CHAPTER 8

The Astronomical Resources for Ancient Astral Prognostications

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My purpose here is to examine the astronomical knowledge, and more specifically the astronomical tools, that ancient astrologers in Mesopotamia and the Greco-Roman world possessed and used. Much of what I will say will be well known to specialists in ancient astronomy and astrology. To the best of my knowledge, however, a broad treatment of the topic has not yet been written. I offer this chapter as a contribution to understanding the expertise of an ancient astrologer as well as its limits.

The roughly 1200-year evolution of astrological practice that I survey is characterized by several shifts. First, interpretation of direct observations of the heavens was progressively supplanted by reliance on predicted astronomical data. Second, prediction based on the principle that astronomical phenomena observed in the past would approximately repeat after certain time intervals (called recurrence periods) gave way to mathematical models that had a more remote derivation from observations. Finally, astrologers became increasingly removed from the production of the astronomical information they used and increasingly dependent on published almanacs comprising precomputed data.

Distinguishing Astronomy and Astrology

It is often said that there was no distinction or separation between astronomy and astrology in the ancient world. Such a statement, when it is made in the most general terms, is practically meaningless. In reality, the relationship between astronomy and astrology varied from one cultural milieu to another; moreover it makes a big difference whether one is considering the practices or the practitioners.

For the purposes of this chapter, I will adopt an ahistorical definition of astronomy and astrology, according to which astronomy is concerned with observed or theoretical configurations of the heavenly bodies (fixed stars, Sun, Moon, and planets) and the observable celestial phenomena connected with them, whereas astrology is concerned with relations between these celestial

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configurations and phenomena and mundane, human circumstances. By 'ahistorical' I do not mean that this distinction was never made in antiquity; in fact, it is essentially the distinction that Ptolemy draws at the outset of his astrological treatise, the *Tetrabiblos*:

> Of the things that serve a prognostic purpose by means of *astronomia*, O Syros, two are greatest and most important: one being first in both rank and power, in accordance with which we grasp the configurations that arise at all times in the motions of Sun and Moon and stars relative to each other and to the Earth, and a second one, in accordance with which, by means of the physical specific tendencies of their configurations, we make inquiry into the changes effected in the things that are enclosed within . . .[1]

Ptolemy expresses his distinction (which for him is between two predictive faculties depending on a single science that he calls *astronomia*) in terms of the basically Aristotelian cosmology that he accepts.[2] According to this cosmology, we and our immediate environment constitute a spherical world composed of the four elements earth, water, air, and fire, which are kept in a perpetual condition of change and interchange through physical agencies transmitted from the heavens, a surrounding spherical shell composed of a fifth element, ether, and comprising the visible heavenly bodies embedded within a plenum of invisible etherial bodies. Leaving this rationale aside, his definitions provide a criterion for deciding whether a particular kind of prediction involving the heavenly bodies falls within the scope of his first faculty or his second, and this turns out to be essentially my criterion for whether the prediction is astronomical or astrological. It is ahistorical, for Ptolemy as much as for us, in that it pays no attention to the historical origins, evolutions, and paths of cultural transmission of predictive practices. It also does not require us to decide whether a form of prediction is 'rational', 'scientific', or 'pseudoscientific', considerations that are not so much ahistorical as anachronistic. The advantage of using Ptolemy's criterion is that it allows us to classify a practice, or for that matter a text dealing with astral matters, as astronomical or astrological (or both) by looking at its explicit contents and without having to invoke historical recon-

1 *Tetrabiblos* 1.1 (W. Hübner, ed., *Claudii Ptolemaei opera quae exstant omnia. Volumen III 1. ΑΠΟΤΕΛΕΣΜΑΤΙΚΑ* [Stuttgart: Teubner, 1998], 3).

2 A. Jones, "Ptolemy's Mathematical Models and their Meaning," in *Mathematics and the Historian's Craft: The Kenneth O. May Lectures* (eds. M. Kinyon and G. van Brummelen; New York: Springer, 2005), 23–42.

structions, assumptions about the (usually unstated) purpose and underlying rationale of the practice or text, or the muddled ancient terminology for astral disciplines and professions.[3] Of course a text or practice that is astronomical according to its contents may have come into existence as a resource for astrology, but that is usually something we have to infer from context.

