What did the boys from Cyzicus, and their leader from Cnidus, do? My talk today is mostly a philosophical look at some issues in the history of observation, but I will look at some biographical issues as well. I shall be arguing for some sceptical theses, to mark off what we do not know and to emphasize what is likely. Many discussions in the history of astronomy in the 4th century, I fear, have taken on a theological tone. If such and such is possible, it must be so, especially if it is consistent with our prior ideology. In this, as in so many other academic fields, we have the grand pendulum. One hundred years ago, the boys from Cyzicus were doing careful observations to build astronomical theories. Today, in the words of one, dare I say, theologian, they made no observations at all and took what pittance they had of data from Babylon. As with music, between the heavy romantics of a hundred years ago and the minimalists of the present, I tend to prefer something in between, although I can still admire both. I shall also be concerned with evidence and how we read evidence. I sometimes read claims of the form, "there is no evidence for p," where this is clearly false. Even bad evidence is evidence. Even if we take a normative view of the application of 'evidence', the alleged 'bad' evidence is usually not as bad as some of the plausibility arguments that we find. After a brief preamble, I shall make some biographical remarks and then will turn to some issues about observation, data, and evidence.

§1 The Boys from Kyzikos, the horrors of biography

First some names and dates. The leader of the group was Eudoxos of Knidos. Those for whom we have some testimonia include: the mathematician brothers from nearby Alopekonnesos or Proikonnesos, Menaikhmos and Deinarkhos, and the astronomers from Kyzikos: Kallippos, Helikon, and Polemarkhos. We tend to focus on the grander work that they did, but probably the most important for them was constructing calendars, descriptions of the relative positions of fixed stars in constellations of fixed stars (perhaps ultimately on Aristotle's beloved bronze sphere, as someone once suggested to me), and parapegmata, inscriptions that allow one to mark off with a peg the days of the year with matching regular events, mostly celestial with weather. Here is one from Miletos at the end of the late 2nd cent. BCE. I suspect that an inscription listed in the inventories at Delos was the parapegma of Eudoxos. Both descriptive and mathematical geography were also concerns. In addition to looking at qualitative features of the heaven, they also sought to produce explanatory models of celestial movement (the famous models of Eudoxos and Kallippos) and probably tried to construct physical representations of the movement, although this is less clear. Did they try to make predictions? The evidence is strong, but controversial. My main concern today, however, will be with observations. To what extent did they make and encourage their Akademic colleagues to make systematic observations. That they made observations is apparently in dispute, but not in question!

Most recent literature on Eudoxos' life curiously takes the biography of Diogenes Laertius quite uncritically. I have little problem with this, except to note that it does seem to me, in my ignorance, to be unusual, and, secondly, that any analysis of the biography should take into account the rival sources that Diogenes collates, Callimachus, Sotion, Favorinus, Apollodorus, Nicomachus (a.k.a. Aristotle), as well as a pupil, Chrysippus son of Erineus. Are the sources consistent? Is the *Reminisces* of Chrysippus the principal source for the others? If so, we are, perhaps, on descent ground, but still need to work out the ideological proclivities of these sources. Well, I shall accept that Eudoxus went to Egypt as a young man of 23 (of how many others do we accept claims of foreign travel in Diogenes?), that he studied astronomy there for 16 months and then went, very successfully, on the lecture circuit. After picking up a coterie in Cyzicus, they all travelled to Athens and the Academy. And they seem to have spawned some descendents, enough that Autolycus of Pitane is probably of their ranks, and so too the unnamed targets of Epicurus' rant on solar modeling, as David Sedley argued. Given that Helikon spent time in Syracuse and that we have a report of an observation made there in 330 BCE, it is plausible that Pheidias, the father of Archmedes, as an intellectual descendent.

First, I would like raise some sceptical issues about dates. We really have very little that is reliable. I won't spend much time on this issue but will mention some highlights, as this is another topic. It is remarkable in recent literatrue that it is so widely accepted that the group's leader, Eudoxus, was born in 491/0. Unfortunately, if we were to spend time on the argument for this, we would see that it is based on plausibility arguments that are as flimsy as any you might find. I will point out some of the weirder suppositions. We can make precise the year Eudoxus went to Egypt from the letter of recommendation that the Spartan king Agesilaos wrote for him, namely that he would not have written the letter during the years he was ill and out of history (376-71), i.e., lame, but not comatose, nor when he was busy defending Sparta (370-67)--these monotasking Spartan kings, that he would only have written a letter when visiting Mausolos after 366. De Santillana follows Jaeger in taking the physician Khysippos who went to Egypt with Eudoxos to be his student, the son of Erineus. However, he also tacitly assumes that they were the same age! Why? I am happy to go over more of these arguments if you like. My inclination for the birth of Eudoxus remains 395-390, but I would not insist on the precision of this. He lived to 53, that is to approximately 342-337, again with the same lack of insistance on precision.

