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BERNARD R. GOLDSTEIN* AND ALAN C. BOWEN**

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*Department of History and Philosophy of Science, University of Pittsburgh, Pittsburgh PA 15260; and Institute for Research in Classical Philosophy and Science, 1314 Browning Road, Pittsburgh PA 15206-1736, USA.

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dated observations by a Greek astronomer are those by Timocharis in Alexandria beginning in -294 and ending in -271: the first 4 report lunar occultations of fixed stars and the last reports the position of Venus.⁴ (Little more is known of Timocharis than that he flourished in Alexandria during the first half of the 3rd century, and that he is the only Greek in the period before Hipparchus who is credited with more than 1 observation.)

The first four of Timocharis' observations are dated according to a day in an Athenian month and a year in the 'First Callippic Period (περίοδος)',⁵ a lunisolar calendar of 76 years, whose epoch is summer solstice in -329 or a day or two later with the appearance of the new Moon. Again the corresponding Egyptian dates are also given. The last two observations, however, are given only in the Egyptian civil calendar with regnal years of Ptolemy Philadelphus. No further observations are reported in either the Athenian calendar or in the First Callippic Period, though there are observations reported in the *Almagest* to begin in -200 and dated in the Second and Third Callippic Periods with Egyptian months only. Again we have puzzles: Why are (only) some of Timocharis' observations dated in an Athenian calendar though he was in Alexandria?, and What is the significance of the epoch of -329 for the First Callippic Calendar? We might also add, What is the reason for making careful observations of lunar occultations, phenomena for which there is no evidence of previous Greek interest?⁶

In this paper we will focus on the following topics: (1) the relationship of Timocharis' observations to Babylonian observational activity, (2) the problem of the transmission of Babylonian astronomy to Timocharis, (3) the distinction between calendars and calendrical cycles, and (4) the relationship of dates in the First Callippic Calendar to the Macedonian and Egyptian calendars.⁷

It may be helpful at this point to summarize our conclusions to serve as a guide through the maze of data to be presented. Timocharis was a Greek in Alexandria in the early 3rd century BC who learned of observational activity in Babylon and was inspired by it to make his own astronomical observations. So far as we can tell, there is, unfortunately, no evidence to indicate the theoretical framework in which he worked, and no evidence that he intended to use his observations to create or modify astronomical theories. Timocharis' observa-

tions are given in years of the First Callippic Calendar whose epoch is 29 June –329, that is, the first new Moon (computed from what we call ‘Parker’s scheme’) following summer solstice in the year in which Alexander assumed the title of Great King. The calendar used for these observations, which we call the First Callippic Calendar, was lunar in the sense that the year began on the first new Moon after summer solstice and contained either 12 or 13 months. Moreover, the intercalary months were determined according to the Callippic cycle of $76 \cdot 365\frac{1}{4}$ days, the day began at sunset, and the lunar month was given an Athenian month name. We will argue that this calendar may not have been used in the original reports; indeed, it may have been invented later in the 3rd century and applied retrospectively to these observations.

I

To solve some of the questions raised here, we must first turn to Mesopotamia where we know of astronomical activity including observations long before Timocharis. There remains the difficulty of accounting for transmission, but some clues can be found that may serve to delimit the date of transmission and its character.⁸ Our immediate goal, then, will be to compare Timocharis’ observations with similar ones from Babylon.

Let us begin with the first observation ascribed to Timocharis, reported in *Almagest* vii.3 [trans. Toomer 1984, 337]:

Again, Timocharis, who observed in Alexandria, says that in the 36th year of the First Callippic Cycle,⁹ on Poseidon 25, which is Phaophi 16, at the beginning of the tenth hour, the moon appeared to occult the northernmost of the stars in the forehead of Scorpius¹⁰ very precisely with its northern rim.

The occurrence of an occultation on the night of 20/21 Dec. –294 is confirmed by modern computation, and this date corresponds exactly to the date given in the Egyptian calendar. Note that the time of night is given in hours (ῥῆραι): these are in fact seasonal hours such that the daytime is divided into 12 equal divisions from sunrise to sunset (the diurnal seasonal hours) and the night into 12 equal divisions from sunset to sunrise (the nocturnal seasonal hours). Though some have

claimed that seasonal hours were known in the Greek world prior to the time of this observation,¹¹ we are convinced that Timocharis' use of ὥρα is the earliest attested example of this meaning of a word which had the relevant sense of 'portion of the year' or 'season' in earlier Greek. It is also worth noting that no unit for measuring distances is given, and that this is consistent with the claim that degrees (i.e., a division of the circle into 360 equal parts) were not introduced in Greek until early in the second century BC as attested by Hypsicles.¹² We will return to the question of the date formula later.

