs rather than constellations, since this is clearly what the later tradition was doing whereas there seems to be no instance of a Greek text from any period speaking of sequential solar entries into the zodiacal constellations.

The distinctive set of twelve zodiacal constellations appears to have been present already in the *Phaenomena* of Eudoxus, who may in fact have been the person responsible for introducing them as a concept in Greek astronomy. On the other hand, we have no clear evidence that a division of the zodiacal belt into twelve equal signs figured in Eudoxus' work.[15] The current consensus is that the earliest parapegmatists, who were active a generation or more before Eudoxus, would not have organized parapegmatic data by dividing the year according to the sun's passage through the twelve signs.[16] When this practice began is anyone's guess, but the Hibeh parapegma's zodiacal references, garbled though they appear to be, establish the end of the 4th century BC as a probable *terminus ante quem*. I am tempted to suggest that the innovation was due to Callippus, in the light of his preoccupation with zodiacal constellations as significant objects to correlate with weather.[17]

So far as one can tell from the extant parapegmata, the sun's entry into a zodiacal sign was not regarded in its own right as an event to be linked to weather phenomena. What, then, was the purpose of including them in a parapegma? One rather trivial motive is that a year is a cumbersomely large block of days within which to keep track of the current date. Partitioning the solar year into seasons delimited by the solstices and equinoxes and perhaps by the most important stellar dates would be a helpful step, but a division into twelve more or less equal parts, resembling traditional calendar months in length though not tied to lunar phases, would have an obvious attraction, not least because each part would tend to occupy a roughly uniform space in a manuscript or inscription.

Another, more theoretical consideration that might lie behind these zodiacal references is an interest in modelling and predicting stellar visibility dates, such as we can see in the surviving mathematical literature on spherical astronomy. Equal twelfths of the ecliptic, sometimes identified by the names of the zodiacal signs and sometimes not, were regularly employed in Greek "spherics," both as the objects for investigation in their own right in relation to the times in which they rise and set (e.g. in Euclid's *Phaenomena*) and as references for developing theories of conditions of stellar visibility (e.g. in Autolycus' *De Ortibus*). Of particular relevance for parapegmata is Autolycus' modelling assumption, that the condition for a star's visibility is that the point of the ecliptic that rises (or sets) simultaneously with the star should be ahead (or, for setting, behind) the sun by half a zodiacal sign in longitude.[18] We can only guess at the existence of a lost astronomical literature—and how early?—bridging the purely theoretical treatment of visibility in spherics to the bald lists of dates in the parapegmata.[19] For that matter, it is not clear whether the dates assigned to stellar phenomena in the "Geminus" parapegma and others are purely empirical or in part derived from modelling.

Since a parapegma is by its nature an idealization applicable to *any* solar year, the division of the year into twelve sections according to the sun's traversal of the zodiacal signs does not properly speaking constitute a calendar, which would entail reference to specific dates. On the other hand, Ptolemy's *Almagest* preserves eight instances of dates expressed in a true zodiacal calendar that has so far not turned up in any other ancient source. The formulae are uniform in structure in providing a year number "according to Dionysius," a month name derived from a zodiacal sign, and a day number. These were dates of observations of the positions of one or another of the planets relative to fixed stars, and in discussing them Ptolemy provides what he asserts are equivalent dates in his own chronological framework, which uses the Egyptian calendar with year numbers counted from the "first year of Nabonassar" (i.e. the Egyptian year that began in 747 BC). Ptolemy's Egyptian dates can be converted into our Julian chronology. Since, however, the planetary observations took place at night, either after sunset or before sunrise, it is not clear whether Ptolemy understood the Dionysian dates to pertain to the days preceding or following the nights that he specifies (without ambiguity) in his Egyptian reckoning; in other words, we do not know whether he believed that the Dionysian day was considered to begin with sunset, sunrise, or the middle of the night. The following lists the eight Dionysian date formulae with Ptolemy's equivalents translated into the Julian calendar.

Year 13 Aigon [Capricorn] 25, morning	272 B.C. January 17/18
Year 21 Skorpion [Scorpio] 22, morning	265 B.C. November 14/15
Year 21 Skorpion 26, morning	265 B.C. November 18/19
Year 23 Hydron [Aquarius] 21, morning	262 B.C. February 11/12
Year 23 Tauron [Taurus] 4, evening	262 B.C. April 25/26
Year 24 Leonton [Leo] 28, evening	262 B.C. August 23/24
Year 28 Didymon [Gemini] 7, evening	257 B.C. May 28/29
Year 45 Parthenon [Virgo] 10, morning	241 B.C. September 3/4

Ptolemy provides no explanation of the Dionysian calendar and its conventions, and the only supplementary information that we have came to light only in recent years and consists of three brief scholia from the margins of medieval manuscripts of the *Almagest*, one of which is quoted at the head of this section.[20] These texts declare various things: (1) Dionysius lived in Alexandria; (2) the first of his "summer solstices" was in Nabonassar year 463 (i.e. the Egyptian year beginning November 3, 286 BC); (3) the months of his calendar were named for the zodiacal signs, and had thirty days each; and (4) the days approximately corresponded to the degrees of the sun's mean longitude within the relevant sign.