It used to be the case that Eudoxus was head of the Academy when Aristotle arrived, as reported in the *Vita Aristotelis* (the Latin and Marciana versions). It has been suggested, wrongly, I believe, that this is a confusion, and that the text actually was referring to Aristotle's arrival in the Academy in the archonship of Euboulos or Euboulides (394/3, a year that curiously pops up in another context of Eudoxan doxography). In an unpublished note that I am

reconstructing from memory (I apologize), Wilbur Knorr gave the right explanation. *Vita Aristotelis* is a defense of a Platonizing Aristotle and so cites an author who wants Aristotle to have as little to do with Plato as possible. There are two versions of this, but the Latin translation is very confused, since it needs to have Aristotle doing three stints of education rather than two (one with Socrates and one with Plato—this is not a joke). So the translator accuses the mendacious biographer placing Aristotle literally in the cradle of the Academy. Thus the liar is a super-Platonist. We expect the reverse. According to the *Vita Marciana*, the mendacious biographer is an anti-Platonist. Aristotle didn't arrive in the Academy in his youth, he was 40, and it was in the time of Eudoxus, that is, Plato wasn't even around when Aristotle arrived. In the light of this, it is hard to say that Eudoxus was ever acting head of the Academy. But it is also possible that our unnamed peripatetic knows something. I don't think, however, that we are ready to throw out Diogenes Laertius for the sake of this. By the way, that the *Vita Aristotelis* is Chock Full O' Error. But that is another story, as well.

We also find a common claim that since the Callippan solar/lunar cycle begins in 330 BCE that this is the year that Callippus published this work AND his revisions of Eudoxus' astronomy. Certainly, the latter is an odd assumption, albeit a common one in the world of fragment scholarship, that people develop all their work at once and publish it all together. But even the date for the creation Callippan calendar is suspect; namely, why do we think someone must begin a calendrical cycle in the year they publish it? I note that a scholion published by Alex Jones puts the beginning of a 19 year Eudoxan cycle as 394/3 (the year of his birth?), certainly before he was an active astronomer. The virtue of the Callippan year is the coincidence of the solstice with the new moon, not a publication date. I note that this might lead some plausibly to suggest that the publication of the calendar was later than 330. In fact, If Goldstein and Bowen are right that the epoch begins with the Great Kingship of Alexander, a coincidence too good to be wrong, its invention should be later. In any case, it tells us little about the date of Callippus' astronomical theory, and nothing about the date of *Met*. 12.8, which discusses it. I say, "little" because it is very likely that Callippus' modification of Eudoxus' astronomical models pre-dates his parapegma. For Simplicius says that he modified the solar theory in order to make it consistant with the lengths of the seasons of Euctemon and Meton. Surely, he would have modified it to fit his own theory if he had it. If the calendar arose from similar considerations, then it might also predate the calendar. But this is speculation that indeed adheres to the historical principle I just ridiculed.

It has also been argued that we can infer something about the birth year of one member of the school from his being the student or grandstudent of Eudoxus. Again, it is, I believe, silly to suppose anything about the relative age of students and teachers, except that they should be contemporaries, one usually, but not necessarily older than the other.

We are on slightly firmer ground with observations and celestial events.

§4. The Elephant in the Room: Babylon vs. Egypt vs. Greece

The Greeks did not invent astronomy whole cloth. This is obvious. The names of most constellations come from Babylon, as well as the division of the zodiac into twelve parts, and if the equal division of the zodiac is 5th century BCE Babylon, the Greek division, whether a 100 years later or 150 years later, one of many disputes, would also be Babylonian. More controversial is whether some other endoxa are Babylonian, such as the 19 year Metonic cycle or the rule that there are more full, 30 day months than hollow, 29 day months. Herein lies a well known difficulty for the 4th century BCE and the boys from Kyzikos.