In contrast to the few dated observations preserved in Greek, we have an entire corpus of Babylonian observations that stretch from the 7th century BC to the 1st century BC, known in modern times as the *Astronomical Diaries*. This is only one of many genres of Babylonian astronomical texts, but the decisive one for us in this context.¹³ These diaries contain observations of the Moon, planets, stars, eclipses, as well as information about the weather and historical events of various kinds. This series of observations is thought to go back to Nabonassar in the 8th century BC,¹⁴ and constitutes the longest series of continuous astronomical observations from one place known to us. (Contrast the Greenwich Observatory that recently celebrated its 300th anniversary.) Let us consider an excerpt from a Babylonian diary for -289:¹⁵

Month I[II], the 1st (of which followed the 30th of the preceding month), sunset to moonset: 22°;¹⁶ the moon was [nn cubi]ts in front of Mercury. Night of the 2nd, beginning of the night, the moon was 1½ cubits in front of Venus. [Night of the 3rd], beginning of the night, α Leonis entered the moon. Night of the 4th, be[ginning of the night, ...] when Saturn entered the [northern?] horn of the moon.

The diaries are arranged in sections by month in the Babylonian calendar. The entries for a month begin with a statement concerning the new lunar crescent – whether the preceding month was 29 or 30 days, and the time interval from sunset to moonset measured in time degrees (where 360 time degrees equals our 24 hour day). Distances between celestial bodies are usually measured in cubits (where 1 cubit is most often 2°).¹⁷ Finally, we note that the Moon occulted the star Regulus (= α Leo) on the 3rd night of the month and Saturn on the 4th night of the month.

It would appear, then, that the report of Timocharis' observation is

in the style of a Babylonian observation in a diary; yet the mode of expression is different and no report of Timocharis includes a unit of angular measure. Further, the Timocharis reports use seasonal hours whereas the diaries generally give the time of an event in time degrees. Nevertheless, seasonal hours are attested in other Babylonian texts of the Achaemenid and Seleucid periods, notably the horoscopes.¹⁸ Though it has often been assumed that seasonal hours arrived in the Greek world on analogy with Egyptian usage,¹⁹ we see no reason to prefer an Egyptian origin for Timocharis' use of seasonal hours to a Babylonian one.²⁰

II

We assume that the similarities between the observational reports ascribed to Timocharis and the Babylonian astronomical diaries²¹ are not fortuitous, because dated astronomical observations are absent in the antecedent Greek scientific literature as is the interest in lunar occultations and planetary positions. Thus, we are faced with the problem of accounting for transmission, a problem that would be solved if it could be shown that Timocharis were a Babylonian who moved to Alexandria (the name, however, suggests a family origin in Rhodes²² and there is no testimony tying him to Babylon). In any event, to account for transmission we could posit either an astronomically trained scholar who left Babylon, or a Greek who spent time in Babylon, gained access to Babylonian astronomical lore there, and then passed it on to someone in Alexandria – all this to take place between Alexander's recognition as sovereign of Babylon in –330 and Timocharis' first observation some 36 years later. But in fact there is no candidate for the role of intermediary at that time, though Berosus has often been suggested.²³ We are not helped much by positing that the general idea was transmitted without any details, because we are just as ignorant of the path of transmission from Babylon to Alexandria as we were of the identity of an agent. In sum, there is reason to suppose Babylonian influence on the nature of Timocharis' project, but we cannot specify exactly what was transmitted or how it reached him.

III

We come now to the calendrical information in Timocharis' observations. First we must distinguish calendars from calendrical cycles. A calendrical cycle is a period of time such that a certain number of years is set equal to a certain number of months and frequently to a certain number of days. For example, the Metonic cycle is a period of 19 years set equal to 235 months and 6940 days.²⁴ On the other hand, a calendar has an epoch (or starting point) from which the years are counted, a day that marks the beginning of the year, a definition of the beginning of the month, and a definition of the beginning of the day, as well as an intercalation scheme or an observational decision procedure (for determining the number of months in a particular year) and a calendrical cycle. If most of the elements of 2 calendars agree, we shall call each of them a variant of that calendar. So, for example, there is a Julian calendar in which 1 Jan. is taken as the beginning of the year and a Julian calendar in which 1 Mar. is taken as the beginning of the year; these are distinguished as the Julian calendar new style and the Julian calendar old style.

The calendars used for astronomical observations in the 3rd century BC use Athenian, Babylonian, Macedonian, and Egyptian month names.²⁵ The best example of a calendar which has all the necessary components is the Seleucid Era (S.E.) used by the Babylonian astronomers. It is based on a 19-year cycle in which 7 intercalary months are inserted according to a fixed rule; its epoch is 1 Nisan S.E. 1 ($\approx$ 2/3 April – 310, i.e., the beginning of the first regnal year of Seleucus I);²⁶ the year consists of either 12 or 13 lunar months; the beginning of the month is defined by the visibility of the new lunar crescent, and the day begins at sunset.

For the Egyptians, the civil calendar is defined such that a year consists of 12 months of 30 days followed by 5 epagomenal days; its epoch is 1 Thoth of the year taken to be the beginning of the first regnal year of the current ruler,²⁷ and the day begins at sunrise. This seems fairly straightforward, but we have 2 cases in the 3rd century BC where an Egyptian ruler decided to change the numbering of his regnal years giving the impression that his reign began at an earlier time. We will consider these as variants of the Egyptian civil calendar. There was also an Egyptian lunar calendar which used the same