There is no question that Dionysius' year reckoning counted from the summer solstice of 285 BC as the beginning of year 1, and it may be significant for the meaning of this epoch that the Egyptian year that Ptolemy calls Nabonassar year 463 was by convention considered to be the first regnal year of Ptolemy II Philadelphus. Concerning the structure of the calendar, the scholia are unfortunately not consistent, since it is not possible for zodiacal months and days to be coordinated with the signs and degrees of the sun's mean solar longitude if every zodiacal month has exactly thirty days. All attempts to reconstruct the Dionysian calendar have attempted to find a pattern fitting the eight dates in the *Almagest*.[21] The earliest efforts supposed that Dionysius' zodiacal months were unequal in length, resembling the divisions of the year in parapegmata. In the mid 19th century Karl Lepsius and August Böckh showed that no such scheme could be made to be consistent with all the date reported by Ptolemy. Instead, they deduced that the Dionysian year was analogous in structure to the Egyptian year, comprising twelve months of exactly thirty days followed by a supplementary period of five days, but with the year beginning at the summer solstice. Since the Dionysian years exhibit no long term backwards shift relative to the solstices as they would if all years had 365 days, Lepsius and Böckh further hypothesized that a sixth supplementary day was inserted at four-year intervals. Thus the Dionysian calendar would seem to have anticipated the reform of the Egyptian calendar that Ptolemy Euergetes abortively proposed in the

"Canobic Decree" (*OGIS* 56) in 239/238 BC and that was finally adopted at the beginning of Roman rule in Egypt.

The reconstructed Dionysian calendar of Lepsius and Böckh fits Ptolemy's equations of Dionysian and Egyptian dates almost perfectly, though there is a single discrepancy of one day. However, Lepsius and Böckh were unaware that not all the planetary observations that Ptolemy reports describe what should have been seen on the nights that he associates with them: one of them seems to be dated one or two days too early, and two others seem to be one or two days too late for the situation he describes the planet as being in.[22] Now internal consistency guarantees that the wording of the reports, and the Egyptian dates that Ptolemy assigns to them, have been transmitted accurately as he wrote them. The inconsistencies must be due to one of four causes: (1) the original observers may have inaccurately described what they saw (though this is hard to believe in the present instances), (2) Ptolemy's version of the reports may not correctly reproduce the originals, (3) the Dionysian day numbers in our manuscript tradition of the *Almagest* may be corrupt, or (4) Ptolemy's conversions of the dates from the Dionysian to the Egyptian calendar may not be reliable. Of course more than one of these sources of error may apply; but the high frequency of discrepancies suggests a common explanation, and the most plausible one is that Ptolemy had an incorrect or only approximate rule for converting between the calendars. And interestingly, if we replace the problem dates with dates that better fit the observation reports, the equations are no longer consistent with an Egyptian-style division of the year into thirty-day months, but suggest a parapegma-style division into zodiacal months that are shortest in the autumn and longest in the spring.[23] Enough uncertainties remain to prevent us from offering a complete reconstruction of the calendar; in particular it would seem that the summer solstices marking the beginnings of the years cannot have followed a rigid four-year cycle of 365-day and 366-day intervals. Nevertheless this interpretation of the Dionysian dates makes good sense in the context of contemporary astronomical practices. By contrast it is difficult to understand why one would have adopted a calendrical structure according to which the months progressively run ahead of the sun's passage through the homonymous zodiacal signs, accumulating a lead of five days by the end of the year that nominally belongs to none of the signs.

If, as seems likely, Dionysius was himself active as an astronomer during the inaugural year of his calendar, then the calendar had a career of at least forty-five years, which is probably too long for a single astronomer's career; on the other hand there is no reason to suppose that anyone outside a small localized team of observers used it. The purpose of their observations is anyone's guess—were they investigating the patterns of planetary motion in their own right, or tracking supposed correlations between these motions and mundane phenomena? In any event, the Dionysian calendar failed to catch on among later Greek astronomers, perhaps because it fell between two stools: the Callippic calendar offered a more natural mapping on to the calendars in local use throughout Greece and the Near East, while the Egyptian calendar was simpler and more regular, and thus suited to long term astronomical calculations.[24] In due course Roman power accomplished what the astronomer Dionysius could not, imposing upon the eastern Mediterranean region a family of calendars modelled on Caesar's Roman calendar with its solar years, albeit divided into months of no astronomical significance whatsoever.