Eudoxos chose to Egypt in the reign of Nektanebo I and lived in Heliopolis to study astronomy and make observations (according to Strabo, but in a very dubious discussion). If Babylon was the hot spot and Egypt was second rate, why go to Egypt? As a talented citizen of Caria, surely it would have been easier to for him to get a letter of recommendation from his Satrap Mausolos for study in Babylon than to get one from the king of Sparta Agesilaos for study in Egypt, possibly through Mausolos.

That said, we know nothing of Egyptian astronomy. It is thrilling to quote Neugebauer's infamous, "Egypt has no place in a work on the history of mathematical astronomy (HAMA, p. 559." The most Neugebauer allows to the Egyptians is a 25 Egyptian year lunar calendar from the 4th cent. BCE[1] and the adaption of Babylonian methods in the Hellenistic Age. Yet, we must assume more to make the biography minimally plausible, in addition to the evidence in Aristotle, for which Eudoxos must be the conduit. In other words, it is reasonable to suppose that the Heliopolis priests took up Babylonian styles earlier in the Persian period, enough so to make it attractive for Eudoxos to opt for Heliopolis over Babylon. Why none of this survives is a question for papyrologists and not for little me? It is troubling, perhaps damning, for this thesis that Ptolemy does not use a single Egyptian observation made before the Ptolemies.

§3. Disputations and Agreements

Let me be clear about some matters at the outset. Whatever the boys from Kyzikos did, they could not engage in systematic, observation at all comparable to that of the authors of the Babylonian Diaries. For one thing, the total time under consideration isn't more than 40 years or so, quite different from the hundred of years that the Diaries cover. Secondly, one gets the impression that people did a lot of travelling. This is not deadly to consistent observation, but it does make it more difficult. On the other hand, if one can justifiably see oneself in an estabished

[1] The calendar, text from a Roman period papyrus P. Carlsberg 9, involves 136 pairs of months at 59 days, 5 pairs of months at 60 days, and 9 triples of months at 89 days for a total of 9125 days over 309 months or 29.5307 days per month. In standard terms, this is 164 full months and 145 hollow months. Egyptian years are 365 days.

tradition, one can augment the past. We shall see that Aristotle sees himself in this way. Even if they did engage in observation and were in a tradition, it is something quite different to say that they engaged in any systematic observation and theory building from observation? That question remains.

Secondly, no one should dispute that there must have been transmission in the 5th and 4th century from the Babylonian world to the Greek world. The question, as always, is of what? What do we use as evidence? If Egypt was the place to for a Greek to study astronomy in the 4th century, perhaps the transmission is merely indirect.

Finally, we can all agree that later writers tend to read their interests and distinctions and practices into earlier philosophers. The calling card of a post-Ptolemaic planetary theory is the establishment of stations and retrogradations. Bowen and Goldstein are right to ask whether Simplicius projects this onto a 4th cent. BCE theory of planetary motion. However, once we recognize this, we can ask how does this affect any interpretation? For example, is it plausible that someone would not see retrogradation who is looking at the movement of Mars relative to Spica. At the same time, is it implausible that the phenomenon might not have been worthy of modeling? We all know, in addition, that an argument that something could be done in a way different from our late sources does not thereby entail that the alternative is plausible.

A basic issue in dispute is whether non-technical evidence should count as good evidence. Here I am at a loss. One needs to treat every case on its own. As a general rule, owever, on the absence of contemporary technical evidence, we should take seriously contemporary literary evidence while recognizing the constraints of the evidence. This does not mean that we should accept it uncritically. I wish this were a platitude.

When absence of evidence is not evidence of absence, tempered scepticism is the wisest policy. To often we find in contemporary discussions two dogmatic vices, one where the absence of evidence is a free pass to anything, the other, my concern, where the absence is a blanket denial of the possibility of a practice. In fact, we are not dealing here with complete absence, just a very weak presence.

I also assume two other matters. First, Athenians in the 5th century, and I suppose even Kyzikans, used the acrophonic numerical system. As a result, they had only really crappy ways of representing fractions. This is not unimportant in understanding why a period would be described in whole numbers and not say, as an amount plus a fraction in a given year.

Secondly, the Athenian calendar was also pretty crappy. Even if Ptolemy had a date in the Athenian calendar, he wouldn't really want to use it, as that would require an Herculean research project into the lengths of years.