epoch, the same definition of the year, and the same definition of the day, but which introduced lunar months in a 25-year cycle such that 25 Egyptian years equal 309 months or 9125 days. In this calendar there are sometimes 12 and sometimes 13 new Moons in an Egyptian year of 365 days.²⁸ According to Parker, day 1 of the Egyptian lunar month was defined as the day following last visibility of the old Moon (called by Parker 'the first day of invisibility') and day 2 of the Egyptian lunar month was defined as New Crescent Day.²⁹ On the basis of a late demotic papyrus, Parker reconstructed a fixed scheme for determining day 1 of each lunar month (henceforth, 'Parker's scheme'),³⁰ and he argued that the starting point was 1 Thoth in the year corresponding to 357 BC such that the first day of that year was the first day of an Egyptian civil month as well as an Egyptian lunar month. Since there is no direct evidence for starting the Egyptian lunar calendar in that year, Parker conceded that 1 Thoth in an Egyptian year exactly $n \cdot 25$ years before or after 357 BC would work equally well (though he preferred to limit the values for n to 1 or 2). In the texts that Parker cited the names of the Egyptian lunar months are not distinguished from the names of the Egyptian civil months.³¹

We next turn to dates with Athenian month names. In Athens, the year began with the first new crescent following summer solstice and the year was given the name of the current archon (hence, there is no epoch for the Athenian years, but lists of the archons in chronological order are preserved). In principle, the month began with the new lunar crescent, but in practice there were serious deviations from the astronomical phenomena.³² There was no fixed intercalation scheme and the day began at sunset. In the *Almagest*, Athenian month names appear in several observational reports:

1) 3 lunar eclipses in Babylon for -382/-381 where the year is given by the archon of Athens, the month is given by an Athenian month name, but no day of the Athenian month is stated (though an Egyptian month and day is mentioned);

2) 4 lunar occultations of fixed stars observed by Timocharis where the date is given by a year in the First Callippic Period, an Athenian month name, and a day in the Athenian month (an Egyptian month and day are mentioned as well).

For the lunar-eclipse observations of -382/-381 it is reasonable to suppose that at some time someone translated a Babylonian date into an Athenian year and month and avoided the difficulty of deciding

what day of the Athenian month it was – if these reports have been reliably transmitted.³³

The year in Timocharis' first observation is designated 'the 36th year of the First Callippic Period' which implies that the epoch of this calendar (based on a cycle of 76 years) was –329. Some have assumed that Callippus, while resident in Athens, observed a summer solstice in that year;³⁴ but there is no ancient support for this claim. All the other calendars of this period use regnal years of some sort, and it would be surprising for an astronomer in the 4th century BC to invent an era that had an astronomical but no civil purpose (though this has frequently been asserted). Rather, one should note that this was the year when Alexander took on the title, Great King, and it would be an appropriate epoch to begin counting years (as the Babylonians may have done for a short while).³⁵ In this case, the expression 'First Callippic Period' was applied retrospectively to an era based on the regnal years of Alexander the Great for reasons that may have to do with political affairs in Alexandria (probably under Philadelphus or Euergetes: indeed, the last 2 observations of Timocharis are dated in regnal years of Philadelphus).

The difficulty for Timocharis, if he were to use either a 'real' Babylonian month or a 'real' Athenian month (i.e., as they were determined in Babylon and Athens, respectively), is that of getting information sufficiently current to be of use at the time he was taking an observation. Since the timely arrival of information from either Babylon or Athens is highly implausible, we exclude these two possibilities. It has been posited that he used a schematic astronomical month based on conjunction,³⁶ but this hypothesis rests entirely on these 4 observations and, in the absence of anything comparable in antiquity, seems to be a move of desperation. There remains the possibility, never before considered, that the dates are really Egyptian despite the Athenian names. (We are not aware of any other evidence for the use of Athenian month names in Egypt.) But before exploring this alternative we must examine the calendars with Macedonian month names.

To begin let us note that in some texts (including the *Almagest*) Macedonian month names are used for months in the Babylonian calendar.³⁷ In Egypt, however, the day number in a Macedonian month was sometimes set equal to 1 less than the day number in the

Egyptian lunar calendar, sometimes to the day number in the Egyptian civil calendar, and sometimes it was arbitrarily displaced by a fixed amount from the day number of the Egyptian civil calendar.³⁸ This indicates that the name of a month does not necessarily provide information about the calendar in which it is embedded. Thus, we conclude that the occurrence of Athenian month names in Timocharis' observations does not entail his use of the Athenian calendar.

The various Macedonian calendars in Egypt had in common the use of lunar months with intercalations, an epoch defined by the king's accession, and a day beginning in the evening. Further, the year began on the anniversary of the king's accession. But, a peculiar feature of these calendars in Egypt was that the epoch was not necessarily fixed for an entire reign: Ptolemy Soter decided at some point to begin counting his regnal years from the death of Alexander in -322 instead of from -304 (the year Soter assumed his royal title) as he had done previously; and Ptolemy Philadelphus decided to begin counting his regnal years from -284 (when he became co-regent with Soter) instead of -282 (the year of Soter's death) as he had done until -266. This latter change in epoch affected the report of Timocharis' last 2 observations: these are said to have taken place in the 13th year of Philadelphus where the epoch of his reign is -284. But in that year (-271) the epoch of his reign was still -282. Here, then, is a clear instance of 'retrodating', a practice that is also attested in Egyptian hieroglyphic documents:³⁹ Timocharis' observations, originally taken in year 11 Philadelphus were later dated to year 13 Philadelphus. Moreover, in these cases, the change in epoch of these reigns also involved changing the first day of the Macedonian year.