Applying the criterion of contents, we find that there was a high degree of separation between astronomy and astrology in ancient astral texts and documents, whether we are looking at cuneiform texts from Babylonia in the second half of the first millennium BCE (also including a few tablets from Babylon from the first century CE), Greek and Latin texts from the Hellenistic and Roman periods transmitted through the medieval manuscript tradition, Hellenistic Greek inscriptions, or Greco-Egyptian papyri. Theoretical and instructional texts that are about explaining or predicting the phenomena, positions, and motions of the heavenly bodies rarely also discuss the application of these things to making predictions about terrestrial and human affairs, while texts that are about making such predictions seldom discuss either how one obtains the astronomical data on which they depend or the underlying astronomical theories.[4] Tables for calculating astronomical data and almanac-like tabulations of computed astronomical data, even when it seems obvious to us that they existed for the sake of making astrological predictions, hardly ever make this purpose explicit.

Although it is comparatively rare to find astronomical and astrological material in the same texts, it does not necessarily follow that different groups of people produced them. In Babylonia, the same people appear to have

3 For example, *astrologia* and *astronomia* can mean either astronomy or astrology, and *astrologos*, *astronomos*, and *mathematikos* are terms applied to practitioners of astrology as well as to astronomers. See Hübner, *Die Begriffe "Astronomie" und "Astrologie" in der Antike. Wortgeschichte und Wissenschaftssystematik, mit einer Hypothese zum Terminus "Quadrivium"* (Stuttgart: Steiner, 1989).

4 There are some exceptions: Geminos's *Introduction to the Phenomena* (first century BCE), an elementary exposition of aspects of astronomy, has a chapter (2) on astrological relations ('aspects') between zodiacal signs, and another (17) that discusses weather predictions based on the visibility of fixed stars. Vettius Valens' *Anthologiae* (second century CE), an astrological treatise, devotes some chapters (1.15–18 in Pingree's edition, *Vettii Valentis Antiocheni anthologiarum libri novem* [Leipzig: Teubner, 1986]) to rather crude methods of calculating the positions of the Sun, Moon, planets, and lunar nodes. Some Babylonian tablets mix sections containing astronomical and astrological schemes (e.g., Louvre AO 6455 = TU 11, for which see L. Brack-Bernsen and H. Hunger, "TU 11, a Collection of Rules for the Prediction of Lunar Phases and of Month Length," *SCIAMVS* 3 [2002]: 3–90). Such crossings of the astronomy-astronomy divide represent a minuscule fraction of the surviving textual materials.

practiced both astronomy and astrology at the highest level. For the Greco-Roman world, however, it is hard to find many examples of individuals engaging in, or writing as experts about, both astronomy and astrology. There was, indeed, a particular specialized type of prediction that our definition (or Ptolemy's) would categorize as astrological but that was closely associated with people whom we would unhesitatingly consider astronomers, namely the so-called parapegma tradition of predicting weather changes through correlation with an annually recurring cycle of appearances and disappearances of stars in the morning and evening sky. The figures whose names are linked to such predictions—we have no original texts attributed to them, only citations in later documents—are people we would not hesitate to call astronomers, for example Meton of Athens (late fifth century BCE), Euktemon (late fifth century BCE), Eudoxos (early fourth century BCE), Kallippos (mid-fourth century BCE), and Hipparchos (mid-second century BCE). However, if we look for astronomers who engaged with astrology more broadly, Ptolemy comes immediately to mind, but there is practically no one else.[5] It appears that the practitioners of Greco-Roman astrology were not normally the originators of the astronomical knowledge and data on which their work depended.