§4. Dates: a Warm-up

Let us turn to what they did. My issue is whether the Kyzikans engaged in observations and of what sort. So to warm us up, let us recall the work of the forgotten 17th century philologist and somewhat backwards historian, Gerhardt Froschstern, who argued in his dissertation, *Calendarium in Historicos Graecos*, that the Athenians in the 5th and early 4th century did not date events, that any interest in dating events was an innovation of the mid-4th century, as we see in the orations of Aeschines and Demosthenes. His argument is instructive. In no 5th century orator are dates mentioned; nor in any historian of the 5th to 4th cent. except Thucydides. And here only two Athenian dates are mentioned, 14 Elaphebolion (4.118.12), the date of the truce with Sparta of 423 BCE, which we also learn is 12 Cerastius in the Spartan calendar, and 6th from the end of Elaphebolion (5.19.1), a translation of the Lacedaemonian date (4.119.1), the 4th before the end of Artemision, for the treaty of 421 BCE. A further, pseudo-Lacedaemonian date also appears in Thucydides (5.54.3) for 419 BCE, the 3rd to last day of the month before Carneus, noteworthy since the Spartans extended the date over several days to avoid making war during Carneus. So, in effect, the only Athenian dates are translations of Spartan dates. Spartans may have dated events; Athenians did not. There we are.

Of course, we know that this is all hogwash, that Froschstern did not look at inscriptions. How could he, tucked away in the Sud Königsbergliche Akademie der Theologie und Astronomie? Okay, so this is just a parable, and at least the Greeks here get the bad joke. But the joke is instructive. If we look carefully at the three dates, the third is a kind of joke; the Spartans extended a date to avoid a sacrilage, their favorite pastime of looting and pillaging during the Spartan sabbath. The other two dates are parts of the peace treaties.

In fact, my beloved scholar is not quite right, there are dates in orators earlier than Aeschines and Demosthenes, but it are rare, i.e. Antiphon (*De choreuta* 44.2.5), and so the point about dates in literary authors is dead right. Athenian society was obsessive about recording dates, even if, perhaps, less so in the 5th century than the second half of the 4th, where or example, Cynthia Schwenk[2] lists 141 fully dated inscriptions for 338-322 B.C., the last 17 years of Aristotle's life. This gets reflected in 4th century oratations, which often quote or cite laws and decrees with their dates. As the works of Xenophon and Thucydides illustrate, literary works have no such compulsion.[3]

Nowhere is this more clear than in the writings of Plato and Aristotle. There are no dates in Plato. As for Aristotle, there are no dates in the *Politics* nor indeed any of his more theoretical writings, and, except for the *Meteorology*, not even a month. Months do appear in the data

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2 Athens in the Age of Alexander (Chicago: Ares, 1985),

3 There are dates cited in the fragments of 4th cent. historical writers, e.g., Phanodemus, Theopompus, Hellanicus, and Callisthenes.

collection of the *Historia Animalium*, but no dates, although there are references to celestial events as time keepers, the rising of Arcturus, the soltices.[4] And for obvious reasons. Celestial events are tied to the solar year in ways the Athenian calendar barely approximates. Dates (text 4) only appear in the *Constitution of Athens* (32), albeit not in abundance, namely three dates, all in the same discussion about the establishment of the oligarchy in 411, and here there is a reason, a momentous event, namely the dissolution of the democracy (date 1) followed by the installment of the oligarchic Council of Four Hundred (date 2) before the completion of the term of the regular Council and the normal installment of a new Council (date 3).

Moral of the Prologue: It is unwise to infer on the basis of literary texts that the Athenians were not enthusiasts of dating events. We need to be senstive to when absence of evidence is not evidence of absence.

In particular, the fact that dates do not show up in 4th reporting of celestial events is not, by itself, good evidence that no one ever noted the dates of celestial events.

§4. Some Classifictions

I find that there are 4 useful ways of classifying the times of observations and three for speaking about the locations of observed stars or events

1. No Time in the report. This is most of the observations we find in Aristotle. For example, some odd feature of a star or an odd event. Sometimes an event is mentions, the location of a constellation at culmination without any time other than, when it culminates. Strictly, these might not be observations at all, but generalizations based on an observation.
2. A contrast of two events at different times, without times being mentioned. One mentions that a comet did one thing and later disappeared
3. A tracking of times with perhaps difference in times being mentioned. The most famous example of this is Aristotle's egg experiment, but we do find events tracked in, e.g., the *Constitution of Athens*, but more to our point, of comets.
4. Events fixed by an absolute dating system. As explained, we do not typically find precise dates even in 4th century literary texts, except for oratory and the *Constitution of Athens* and fragments of historians. However, the year, season, or month are common.