There were other ways as well in which the Macedonian calendars in Egypt went astray. During the reign of Philadelphus an intercalary month was added every other year⁴⁰ (in fact, this is too often) and, under his successor, Ptolemy Euergetes (-245 to -221),⁴¹ the intercalations became irregular.⁴² From a set of double dates (i.e., dates given in Egyptian documents with both Macedonian months and Egyptian civil months) Samuel has argued that the beginning of the Macedonian months in Egypt was fixed by Parker's scheme such that day 1 of the Macedonian month began in the evening of day 2 of the Egyptian lunar month.⁴³

IV

By modern computation, the first day of the month for all 4 of Timocharis' earlier observations took place a day before the first visibility of the new lunar crescent in Alexandria (see Table 1).⁴⁴ Now it is possible to miss first visibility and to see the crescent for the first time on the following day, but it is not possible to see the crescent a day before it first becomes visible. This implies the use of a schematic calendar for the lunar dates with Athenian month names, and excludes the possibility that Timocharis determined the first day of the month by the visibility of the new crescent. It seems altogether unlikely that Timocharis, whose observations are of reasonably high quality by ancient standards,⁴⁵ would make up a schematic calendar that failed to do the job for the very months of his observations. There is, however, a way out of this difficulty. When we compute the dates for the beginnings of the Egyptian lunar months according to Parker's scheme for the months of Timocharis' 4 earlier observations, it follows that day 1 of the Athenian month is day 2 of the Egyptian month.

Thus, we have the First Callippic Calendar whose epoch is New Crescent Day (as computed according to Parker's scheme) immediately following summer solstice in -329 (Alexander's first regnal year as Great King), i.e., sunset, 29 June -329;⁴⁶ a year of 12 or 13 lunar months beginning on the New Crescent Day following summer solstice each year; and lunar months with Athenian names arranged in a 76-year cycle where day 1 of the month is computed according to Parker's scheme. The reports of these 4 nocturnal observations do not allow one to tell if the day was counted from the morning or the evening (the day number is not affected in these cases); but, given the

Observation Number	Egyptian day 2 ('Athenian' day 1)	Computed New Moon	Date of Observation	Day of the 'Athenian' month
1	-294 Nov. 26	-294 Nov. 27	-294 Dec. 20/21	25
2	-293 Feb. 23	-293 Feb. 24	-293 Mar. 9/10	15
3	-282 Jan. 22	-282 Jan. 23	-282 Jan. 29/30	8
4	-282 Oct. 15	-282 Oct. 16	-282 Nov. 8/9	25

Table 1.

Athenian names and the evening epoch of the Macedonian calendars in Egypt, we assume that the days were counted from the evening. It is clearly impossible to reconstruct the intercalation scheme from these 4 data points, but the use of the Callippic cycle suggests that 7 intercalary months were inserted in every 19 years (as in the Metonic cycle).

We have established that the dates with Athenian month names in the reports of Timocharis' 4 earlier observations belong to a calendar based on Parker's scheme. Now we may ask if the Athenian dates were part of Timocharis' original report, or if they were computed from the Egyptian date at some later time. Given the nature of the evidence, no firm conclusion can be reached. Still it is possible to clarify the alternatives. But this requires addressing two related questions: What is the evidence for double dating and how early does it occur in documents from Egypt?, and When was Parker's scheme introduced and for which calendar?

According to Samuel, double dated documents in Greek papyri with Egyptian civil and Macedonian lunar dates go back to -256, and a demotic papyrus gives a double date in Greek for Philadelphus' Egyptian regnal year 21 (= -264).⁴⁷ Samuel concludes that the correlation of Egyptian lunar dates and Macedonian dates probably was put into practice late in the reign of Ptolemy Soter (d. -281) which we take to be Samuel's *terminus a quo* for the introduction of Parker's scheme in the Macedonian calendar. The earliest double date with Egyptian civil and lunar months cited by Parker only goes back to -236,⁴⁸ which we take to be the *terminus ad quem* for the introduction of Parker's scheme with Egyptian lunar months.

With regard to the time when Parker's scheme was invented and the calendar which it was originally intended to serve, a consideration unknown to Parker or to Samuel (who both assume that this scheme was designed for the Egyptian lunar calendar) is that the month length underlying the 25-year cycle ($25 \cdot 365 \text{ days} = 9125 \text{ days} = 309 \text{ months}$) is for all practical purposes identical to the month length in the Callippic cycle ($76 \cdot 365\frac{1}{4} \text{ days} = 27,759 \text{ days} = 940 \text{ months}$). If one takes the month length of the Callippic cycle, which in decimal form is 29.53085, and multiplies it by the 309 months in the 25-year cycle, the result is about 9125.03 days or very nearly 9125 days. Thus, Parker's scheme could have been derived from the Callippic cycle without any

additional observations. Of course, to turn this cycle into a calendar one would still have to decide on an epoch and an intercalation scheme. But this argument undermines Parker's assumption⁴⁹ that the month length derived from a series of observations in Egypt during the 4th century BC which are otherwise unattested; as Neugebauer put it.⁵⁰ 'Among the enormous mass of Egyptian inscriptions and papyri from all periods of Egyptian independent history there has not been found a single record of astronomical observations.' Since there is no textual evidence for Parker's scheme prior to the 3rd century BC, we see no obstacle for its invention at that time. Moreover, the earliest textual evidence for Parker's scheme, as we have indicated above (excluding the fragments reported by Ptolemy containing the dates of Timocharis' observations), relates to the Macedonian calendar in Egypt; it is therefore possible that this scheme was originally developed for use in the Macedonian calendar to determine the beginnings of the months and later applied to the Egyptian lunar calendar.