Notes

1. Samuel (1972); Trümpy (1997).
2. The scholarship on the Athenian calendar is vast, and it is difficult for the neophyte to strain the secure facts out of a brew of a priori conjectures, tralaticious assumptions, and polemics. A patient reader can trace a substantial bibliography by working backwards from the references in Pritchett (2001). The thesis presented in Pritchett & Neugebauer (1947) (and maintained in Pritchett's many subsequent publications on the subject) that the Athenian calendar was subject to irregular and capricious intercalations of months and insertions and compensating deletions of days has on the whole held up well against a steady barrage of rival models. Müller (1991) and (1994) infers from numismatic evidence that the Athenian calendar was intercalated according to a 19-year cycle from the 2nd century BC; J. D. Morgan's often-cited researches on Athenian chronology, which also entail an effective 19-year cycle of intercalation already in the early 4th century BC, were endorsed by Habicht (1997), pp. v–vi but unfortunately remain unpublished (cf. Morgan (1996) and (1998)). Presuming his results are correct, it remains unclear whether the Athenian year's length was ever consciously regulated by a cycle (which ought then to have specified which months were repeated as well as the dates of summer solstices) or whether the cyclic pattern was an automatic consequence of starting the new year consistently with the first new moon following an independently determined summer solstice.
3. Jones (2000) and literature cited therein. The hypothesis that the Athenian month names (accompanied by Athenian archon-names for the years) in the reports of three 4th century BC Babylonian lunar eclipse observations cited in Ptolemy, Almagest 4.11 pertain to a putative calendar devised by Meton is plausible enough but cannot be confirmed.
4. The Homeric poems refer by name to a few constellations but contain little else that counts as astronomy.
5. The most concrete evidence for the date of writing of the Epidemics is the inclusion of case histories from Olynthos in Books 5 and 7, which situates these books before the destruction of the city in 348 BC. The other books are generally presumed to be several decades older than this pair.
6. Lehoux (2007).
7. On Euctemon's parapegma see Hannah (2002).
8. Hannah (2005), pp. 62–70 suggests that the density of stellar dates in Euctemon's list may have been motivated by the varying seasonal activities, agricultural and other, of a Greek community. I am not quite convinced that the pattern of gaps and dense patches in figure 1 bears this out.
9. Lehoux (2005).
10. Price (1974), pp. 18 and 46–49.
11. Grenfell and Hunt (1906), pp. 138–157.
12. The original editors of the papyrus tried to remove this anomaly by conjecturing an omitted day number (5) following "Tybi," effectively turning one entry into two separate ones; this editorially inserted day number has been treated as if it was actually in the papyrus in some of the more recent scholarship. The day numbers in the papyrus are all guaranteed to be correct by the associated figures for the length of night and day, which conform to an arithmetical scheme.
13. Spalinger (1991) proposes a different, rather complicated hypothesis by which a scheme comprising only 30-day and 31-day zodiacal intervals could have been distorted in the transition from a Greek parapegma to a parapegma structured on the Egyptian calendars (both civil and lunar). The stellar phenomena play no role in his reconstruction.
14. If the dates in the papyrus are to be taken seriously as the actual passage dates, then no consistent alignment of the solstitial and equinoctial points in the signs is possible, but all would be at or past the middle of their respective signs.
15. Bowen and Goldstein (1991), pp. 241–245. Aristotle, Metaphysica 1073b, appears to be the first extant author to speak of the ecliptic circle as the circle "through the middle of the signs [dia mesôn tôn zôidiôn]," in the context of his summary of the homocentric sphere models of Eudoxus, but one cannot be sure whether zôidion here meant equal signs or constellations. In 3rd century BC authors such as Autolycus and Aristarchus zôidion definitely means a twelfth of the ecliptic or by extension a twelfth of a great circle in general.