Resources for Event-driven Astrology

Schemes for categorizing the varieties of astrology practiced in antiquity often take as their starting point Ptolemy's division of the subject into two major parts according to their mundane reference: the "more general" one that deals with "entire peoples and lands and cities," which he calls universal (καθολικόν), and the "more particular" one that deals with individual persons, which he calls nativity (γενεθλιαλογικόν) astrology.[6] A complementary approach, more productive for the topic of this paper, is to consider how the occasion for examining what is going on in the heavens as a basis for mundane predictions is

5 Apollinarios of Aizanoi (first or early second century CE) was an astronomical author known from a handful of ancient references (see O. Neugebauer, *A History of Ancient Mathematical Astronomy* [Berlin: Springer, 1975], 601 note 2; Jones, *Ptolemy's First Commentator* [Proceedings of the American Philosophical Society NS 80.7, 1990], 12–17), among which some attribute to him opinions on astrological matters. There are also a few rather doubtful ascriptions of astrological doctrines to Hipparchos (Pingree, *From Astral Omens to Astrology: From Babylon to Bīkāner* [Istituto Italiano per l'Africa e l'Oriente, Serie Orientale Roma 78. Roma: Istituto Italiano per l'Africa e l'Oriente, 1997], 25).

6 Ptolemy, *Tetrabiblos* 2.1, ed. Hübner, 88.

chosen. One kind of astrology, which we can call 'event-driven', waits for a specific type of astral phenomenon or configuration to occur and takes this as the moment to be examined. The other kind, which I will call 'date-driven', chooses the date and time for which the configuration of the heavenly bodies is to be examined based on mundane circumstances. Event-driven astrology, as it turns out, is practically coextensive with Ptolemy's universal astrology, while date-driven astrology comprises Ptolemy's nativity astrology (in which the given date is that of the birth of an individual) as well as catarchic astrology, a kind of ancient astrology that Ptolemy does not treat, in which the given date is that of a contemplated or actual action, such as getting married or going on a voyage.

The Mesopotamian astrology attested as early as the Old Babylonian period in the early second millennium BCE, though best known from the Neo-Assyrian (mostly seventh century BCE) letters and reports of scholars to the kings at Nineveh, was event-driven, constituting a major part of the broader tradition of divination through the interpretation of ominous events. The basis of prediction was a repertoire of 'omen texts', concatenations of a described ominous occurrence and a described predicted outcome, usually expressed in the form of a conditional sentence, such as: "If an eclipse occurs on the 15th of (the month) Simanu and the west wind blows, then the land of Amurru will be victorious."[7]

The operative model of Neo-Assyrian omen astrology was observational. For an omen text such as the eclipse omen text just quoted to be brought into play, an expert would have to actually observe an event, in this case a lunar eclipse, that matched the "if" clause (protasis) of the text, identify the text as pertaining to the observed event, and interpret the "then" clause (apodosis) in relation to the current state of affairs. We know from the letters and reports that the scholars who practiced omen astrology had methods of forecasting the likely occurrence of certain ominous astral events, such as eclipses.[8] However, even if it was strongly expected, the omen was not considered valid unless an observation of it took place, and the identification of pertinent omen texts—sometimes many texts would be applied to a single event—depended on circumstances that could not be forecast, such as, in the above-quoted example, the direction the wind blows during the eclipse. The practice of astral omen observation thus demanded considerable expertise in knowing not only

7 F. Rochberg, *Aspects of Babylonian Celestial Divination: The Lunar Eclipse Tablets of Enūma Anu Enlil* (Horn: Berger, 1988), 91.

8 J. M. Steele, "Eclipse Prediction in Mesopotamia," *Archive for History of Exact Sciences* 54 (2000): 421–54.

the right times to watch for phenomena (guided, where possible, by methods of astronomical forecasting) but also what conditions to watch for that might be relevant as elements in the protases of omen texts. Quantitative elements hardly enter into these protases, and the observers seem to have employed no instruments except water clocks.[9]

Very little is known about the extent to which omen astrology was practiced in later first millennium BCE Babylonia. Astral omen compilations such as the great tablet series *Enūma Anu Enlil* were still copied during this period, and the professional title "Scribe of *Enūma Anu Enlil*," found previously among the Neo-Assyrian scholars for whom the series was undoubtedly of living importance, was also held by some of the copyists and owners of tablets in Hellenistic Uruk and Babylon. The Astronomical Diaries record observations of celestial events that the omen texts recognized as ominous, often with details that could have been applied to astrological interpretation; for example, the reports of eclipses take note of the wind direction. However, we lack direct archival documentation confirming that anyone was actually interpreting astral events in a manner comparable to what we find in the Neo-Assyrian period, though some Greco-Roman sources speak of Babylonian scholars providing omen-based forecasts and advice to Alexander the Great and the Hellenistic successors to his empire.[10]