These may be precise or imprecise. So even if a date is not given, the time might be, or vice versa, or something much more vague, such as the year or the month.

I distinguish for locations the following:

1. No location in the report
2. Locations relative to other objects, e.g., a star in Gemini.

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[4] *Hist. An.* VI 29.578b13; V 8.542b6, 9.543a11

3. Locations relative to some standard object treated as the origin for an absolute system, e.g. the equinoctial line, or the north. Longitude measure is not 4th century Greek.

Again, these may be precise or imprecise. The circle through the middles of the zodia is a precise line, even if measures on the line need to await a system. In addition, one can take the line and divide it up without having to divide it into degrees. The real issue is when the line was divided into 12 equal parts. My suspicion (but not certainty) is the line was so divided in the 4th century because it seems to me that this is exactly what Eudoxos as a geometer would do, whether or not he adopted the mid-5th century Babylonian division; others claim differently.

With this in mind, I shall take up a small sampling:

- The solar eclipse attributed to Helikon
- The most documented eclipse of the 4th century BCE
- Three odd lunar eclipses in Ptolemy
- Observations in Aristotle
- The parameters of Eudoxus
- The year length of Callippus

I shall not claim that these all involve observation. Rather, I shall say that we can get at them through a modest assumption of an interest among the Boys in observation.

§5. Observations and Predictions.

Let's start with the prediction of the solar eclipse by Helicon made in the court of Dionysius II and reported by Plutarch in his life of Dion (19), for which being proved correct he was awarded a talent of silver. This is the most contentious because no reasonable scholar who knows anything about the history of eclipse prediction thinks Helicon could have predicted the eclipse, at least as we understand the word 'predict (προεῖπεν)'. It is easiest to dismiss the story completely, as minimalists would inclined to do. Plutarch is full of stories of a miraculous nature, but this story is an intrusion on Plutarch's narrative of the conflict between Plato and Dionysius, which makes one suspect that there is something there. What, we cannot know. In fact, the eclipse often cited, of 12 May, 361 BCE was an annular eclipse and in Syracuse of 2 ½ minutes duration at around 17:30. If one wants the story, one wants a minimum. Here's a minimum: through a standard calculation of his time made by someone, I don't know whom, Helicon could have been looking to see if an eclipse would occur and, noticing the partial eclipse coming on, say sometime after 16:20, proclaimed that it was happening. When it hit annular totality, people were amazed, and Dionysius rewarded him. Such a prediction requires that he knew to look, that he saw, that he saw before anyone else (and didn't go blind), and, most of all, that he was lucky, since the eclipse might not have hit full in any sense in his neighborhood. Is this story true? I have no idea. However, I put it forward as an example of how one can find an story consistent with the evidence, while recognizing the limitation of the evidence.

Of course, once we tell the tale in this way, there is nothing special about the 12 May eclipse. Helicon could as easily have 'predicted' the 13 July, 364 BCE eclipse. Our only restriction is his being in the circle of Eudoxos. In other words, for the story to be true it needs to be between the arrival of Eudoxos in Athens and the first expulsion of Dionysios II from Syracuse. I put this forward because, unless one denies that a boy from Kyzikos could do a SAROS calculation of a lunar eclips, one cannot deny this version of a solar eclipse prediction. Beyond that, let's do the sceptical dance. Remember that Babylonians included eclipses in the Diaries that were at night as so invisible.

§6. The most reported eclipse in antiquity

Well, maybe this is an exaggeration. But just as Froschstern missed a 5th century date, so Goldstein and Bowen, in their wonderful paper on dated observations, omitted the lunar eclipse that took place on 20 Sept. 331 BCE, 10 days before the eve of Gaugamela, the battle that would seal the fate of the Achaemenids and establish the last of the Great Kings of Persia, Alexander. Here are the reports of it:

1. Plutarch (Alexander): At the time of the Mysteries in Boedromion, the 11th day after was the eve of the battle.
2. Plutarch (Camilla): The battle is on the 5th from the end of Boedromion, i.e., the 26th, so that the eclipse should be 15, actually the 14th day of the month if the 2nd is skipped for good luck.
3. Arrian puts the eclipse and battle in Puanepsion (oops).
4. Cicero really gets it wrong.
5. Quintus Curtius, on the other hand, gets the time right, as well as the character. He also tells a nice story about how the Egyptian priests (and not the Greek astronomers) made a nice omen of it, even though they really knew how eclipses come about.
6. Pliny also gets the time right, the first hour of the night, and reports that in Sicily it was at sunset.
7. Ptolemy gets the time in Arbella wrong, and another time in Carthage barely right, which messes up his calculation of the length of the Mediterranean.