The point of this argument about Parker's scheme is that the burden of proof is on an advocate (such as Parker or Samuel) for its origin in the 4th century given that the earliest evidence comes from the 3rd century. It is perhaps worth emphasizing a remark by Neugebauer: since the agreement of the dates in the Egyptian schematic lunar calendar with actual lunar dates 'will vary only very slowly, one cannot exclude a date of origin of the cycle, say, in the fifth century BC' rather than in the 4th, as Parker claimed.⁵¹ The same argument can, of course, be used to defend a 3rd-century date of origin for the scheme as well.

An alternative is to consider that the double dating was part of the original reports by Timocharis. This means that the notion of double dating would be put back to -294. Of course, this also implies that Parker's scheme for the Egyptian lunar calendar was also in place at that time.

An other alternative is that the Athenian dates were added later together with the year in the Callippic Calendar. If the double dates were part of the original report, it is difficult to account for Timocharis' use of Athenian rather than Macedonian month names, and years beginning near summer solstice rather than Macedonian regnal years. The Macedonian and Egyptian calendars were, after all, in civil use; and no problem had yet arisen with them. Moreover, it is unlikely

that Timocharis invented a calendar for the unique purpose of keeping track of dated observations before the series of observations had actually begun.

But after Philadelphus changed his epoch date in -266, one can easily imagine the dissatisfaction with the Macedonian calendar by astronomers who wished to know the precise time difference between observations: it could well motivate one or more of them to replace Macedonian month names with month names which could not be affected by the whims of the Egyptian rulers. The preference for defining the beginning of the year in the Athenian manner may account for choosing Athenian month names. The introduction of a way to count the number of years from an epoch that is independent of the current ruler would also make it possible to date astronomical phenomena that are calculated in advance without awkwardness when the ruler is replaced. (Nevertheless, we have found no evidence of astronomical phenomena calculated in this way during the 3rd century BC in Egypt.) Further, the intercalation scheme in the Macedonian calendar was clearly faulty and the problem was noticed early in the reign of Euergetes. Hence, it is more plausible that the original reports only contained dates in the Egyptian civil calendar.

It follows that if Parker's scheme had not been introduced at the time of Timocharis' earlier observations, he could not have used it, and so the lunar dates were added later by someone familiar with the scheme. To change dates from the Egyptian civil calendar to dates in the First Callippic Calendar requires that one determine the beginning of the lunar month following summer solstice with respect to the Egyptian civil year, the number of years since Alexander took the title, Great King (the epoch of the First Callippic Calendar), and the intercalary scheme in the Callippic cycle. To determine day 1 of a lunar month one need only have recourse to the sort of scheme presented by Parker and take day 2 of the Egyptian lunar month as day 1 of this 'Athenian' month. (The use of the same length of the lunar month in the 2 calendars ensures that this transformation will work.) All the requisite information was readily available when the problems with the Macedonian and Egyptian calendars arose in the middle of the 3rd century BC. Accordingly, we see no reason to date the invention of the Callippic Calendar before the middle of the 3rd century BC. In that case, we may have the Callippic cycle at the end of

the 4th century BC, which then served for the construction of the Egyptian Macedonian calendar in the middle of the 3rd century BC, followed by the Egyptian lunar calendar and Callippic Calendar perhaps somewhat later in the 3rd century BC. Egyptian civil dates in the past could then have been transformed into either the Egyptian lunar calendar or the Callippic Calendar by means of a simple set of rules.

Further, we tentatively suggest that the First Callippic Calendar was invented in Egypt some time between -266 and -237; and not in the 4th century BC in Athens by Callippus who, we think, was only the discoverer of the 76-year cycle that bears his name. Criticism of the Egyptian civil calendar for failing to maintain the correlation of particular months with the seasons is expressed for the first time, as far as we know, in the Canobic Decree promulgated in Greek, demotic, and Egyptian hieroglyphic, and dated to the ninth year of Ptolemy Euergetes' reign, i.e., in -237.⁵² This criticism entails an attack on the use of Parker's scheme in both the Macedonian and the Egyptian lunar calendars; yet only the length of the solar year is attacked directly. It has been assumed that this decree had no effect at the time of its promulgation because its recommendation to add a 366th day to the Egyptian year once every four years was not heeded until the 'Alexandrian' year was introduced by Augustus in -25.⁵³ The earliest occasion for disappointment with the Egyptian Macedonian calendar may have arisen when Philadelphus changed the epoch of his reign in -266. Since the First Callippic Calendar successfully accounts for both the solar and the lunar motions, we think it can be seen as a response to criticism of the calendars in Egypt that may go back to the latter part of Philadelphus' reign or the early years of Euergetes' reign. The Decree only dealt with correcting the year length, and did not address the lunar calendar that was invoked in fixing important cultic events such as the anniversary of the king's accession. It is this inability to provide a revision or replacement to Parker's scheme for determining the lunar months that, in our view, was the reason for the failure of Euergetes' calendar reform. The basis for his reform may have been the year length in the Callippic cycle, and this is consistent with borrowing one element of the First Callippic Calendar. But Euergetes may have been unwilling to accept the First Callippic Calendar in its entirety because it would have meant abandoning his epoch and regnal years as well as the Macedonian way of fixing New

Year's Day. If this is correct, the *terminus ad quem* for the introduction of the First Callippic Calendar is -237, the year of the Canobic Decree.