We are in a comparable position with respect to event-driven astrology in the Greco-Roman world. In this tradition, which at least in part derived from Egyptian adaptations of Mesopotamian astral omens dating back to about the middle of the first millennium BCE,[11] two varieties of astral event were singled out as ominous: eclipses, and the annually recurring first morning appearance of Sirius, regarded as the harbinger of the Nile flood. Unfortunately, we again have no sources witnessing this tradition in practice, and we cannot even identify who its practitioners were. Nevertheless, the documents that we do possess enable us to learn something about how it was done.

Our main sources of information for Greco-Egyptian event-driven astrology are texts setting out the correspondence between the circumstances of the

9 For the use of water clocks in Neo-Assyrian omen observation, see D. Brown, J. Fermor, and C. Walker, "The Water Clock in Mesopotamia," *Archiv für Orientforschung* 46/47 (2000): 130–48, especially 142.

10 Diodoros, who was exceptionally well informed about the "Chaldeans" (by which he means Babylonian scholars expert in astrology), relates (117.112 and 19.55) that they gave omen-based advice to Alexander the Great and to Antigonos Monophthalmos.

11 R. Parker, *A Vienna Demotic Papyrus on Eclipse- and Lunar-Omina* (Providence: Brown University Press, 1959).

ominous astral events and the outcomes forecast for peoples and geographical regions. Although the doctrines in these texts seem to have been formulated in the Hellenistic period or earlier, we depend for our knowledge of them chiefly on fragmentary Demotic and Greek papyri from the first several centuries CE and on material of the same character incorporated in treatises and compilations in Greek transmitted through the medieval manuscript tradition. The most comprehensive presentation is a series of chapters (1.21–23) in Hephaestion of Thebes's *Apotelesmatica* (ca. 400 CE), which purports to be an abridgement of the teachings of the "Egyptians of old."[12]

Hephaestion states (ed. Pingree 66) that the first appearance of Sirius takes place on a fixed date in the Egyptian calendar (Epiphi 25), so that the event's occurrence was trivially forecastable. (Before the Roman reform of the Egyptian calendar with the introduction of leap years, the assigned calendar date would have had to be shifted one day later every four years.) Sirius' first appearance thus did not acquire its prognostic character through being an anomalous occurrence, but rather as a natural point of beginning for the year, so that the condition of the heavens on this date indicated what would happen during the year. Among the circumstances that, according to Hephaestion, were correlated with mundane outcomes were some that we would attribute to meteorological or optical conditions that could not have been forecast by astronomical methods, such as the apparent colors and brightness of Sirius itself and of visible planets, the direction that the wind was blowing, and thunder (ed. Pingree 66–67 and 73). Other relevant factors are astronomical: the zodiacal signs occupied by the Moon and planets, their distances from the Earth, their proximity to certain stars or to the lunar nodes, and the current stages of the planets in their synodic cycles (ed. Pingree 67–72). While some of these circumstances might have been determined by observation, they are much more amenable to calculation, and some of them (e.g., whether a heavenly body is near apogee or perigee or a lunar node) could only be calculated. For eclipses, too, Hephaestion gives prognostications based on meteorological and optical factors (disk colors, halos, rain, thunder, and wind directions; ed. Pingree 52–53) as well as on forecastable astronomical factors (zodiacal sign occupied by the eclipsed body, time of day or night, and eclipse magnitude; ed. Pingree 53–63).