If we put the Arbella sources together, what more could we want of a dated observation, the date and the time. Well, Arrian and Cicero screw it up a little. But notice, all the way over in Sicily, where Helikon had stayed, we have a second report of the time. And who reported the Carthaginean observation. These yield three distinct dated observation, and in the time of Aristotle! Of course, one of these is arguably part of history and autobiography and not astronomy. Nonetheless, we have no reason to believe that a similar motivation would not have pushed the dating of other grand, celestial events in the late 4th century, which would not show up in our literary sources.

Here, by the way is the fragment of the report of the eclipse in the Babylonian Diaries. Note that the deaths and plague came after the eclipse.

§7. Three odd eclipses in Ptolemy

In the *Almagest*, Ptolemy reports Hipparchus' use of three lunar eclipses from 383-2 for the determination of the lunar anomaly. These were "from the series brought over from Babylon and were observed there." (Hi 340, cf. 340-7, trans. Toomer) What's odd about these reports is that Ptolemy also supplies archons and months for all three, but not dates or times. Hipparchus provides date in the Egyptian calendar that must have been translated from the Babylonian original. So why does he also provide the Athenian archon and month as well, but not the date. Well, maximalist views might be that the original was in the Athenian calendar or, more plausibly, that, although the full Athenian date existed at one time, Hipparchus preferred, for whatever reason, to report data from his primary Babylonian source. On the minimalist side, someone translated the Babylonian date into the Athenenian calendar, or at least the month. I have nothing to little about the maximalist view except that it would strikes me as weird that Hipparchus would not also report the date in the Athenian calendar if he had and needed it. The minimalist view, however, is even weirder. What would be the motive for translating a Babylonian date into a different, foreign date, especially in hunting for the two archons? Of course, people do the strangest things. There is a simpler story that is not weird at all. Hipparchus had an Athenian list of three or more eclipses in the 4th century which he could match up with his Babylonian list and because it is of interest that in his world there was such data. The dates were not part of the account, perhaps because a lunar eclipse can only occur in mid-month, say near the 13 or 14th of the month, or because they weren't of interest. Thucydides mentions two solar eclipses as occuring in summer at the beginning of the month, something less precise, and certainly his claim that the Peloponnesian War accompanied more eclipses is based more on anecdote than consultation of records. Now this moderate view places the eclipses in the world of the early Academy, too early for the Cyzicans, perhaps, but it indicates an activity they would have picked up.

§8. Observations in Aristotle: Comets

According to my hypothesis, the rarity of dated observations in 4th century literature does not by itself rule a practice of 4th century dated observations. So it is important to see the rhetoric of time in observation reports. When we look at Galileo's *Siderius Messager*, one of the most striking things is the meticulous presentations of the times of each observation of the moons of Jupiter, which is intrinsic to the establishing the authenticity these novel astronomical observations. For Aristotle, this is perhaps alien to good literary and rhetorical style. Over in the agora, Demosthenes was participating in a different style in his frequent quoting of laws with their dates (I won't guess when it became de rigour). In the *Meteorology* I 6-7, there are four

reports of comets, one from before Aristotle's time. Let's see how they fit in the typology I presented earlier. There are, in effect, three comets and one meteorite in question.

1. The great comet of 373/2, when Aristotle was just a lad of about 11. This is his primary example of a comet, which he refers to three times. The times are vague, winter and year, but the comet is tracked day by day, for a bit, and then Aristotle leaps to its demise. It is likely to be the case that he is getting his information from some record, perhaps in the Academy, perhaps from somewhere else. Can we know that he is not abridging his source? It seems likely.

2. The comet of 427. Here we have the month and a vague location. Again, it suggests that Aristotle has access to some record. There is no tracking.

3. Aristotle provides nothing further about the meteorite in Aigos Potamoi.

4. The comet of 340. This is the only one Aristotle could have seen as an adult. But note where he was at this time, in northern Greece, away from his Academic colleagues. But the weather report cannot be his. There is no tracking but the location is not totally imprecise, equator. Again, we expect communication on auspicious events, but was there more.

The moral I would like to draw is a modest one. Some people did keep records with months, locations, and trackings. Would there have been more? We should dance the sceptic dance.