V

We have not described Timocharis' purpose for taking these observations because this demands further analysis of the context for astronomy in the early Hellenistic age and deserves separate treatment. So we conclude that knowledge of Babylonian observations as represented in the Diaries and related texts reached Alexandria at the beginning of the 3rd century BC, that Timocharis began making observations that were similar to some kinds of Babylonian observations, and that in the original reports the time was stated in seasonal hours of the night of an Egyptian civil month. It is also possible that a lunar dating of some sort was part of the original report, but it seems unlikely to us because the definition of the month follows Parker's scheme and it is not clear that it had been invented at that time.

In conclusion, we now return to the earlier Babylonian observations cited in the *Almagest* and to Timocharis' observation of Venus. There is no indication of the period when the Babylonian observations were transmitted to the Greek world, and they need not all have arrived together, i.e., the earliest observations may have been the latest to arrive. In particular, the 3 Babylonian lunar eclipses of the 4th century that are dated with Athenian month names need not have been transmitted before Timocharis, and the substitution of Athenian month names for the original Babylonian ones may have taken place in Alexandria. It is tempting to suggest that an astronomer interested in observations of the Moon was responsible for the invention of the Callippic Calendar to which he converted Timocharis' 4 earlier observations. Since the epoch of this calendar is after the 3 Babylonian eclipse observations, he converted their Babylonian dates by substituting Athenian month names for the Babylonian ones and replacing the Babylonian regnal years with Athenian archon years. In each case he used Athenian month names because Macedonian month names were already embedded in a calendar of dubious quality.⁵⁴ This astronomer may not have been interested in planetary observations

and so he left Timocharis' observation of Venus in -271 in the Egyptian calendar. In that case, someone else decided to 'modernize' the dates of Timocharis' Venus-observations by adjusting the regnal years of Philadelphus to conform to the later norm according to which year 1 Philadelphus began in -284 . Subsequent astronomers, observing in the Second and Third Callippic Periods, abandoned the use of this Callippic lunar calendar with its Athenian month names. For them the Callippic Period was simply a way to count years and days according to the Egyptian civil calendar using the period of 76 years and the epoch of the First Callippic Calendar. In effect, they introduced a variant of a previously established calendar, the Egyptian civil calendar.⁵⁵

Postscript

Ptolemy is not to be reproached for any deficiencies or inconsistencies in Timocharis' observational reports, because he could do no better than preserve what his sources recorded. Indeed, Ptolemy suggests that all this information was transmitted by Hipparchus, but we do not know the form of these reports prior to the *Almagest*. In any event, historical accuracy was not the goal of ancient astronomers, but rather that the astronomical facts be put in a usable form.⁵⁶ One should always be cautious in dealing with fragments that seem to preserve the works of an ancient scientist, such as Timocharis, which do not otherwise survive because we are unable to control the distortions (intentional or not) that may have accumulated in the course of time.

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1. There are certainly 32 such reports in the *Almagest*, and Toomer [1984, 133n8] has argued that 3 observations of autumnal equinox in -161 to -157 [*Almagest* iii.1] were probably taken by a predecessor of Hipparchus. (Note that instead of years BC, the astronomical system of negative years is used here, where year 0 corresponds to 1 BC, year -1 corresponds to 2 BC, etc.).