Astrologers practicing the Greco-Egyptian style of event-driven astrology did not have to be able to calculate the astronomical characteristics of eclipses

12 Pingree, ed., *Hephaestionis Thebani Apotelesmaticorum libri tres* (Leipzig: Teubner, 1973), 52–73. The references to the Egyptians are in the opening sentences of 1.21 (page 52), "οἱ παλαιοὶ Αἰγύπτιοι," and 1.23 (page 66), "οἱ παλαιγενεῖς σοφοὶ Αἰγύπτιοι."

or the zodiacal positions and synodic phenomena of the planets for themselves. Determining the situations of the planets at the date of Sirius' first visibility is essentially the same problem as determining them for an individual's birthdate, which I will discuss in the following section. Predictions of eclipses circulated in the form of eclipse canons—lists of descriptions of series of eclipses of the Moon or of the Sun. We have two specimens of this type of text: PBerol. 13146+13147, a Demotic papyrus from the early first century BCE, which is likely to be an abridgement of a canon originally written in Greek; and *POxy astron*. 4137, a Greek papyrus from the middle of the first century CE.[13] These texts provide the date and time of each eclipse and the directions of obscuration of the Moon's disk, and *POxy astron*. 4137 also gives the magnitude, the duration, and the Moon's location relative to fixed stars. It is likely that these canons were generated by applying eclipse recurrence periods to earlier observations or calculations of eclipses,[14] whereas Ptolemy's *Almagest*, Book 6 contains procedures and tables for computing the data in eclipse canons based on his astronomical models for the motions of the Sun and Moon.

The Antikythera Mechanism (ca. 60 BCE or earlier) casts unexpected new light on the shifting roles of observation and prediction in Hellenistic event-driven astrology.[15] This gearwork device translated an input rotary motion rep-

13 O. Neugebauer, R. A. Parker, and K.-T. Zauzich, "A Demotic Lunar Eclipse Text of the First Century, BC," *Proceedings of the American Philosophical Society* 125 (1981): 312–27; Jones, *Astronomical Papyri from Oxyrhynchus* (Philadelphia: American Philosophical Society, 1999), 1.87–94 and 2.16–17.

14 Steele, *Observations and Predictions of Eclipse Times by Early Astronomers* (Dordrecht: Kluwer, 2000), 86–91.

15 The fragments of the Mechanism were recovered in 1901 from the site of a shipwreck currently dated (primarily by coins and ceramics) to about 60 BCE; see N. Kaltsas, E. Vlachogianni, and P. Bouyia, eds., *The Antikythera Shipwreck: the ship, the treasures, the mechanism* Exhibition catalogue. (Athens, 2012). Archeological context and other considerations favor a recent dating of the Mechanism relative to the wreck (Jones, "The Antikythera Mechanism and the Public Face of Greek Science," *Proceedings of Science* PoS [Antikythera & SKA] 038 [2012], available at: http://pos.sissa.it.), notwithstanding evidence that its eclipse cycle's starting date was in 205 BCE (C. C. Carman and J. Evans, "On the Epoch of the Antikythera Mechanism" (paper presented at the workshop on The Antikythera Mechanism: Science and Innovation in the Ancient World, Lorentz Center, Leiden, 17–21 June 2013), available at: http://www.conicet.gov.ar/new_scp/detalle.php?keywords=&id=21332&congresos=yes&detalles=yes&congr_id=2064637; Carman and Evans, "On the Epoch of the Antikythera Mechanism and its Eclipse Predictor," *Archive for History of Exact Sciences* 68 (2014): 693–774; T. Freeth, "Eclipse Prediction on the Antikythera Mechanism," PLOS *One* (*Public Library of Science*) 9.7.e103275 (2014), available at: http://dx.plos.org/10.1371/journal.pone.0103275.

resenting the passage of time into motions of revolving pointers on multiple dials, some of them representing the current date within various chronological cycles, others the current positions of the heavenly bodies in the zodiac.[16] The so-called Saros Dial, occupying the lower half of the Mechanism's rear face, was one of those displaying a chronological cycle, in this instance a 223-lunar-month cycle of predictions of lunar and solar eclipses. The predictions—which were inscribed partly on the scale of the dial and partly in supplementary texts inscribed on other areas of the rear face—specified a time (apparently of mid-eclipse or, more correctly, the moment of opposition or conjunction), a color, a magnitude (small, medium, or large), and a shift in something's orientation from one direction of the horizon to another, which is likely to refer to wind directions.[17] What is interesting about the Mechanism's treatment of eclipses in the present context is not so much the mechanization of cyclic prediction—such devices were scarce, delicate, and surely beyond the means of most astrologers—but the idea that the optical and meteorological aspects of eclipses could also be forecast, obviating the need to make any observations. This possibility may also be implicit in Ptolemy's frequent allusions to methods of predicting weather changes (ἐπισημασίαι) based on the computable astronomical circumstances of eclipses.[18] However, in the context of the *Tetrabiblos*, the forecast weather changes have a status analogous to the apodoses of eclipse omen texts, whereas on the Mechanism the colors and wind