16. Hannah (2002), pp. 120–123.
17. It would be gratifying to adduce as evidence of Callippus' part in incorporating zodiacal elements into the parapegma tradition the scheme of intervals for the sun's passage through the signs published by Rehm as Callippus', for which see Rehm (1949), 1346–1348. Unfortunately I share Neugebauer's scepticism of this as of so many of Rehm's reconstructions of parapegmatic schemes on the basis of considerably later sources (Neugebauer (1975), pp. 628–629).
18. Neugebauer (1975), pp. 761–763.
19. The date commonly assumed for Autolycus, c. 300 BC rests on Diogenes Laertius' report (4.29) that the Academic philosopher Arcesilaus studied with him in his youth; for reservations about the trustworthiness of this story, see Bowen and Goldstein (1991), p. 246 n. 29.
20. The scholia were first published in Jones (2003) as Texts 1–3.
21. For details of the historiography of the Dionysian calendar, with references, see Jones (2006), pp. 284-287.
22. Jones (2006), pp. 258–270.
23. Jones (2006), pp. 287–289.
24. Ross (2006) interprets certain problematic uses of zodiacal signs in Demotic horoscopic ostraca from Roman period Medinet Madi as survivals of the Dionysian calendar. Supposing that the dating formulae in these ostraca have been correctly understood, an independent reinvention of zodiacal dating seems more plausible than a line of transmission undocumented over more than three centuries.

References

Bowen, A. C., and Goldstein, B. R., 1991, "Hipparchus' Treatment of Early Greek Astronomy: The Case of Eudoxus and the Length of Daytime", *Proceedings of the American Philosophical Society* 135, 233–254.

Grenfell, B. P., and Hunt, A. S., 1906, *The Hibeh Papyri* (London: Egypt Exploration Fund).

Habicht, C., 1997, *Athens from Alexander to Antony* (Cambridge, Massachusetts: Harvard University Press).

Hannah, R., 2002, "Euctemon's Parapegma", in C. J. Tuplin and T. E. Rihll (eds.), *Science and Mathematics in Ancient Greek Culture* (Oxford: Oxford University Press), 112–132.

——, 2005, *Greek and Roman Calendars. Constructions of Time in the Classical World* (London: Duckworth).

Jones, A., 2000, "Calendrica I: New Callippic Dates", *Zeitschrift für Papyrologie und Epigraphik* 129, 141–158.

——, 2003, "A Posy of Almagest Scholia", *Centaurus* 45, 69–78.

——, 2006, "Ptolemy's Ancient Planetary Observations", *Annals of Science* 63, 255–290.

Lehoux, D., 2005, "The Parapegma Fragments from Miletus", *Zeitschrift für Papyrologie und Epigraphik* 152, 125-140.

——, 2007, *Astronomy, Weather, and Calendars in the Ancient World* (Cambridge: Cambridge University Press).

Morgan, J. D., 1996, "The Calendar and the Chronology of Athens" (abstract), *American Journal of Archaeology* 100, 395.

——, 1998, "Polyeuktos, the Soteria, and the Chronology of Athens and Delphi in the Mid-Third Century B.C." (abstract), *American Journal of Archaeology* 102, 389.

Müller, J. W., 1991, "Intercalary months in the Athenian dark-age period", *Schweizer Münzblätter* 41, 85.

——, 1994, "Synchronization of the Late Athenian With the Julian Calendar", *Zeitschrift für Papyrologie und Epigraphik* 103, 128-138.

Neugebauer, O., 1975, *A History of Ancient Mathematical Astronomy* (New York, Heidelberg, Berlin: Springer-Verlag).

Price, D. de S., "Gears from the Greeks. The Antikythera Mechanism: A Calendar Computer from ca. 80 B.C.", *Transactions of the American Philosophical Society* N.S. 64.7.

Pritchett, W. K., 2001, *Athenian Calendars and Ekklesias*, ΑΡΧΑΙΑ ΕΛΛΑΣ 8 (Amsterdam: J. C. Gieben).

——, and Neugebauer, O., 1947, *The Calendars of Athens* (Cambridge, Massachusetts: Harvard University Press).

Rehm, A., 1949, "Parapegma", in *Realencyclopädie der classischen Altertumswissenschaft* ("*Pauly-Wissowa*") 18.4, 1295–1366.

Ross, M., 2006, *Horoscopic Ostraca of Medînet Mâdi*, Ph.D. Dissertation, Brown University.

Samuel, A. E., 1972, *Greek and Roman Chronology. Calendars and Years in Classical Antiquity*, Handbuch der Altertumswissenschaft I, 7 (München: Verlag C. H. Beck).

Spalinger, A., 1991, "Remarks on an Egyptian Feast Calendar of Foreign Origin", *Studien zur altägyptischen Kultur* 18, 349–373.

Trümpy, C., 1997, *Untersüchungen zu den altgriechischen Monatsnamen und Monatsfolgen*, Bibliothek der klassischen Altertumswissenschaften N.F. 2. Reihe Bd. 98 (Heidelberg: Universitätsverlag C. Winter).