2. Strassmaier Cambyzes 400 (note that this text is not an astronomical diary): see Kugler 1907–1924, i 61 ff., and van der Waerden 1974, 89. On the basis of these reports and Strassmaier Cambyzes 400, it is now generally acknowledged that Ptolemy had access, probably indirectly, to Babylonian observational reports.
3. The locution, οἱ περὶ Ἀρίσταρχον (cf. Ptolemy, *Alm.* iii.1 [=Heiberg 1898–1907, i 203.10, 206.5–6]), is difficult, as Toomer (1984, 137n19) acknowledges. Though it is normally translated 'the school of Aristarchus', such a rendering probably suggests too much. The usual alternative, 'the followers of Aristarchus', is preferable, though perhaps not as good as 'the Aristarchans'. In any event, one should bear in mind that such followers who may be contemporary with Aristarchus or subsequent to him, may be defined by no more than their sharing assumptions or procedures with Aristarchus, who was notable in his time. Moreover, the modern historian should hesitate to assume that what is attributed to the Aristarchans also holds of Aristarchus: such an identification requires more evidence than the locution οἱ περὶ Ἀρίσταρχον, since there are many cases in which the 'followers' departed dramatically from their 'hero'. Such is the case with Plato and his 'followers', for example. Note, however, that Ptolemy does make this identification: cf. τὴν ὑπὸ Ἀριστάρχου at Heiberg 1898–1907, i 206.26.
4. The first 4 observations of Timocharis from -294 to -282 appear in *Almagest* vii.3, and it is clear that Ptolemy's source is Hipparchus [see Toomer 1984, 329]. Ptolemy uses these observations to determine a value for precession. The last observation of Timocharis, taken in the '13th year of Philadelphus' (= -271), appears in *Almagest* x.4 and probably comes from Hipparchus as well [see *Almagest* ix.1: trans. Toomer 1984, 421].
5. Toomer [1984, 138] translates such phrases as τῆς πρώτης κατὰ Κάλλιππον περιόδου [Heiberg 1898–1907, i 206.5–6] by 'of the First Callippic Cycle'. But, since it is useful in analyzing chronological schemes to distinguish (calendrical) cycles and calendars [see below], rather than follow Toomer and others in rendering περιόδος as 'cycle', we will translate this term as 'period'. Moreover, since it is our view that the First Callippic Period was in fact a calendar, we will generally refer to it as the 'First Callippic Calendar'.
6. For an isolated report of an undated planetary occultation, see Aristotle, *Meteor.* 343b25–35.
7. We postpone to another occasion discussion of Timocharis' undated observations of stellar declinations reported in the *Almagest* vii.3.
8. In his account of this transmission, Fotheringham [1933] accepts a fragment of Hipparchus preserved in Theon of Alexandria's commentary on book 3 of the *Almagest* [see Rome 1943, 838–839] according to which Callippus of Athens derived his values for the length of the year and the length of the mean synodic month by comparing Babylonian observations with his own [1933, 40]. This view is endorsed by van der Waerden [1974, 290], but emphatically dismissed, with sound reasons, by Neugebauer [1975, 602]: 'Theon's story is obvious nonsense.' For the deficiencies in other accounts of this transmission (both ancient and modern), see Neugebauer 1975, 608–610.
9. *scil.* Period: cf. n5 above.
10. *scil.* β Sco.
11. According to Rehm [1913], the earliest references to seasonal hours are to be found in Aristotle and a fragment of Pytheas of Marseilles (ca. -330). However, ὥρα does not mean 'seasonal hour' in the passage cited in Aristotle [*Atheniensium Respublica*, 30.6]: 'Any

member of the Council who did not enter the Council-house at the time (ὥραν) named should be fined a drachma, unless he was away on leave of absence from the Council' [trans. Kenyon 1921]. As for the fragment of Pytheas preserved in Geminus *Intro. ast.* 6, it is by no means certain that the quotation from Pytheas includes the expression in which seasonal hours appear: cf. Aujac 1966, 43.

12. Cf. De Falco, Krause, and Neugebauer 1966, 47; Neugebauer 1975, 590.
13. Cf. Sachs 1948; Sachs and Hunger 1988, 11.
14. Cf. Sachs 1974, 44.
15. Sachs and Hunger 1988, 277. Parentheses in the translation indicate material added by the editors as an aid to the reader; brackets enclose the editors' reconstruction of text missing in the original; ... means that an indefinite number of words is missing; and [nn] means that a number is missing.
16. *scil.* 22 time degrees.
17. Sachs and Hunger 1988, 22. The cubit appears as a measure in a Babylonian observation of Mercury in -244 that is cited in the *Almagest* ix.7. For further discussion of the cubit as a measure of arcs in Babylonian and Greek astronomy, see Toomer 1984, 322n5.
18. Pingree and Reiner 1974-1977; Rochberg-Halton 1989.
19. Cf. Neugebauer 1957, 81.
20. A more subtle point about Greek astronomical observations in the 3rd century BC concerns the names of the planets. In addition to the divine epithets attached to the planets, there are such names as 'Shiner' (*Phaethon*) for Jupiter and 'Gleamer' (*Stilbon*) for Mercury, i.e., names that pertain to some physical characteristic ascribed to a planet. These names are not found in Greek texts before the 3rd century BC, and Cumont [1935, 19 ff.: cf. Stieglitz 1988] claimed that they betray a Babylonian origin, once again pointing to a transmission of Babylonian astral lore in the early Hellenistic period.
21. We are informed by Professor F. Rochberg-Halton that in addition to Strassmaier Cam. 400 (see n2 above) there are other non-diary texts extant containing observational reports, and that some of these reports are earlier than the diaries.
22. Frazer 1972, i 63, ii 146.
23. See, e.g., Cumont 1935, 23; Stieglitz 1988, 446. But, while Berossus' time is approximately correct for this transmission, he can no longer be considered the agent because, as has recently been shown [see Kuhrt 1987, 36-44], Berossus is only known for his history of Babylonia whereas the astronomical and astrological remarks ascribed to him belong in fact to a pseudo-Berossus who probably lived in the 1st century BC. We are aware that new sources for early Greek astronomy may still be found, especially in papyri and in Arabic translations of otherwise lost Greek treatises [see, e.g., Toomer 1985]. But nothing relevant to the question of transmission has yet been identified, as far as we know.
24. See Bowen and Goldstein 1988, 41-51.
25. For present purposes we exclude the zodiacal month names in the Era of Dionysius used in some observational reports in the *Almagest* [see Toomer 1984, 13-14].
26. See Parker and Dubberstein 1956, 20 *et passim*.
27. There is some question in a number of cases whether the first regnal year is antedated or postdated, that is, whether the first regnal year is to begin with the 1 Thoth that respectively precedes or succeeds the actual day of accession. See n45 below.
28. See Neugebauer and Volten 1938, especially 397; cf. Neugebauer 1975, 563, 815-817.