§8. Three Unusual Stellar Observations in Aristotle

1. A fixed star on close examination was seen to have a tail.

2. Jupiter occluded a star in Gemini.

3. Mars disappeared into the dark area of a half moon and reappeared on the other side.

I do not have a view about when these three observations took place, but they do suggest two important things. Remember, Aristotle was not an astronomer. Each of the three does not come with a date or even a location, except where it is unavoidable. The first may be self-deceit for all I know. However, they all involve careful and regular star gazing, especially the second. If the third took place in 341, it would be around the time of the fourth comet when Aristotle was in northern Greece. They are not casual.

The second point is that, given that these are all the unusual observations we find in Aristotle, Aristotle cites the Egyptians as bearing witness to the normality of the event, as well as the Babylonians for the 3rd. One almost feels that they are an afterthought. How would Aristotle come to have such a belief. Well, again, Eudoxos is the obvious source. So maybe we should be snippet less sceptical about the state of an Egyptian practice of observation.

§9. The Parameters of the Outer Planets in Eudoxos.

This is a repeat of something I have said before, but it is worth saying again. If the parameters of Eudoxos came directly from Babylon, we would expect two things, one is that

they would be close to Babylonian values, and secondly that they would be coherent. So let me set up the issue.

The Eudoxan models of the slow planets, Mars, Jupiter, and Saturn, have three components, as for that matter do the fast planets, but they are not my concern here. The outermost sphere is diurnal and also does not concern me. The second sphere that rides this is responsible for the motion of the planet through the zodiac of fixed stars. Let us represent a number of zodiacal cycles by Z. The third and fourth spheres are responsible for the synodic motion of the planet. This is its periods of conjunction and opposition to the sun, the dance of the planets, as Plato puts it. Let us represent a number of zodiacal cycles by S. Finally, there are the years in which a series of cycles takes place, which we'll take as Y. If the number Z of zodiacal cycles takes place in the same number of years as a series of synodic cycles, then

Goal Year Rule: $Y = S + Z$

Now it is worth noting that this is also how you get the relation between the zodiacal cycles of the moon. Since the moon is faster than the sun:

$Z = S + Y$

I believe that this latter relation was built into Eudoxos lunar models, but I may be wrong. Nonetheless, look at the planetary parameters. First, it is a trivial fact that if two planets have different periods they must have different synodic periods. Simplicius reports that Jupiter and Saturn have the same synodic periods, or at least approximately the same. In fact, however, the synodic period of thirteen months (390 days) for Saturn is too high, while the value for Jupiter is way too low, but within bounds. Most people think that the period for Mars needs emendation. However, there is no non-violent way of emending the value to 2 years or 24 months. I conclude that neither the parameters nor the Goal Year Rule were known to Eudoxos, which is a little surprising for a good mathematician, since the rule is a theorem of kinematics.

So where did these parameters come from. You have a choice: Eudoxos made them up, or he learned them. But where? Egypt is the only candidate. Be a sceptic, but a thoughtful one. And here, I should point out that there is much more involved in understanding the models of Eudoxos, since we need to think about what his models were attempting to model. In fact, I believe that we have evidence for two distinct models of Eudoxos. But that is a talk for a different time.

§10. The 365 ¼ day of Kallippos.

Any account of what the boys from Kyzicus were up to needs to make sense of what they did. Let's take up the modification of the Metonic calendar that Kallippos introduced around 330 BCE. We need to start with Meton. The maximalist view is that Meton went out on the

morning of June 27, 432 and so determined the time of the soltstice. He then decreed this date, Skirophorion 13, the beginning of his 19 year cycle. The minimalist view is that he knew from Babylonian sources the time of the solstice, sort of, but wanted to know where the tropic was from some point on the Pnyx. Now, on any account, Skirophorion 13 either cannot be a date in a Metonic system, since, as Goldstein and Bowen hammer home, the new moon was around the third of the month, or the observation date is later than our reports. However, it is possible that Skirophorion 13 is a date in the rambunctious Athenian Civil calendar, that our report of the determination of the solstice is correct, but that Meton then began his own calendar, i.e. Hekatombaion 1, on the first new moon after. In any case, the fact that Skirophorion 13 may or may not be a date in the Metonic System, it is plausible that Meton was interested in determining the solstice rising position and in determining when the morning of the solstice occurred, whether or not it took him days to determine it (and why not) and whether or not he used a Uruk scheme to determine the morning to look. So the Metonic calendar began on Hekatombaion 1, the first new moon after the summer solstice. As I mentioned earlier, there is also a report of a Eudoxan period that began in 394 that was the same as the Metonic calendar. It will make little difference to my discussion. All I need is that there was someone paying attention to the Metonic calendar, marking the days off.