16 M. T. Wright, "Counting Months and Years: The Upper Back Dial of the Antikythera Mechanism," *Bulletin of the Scientific Instrument Society* 87 (2005): 8–13; Freeth et al., "Decoding the ancient Greek astronomical calculator known as the Antikythera Mechanism," *Nature* 444 (2006): 587–91, supplementary information available at: http://www.nature.com/nature/journal/v444/n7119/suppinfo/nature05357.html; Freeth, Jones, Steele, and Bitsakis, "Calendars with Olympiad display and eclipse prediction on the Antikythera Mechanism," *Nature* 454 (2008): 614–17, supplementary notes available at: http://www.nature.com/nature/journal/v454/n7204/extref/nature07130-s1.pdf; Freeth and Jones, "The Cosmos in the Antikythera Mechanism," *ISAW Papers* 4 (2012), available at http://dlib.nyu.edu/awdl/isaw/isaw-papers/4/.

17 *IAM4* ("Inscriptions of the Antikythera Mechanism. 4. The Back Dial and Back Plate Inscriptions," forthcoming), and provisionally Freeth, "Eclipse Prediction, note S2, with a transcription of the inscription by C. Crowther differing in only a few fairly minor readings from transcriptions by Y. Bitsakis and A. Jones, to which Freeth had access since 2009, as well as from the final text in *IAM4*. Freeth asserts that the directional statements refer to directions of obscuration of the eclipses, but if so, both the general method of prediction and the specific predictions in the preserved part of the inscription are astronomically nonsensical.

18 Ptolemy, *Almagest* 6.5–13 (ed. Heiberg, 1.476, 512, 536–546).

directions are best understood as characteristics of the eclipse itself and thus as potential elements of the protases of omens.

The earliest kinds of event-driven astrology in the Greek-speaking world, preceding the influx of Mesopotamian astral omens, were methods of weather prediction. These came in two varieties. One worked through correlations of observed sign and predicted outcome expressed similarly to Mesopotamian omen texts, for example, "If the Ass's Manger [the nebula Praesepe in Cancer] contracts and becomes dusky, it signifies storms."[19] These texts involving astral weather signs are found scattered among a much larger repertoire of weather sign texts in which the observed events are much more commonly behaviors of animals, plants, or meteorological conditions. They were inherently unforecastable, requiring observation but no deep observational expertise beyond the ability to recognize a few objects such as Praesepe and the Pleiades.

The other variety of Greek astral weather prediction correlated weather patterns with the first and last appearances of stars after sunset and before sunrise. A specimen linkage is: "The Haedi rise in the evening: storms occur."[20] Taken in isolation, this resembles a weather-sign text or a Mesopotamian omen text and suggests a similar operative model, in which one makes the prediction of storms in response to observing the Haedi for the first time after sunset after an interval during which the stars could not be seen. However, if we look at the quoted passage within the broader context of the document in which it is transmitted, the picture changes:

> On the 3rd [day], according to Euktemon the Haedi rise in the evening: storms occur.
> On the 4th, according to Eudoxos Capella rises at nightfall.
> On the 5th, according to Euktemon the Pleiades become visible in the evening: weather change. According to Kallippos Virgo finishes rising.
> On the 7th day, according to Euktemon Corona rises: storms occur.
> On the 8th day, according to Eudoxos the Pleiades rise at nightfall.
> On the 10th day, according to Eudoxos Corona rises in the morning.
> On the 12th day, according to Eudoxos Scorpius begins to set at nightfall: and a storm supervenes, and a great wind blows.[21]

19 Pseudo-Theophrastus, *De Signis* 43, ed. D. Sider & C. W. Brunschön, *Theophrastus of Eresus On Weather Signs* (Leiden: Brill, 2007), 86.