29. Parker 1950, 11, 23.
30. In principle, this scheme may be applied to any lunar calendar.
31. The scheme for lunar months preserved in P. Carlsberg 9 serves as the basis for Parker's scheme [see Parker 1950, 25, where the scheme that Parker reconstructed is presented in the form of a table], and this demotic papyrus dates from the 2nd century AD. In another version of the same scheme (preserved in a Greek papyrus, P. Rylands Inv. 666, dating from the 2nd century BC) year 1 in a 25 Egyptian year cycle corresponds to year 2 in the Carlsberg scheme, but otherwise the two schemes are the same [Neugebauer 1975, 817]. Hence, for example, summer solstice in -329, fell in year 2 of the Carlsberg scheme but in year 1 of the Rylands scheme. For double dates involving days of a lunar month in Egyptian texts, see Parker 1950, 17–22.
32. See Bowen and Goldstein 1988, 67.
33. That is, he did not simply equate the day number of the Babylonian month with the day number of the Athenian month.
34. See, for example, van der Waerden 1974, 290.
35. Cf. Parker and Dubberstein 1956, 19.
36. Van der Waerden [1983–84, 121] cites Fotheringham [1924] and rejects Neugebauer's criticism: 'One can safely dismiss as completely unhistorical the concept of a calendar supposedly made for the astronomers alone but nowhere attested in astronomical records' [Neugebauer 1975, 617].
37. Cf. Toomer 1984, 13.
38. Samuel 1962, 34–37.
39. Samuel 1962, 11–24, 66, 70. See n45 below.
40. Samuel 1962, 30, 74.
41. Samuel 1962, 168.
42. Samuel 1962, 101–105.
43. Samuel 1962, 56.
44. Using a computer program for the planetary positions devised by Peter Huber, we found the dates of new Moon in Alexandria immediately preceding the observations by Timocharis. If the month began at first visibility of the new crescent in Alexandria, Observation 1 would fall on day 24 (text: day 25 of Poseidon [Toomer 1984, 337]); Observation 2 would fall on day 14 (text: day 15 of Elaphebolion [Toomer 1984, 335]); Observation 3 would fall on day 7 (text: day 8 of Anthesterion [Toomer 1984, 334]); and Observation 4 would fall on day 24 (text: day 25 of Pyanepsion [Toomer 1984, 336]). But if we begin the 'Athenian' month with day 2 (called New Crescent Day) of the appropriate Egyptian month in Parker's scheme, we get exact agreement with the text (see Table 1: note that Egyptian dates have been converted to Julian dates for convenience).
45. Cf. Britton 1967, 107 ff.
46. This has been computed for year 2 in Parker's scheme. It so happens that new Moon did occur in the evening of 29 June -329 according to Huber's computer program [cf. Parker and Dubberstein 1956, 36].
47. See Samuel 1962, 64–68. In addition, a stele in Egyptian hieroglyphics that includes dates up to Philadelphus' regnal year 21, has a double date in Philadelphus, year 6 [= -279: cf. Samuel 1962, 68–73]. This is a clear instance of retrodating because at the time of the event recorded in Philadelphus, year 6, it would have been called Philadelphus, year 4. Samuel

- [1962, 68 ff.] acknowledges the retroactive dating of the year, but assumes that the double dating goes back to the event. If we eliminate this doubtful case, the earliest double date cited by Samuel is from -264, two years after the reform of the epoch for Philadelphus' reign.
48. See Parker 1950, 21.
 49. Parker 1950, 17.
 50. Neugebauer 1975, 560.
 51. Neugebauer 1975, 564.
 52. See Dittenberger 1903–1905, i 102–104 (= OGIS 56: 34–46): we are preparing an English translation of the Canobic Decree for publication in the near future. Euergetes came to the throne on 29 Jan. -245 and 'this date was used in some calendaric systems to begin the Macedonian regnal year' [Samuel 1962, 106]; hence his ninth regnal year began in -237 [cf. Bickerman 1980, 41]. However, in the King List preserved by Ptolemy, year 1 Euergetes began on the preceding Thoth 1 (= -246 Oct. 24): see Toomer 1984, 10–11.
 53. Cf. Bickerman 1980, 49; Neugebauer 1975, 1066.
 54. The 3 Babylonian planetary observations dated between -244 and -228 (cited in *Almagest* ix.7, and xi.7) belong to a separate story of transmission: in these cases Macedonian months in the Chaldaean Era are just Babylonian months in the Seleucid Era and are unrelated to the use of Macedonian month names in Egypt.
 55. Cf. Toomer 1984, 13.
 56. '[Hipparchus] did not even make a beginning in establishing theories for the five planets, not at least in the writings which have come down to us. All that he did was to make a compilation of the planetary observations arranged in a more useful way' *Almagest* ix.2 [trans. Toomer 1984, 421]. See also n4 above.