The Metonic calendar coordinates the following three items:

19 years

235 synodic months

6940 days

110 hollow, 29 day months and 135 full, 30 day months

This gives in a cycle 12 normal years of 12 months and 7 leap years, with with an extra month.

The year is clearly 365 5/19 days (exercise: write this out in Athenian notation)

With this let me review the argument of Goldstein and Bowen on how Kallippos came to modify this system so that the year would be 365 ¼ days.

They begin with the Octaeteris which they place before Meton. The author came up with 99 months for 8 years, in effect 5 years of 12 months and 3 leap years of 13 months. The problem was how to distribute hollow, 29 day months and full, 30 day months. For this, the author must have made several assumptions of which two are particularly important.

The number of full, 30 day months > the number of hollow, 29 day months.

I don't know how Goldstein and Bowen think the author came up with this principle, but since they deny any observation goes into the theory, I assume that it must come from a lore about calendars, e.g., from Babylon.

The author then makes a simplifying assumption. The regular months of the 12 month calendar are equally hollow and full months. The question then is how to distribute the remaining leap months. Now the first two possibilities won't work because they have more hollow months than full months. So we need to choose between the other two. The author then makes a simplifying assumption, all leap months are full. Why he makes this assumption is not part of Goldstein&Bowen's story. We'll leave it with a big "?" But we now have a year with 365 ¼ days.

We now have two rival calendars (more actually, but let's simplify). Kallippos for some reason decides he needs to combine the two. So, he works out that if he takes 8 years for 2922 days, he can then multiply each by 19, then divide by 2, or the other way around, and get a Metonic style system with the Octaeteris number of days per year. This is very clever. There is only one problem with it. Why would he do it? Why would he so want to have the year length of the Octaeteris that he would mess up the Metonic cycle by quadrupling it? Why would he even think that this gives the right number of days per year? The solution is bizarre.

Now we can make it less bizarre by noting that Eudoxos had, according to one story, endorsed the Octaeteris. So to preserve the core truth of his Doktorvaters calendar, he combined the two. However, if he understood Eudoxos, he would also have understood that the year length is just an artifact of the way of calculating the cycle of full and hollow months. Nothing is gained. So even if the story is true, it is strange.

Maybe, after 102 years of Meton, Kallippos noticed that the solstices were off. Well they wouldn't be off by more than 1 ¼ day. Given that Meton was a day behind (though not on some versions of G&B's story), I don't see how one would begin to notice. Keep in mind that the solstice is not really measurable in this period to any accuracy of a day or two. For one thing, the atmospheric influence alone would muck up the observation.

Well, maybe Kallippos just wanted to round it off. Did you do the exercise? Certainly it is easier to write ¼ than 5 19ths. But still we want to know why this is important. One can round off the year to tell people how long the year is and still keep the Metonic calendar.

Here is a better reason. If one follows the calendar through 3 or 4 cycles (remember that there is a Eudoxan version from 394), one would very painfully notice that the new moons were falling a day earlier than expected. One might attribute this to weather, to variations in the cycle (remember Kallippos also modified the lunar and solar models of Eudoxos), but, like it or not, the moon was early. By taking away 1 day in 4 cycles, one solves the problem. Why 1 day in 4 cycles? I don't know. So this solution isn't perfect either, but we can imagine possibilities.

So to conclude. Egypt or Babylon. You need to pick your poison here. Do you want to go with the historical record, some of it contemporary, or do you want to go with the absence of archeological evidence and evidence in later authors (e.g., Ptolemy's ignorance of Egyptian

observations). I am a sceptic, so that I really don't know. But if I had to place odds, I would go with Egypt. Secondly, what sorts of observations and where. By the way, there is a story about Phaeinos making observations on Lykabettos in the 5th century, which G&B rightlly endorse, though only for horizon positions (I am a little sceptical about this, but one would need to kill the power in Athens to really check it out). Look at east and west from there. It is a natural observatory for horizon fiends. As to the sorts, my last story was really about tracking by time. I think that there is enough evidence of people tracking events that there is no problem of anachronism. As to dating, well we just have to ask whether the astronomers were into their own culture, and here too one can be a sceptic. However, it may not be important for the essential issues of how the Boys from Kyzikos made their models. Here, tracking is adequate. For the rest, be a sceptic.