20 From the "Geminos parapegma" appended to Geminos' *Introduction to the Phenomena* (K. Manitius, ed., *Gemini Elementa Astronomiae* [Leipzig: Teubner, 1898]), 216.

21 Manitius, *Gemini Elementa Astronomiae*, 216, adopting his corrections to the transmitted text.

First, and most crucially, all the statements are given within a chronological framework of numbered days. Taking the document as a whole, we find that the framework (generically called a parapegma) comprises a cycle of 365 days, starting with the summer solstice and portioned into intervals of stated numbers of days, during which the Sun is supposed to travel through each of the twelve zodiacal signs in turn. This means that we are looking at a fixed and repeating cycle, locking all the statements at constant intervals of days from each one to the next. Second, every statement is attributed to an authority, implying that several source documents associated with such figures as Euktemon and Eudoxos have been combined, and in the combined form we get conflicting dates for the same star-event attributed to different authorities. Third, there are many statements of star-events not coinciding with a weather-outcome, and also (elsewhere in the document) statements of weather-outcomes not coinciding with a star-event.

The document that we have been looking at, the so-called *Geminos Parapegma*, is a text transmitted through the medieval manuscript tradition as a sort of appendix to Geminos' *Introduction to the Phenomena* and is thus a static object written on the page, giving few clues to how it was meant to be used, and by whom. However, we also have fragments of a very similar document in the form of an inscription on stone that was apparently erected in a public place in Miletos during the second century BCE, thus seemingly inviting nonexpert viewers to consult it.[22] This inscription has most of the characteristics we have noted for the *Geminos Parapegma*: attributions to multiple authorities, assignment of the same star-events to more than one date according to different authorities, and unlinked statements of star-events and weather-outcomes. All statements are embedded in a fixed, year-long chronological framework, but this framework is represented not by numbered days but by drilled holes representing each of the (presumably 365) days of the year. If a hole has a statement or statements next to it, the statements apply to that day; runs of days with no associated statements are represented by rows of the appropriate number of holes.

According to the most plausible explanation of the holes' function, a peg was moved each day from one hole to the next to indicate where the current date fell within the cycle. Hence this was a dynamic document that in effect identified for the viewer what part of itself was relevant on any day—though of course it required an operator, someone to move the peg from one hole to the next on a daily basis and to restore the peg to the first hole on the day designated

22 IMilet inv. 456A, 456B, 456D, and 456N, most recently edited in D. Lehoux, "The Parapegma Fragments from Miletus," *Zeitschrift für Papyrologie und Epigraphik* 152 (2005): 125–40.

as the beginning of the annual cycle. From the user's perspective, a parapegma (whether static or dynamic) functioned in a way analogous to a hypothetical type of eclipse canon, in which the apodoses of the relevant eclipse omen texts have been appended to the predictions of the astronomical circumstances of the eclipse. The conceptual connection between astral event and mundane outcome is preserved, but no observation of the heavens is required, though the *variorum* type of parapegma leaves it to the user to make a choice among divergent forecasts, rather as a user of the Mesopotamian omen corpora had to choose among multiple omen texts whose protases fitted an eclipse.

Again, the Antikythera Mechanism presents us with an interesting variant type of dynamic parapegma.[23] A list of statements of morning and evening risings and settings of stars and constellations was inscribed on plates mounted above and below the single front dial. Each statement was marked by a letter of the Greek alphabet, and the same letter was engraved somewhere along the scale of the dial, which represented the zodiac and was subdivided by graduations into the twelve zodiacal signs and their constituent degrees. When a revolving pointer representing the Sun in its annual motion lined up with one of the letters, this constituted a prediction that the associated astral event took place on the corresponding date. There were no weather predictions in the parapegma inscriptions, however, and in this respect the Mechanism parallels a second stone parapegma inscription with pegholes, found in Miletos, which lists stellar risings and settings but has only a single reference to weather.[24] Parapegmata lacking weather forecasts would have functioned like the attested eclipse canons, replacing observation as the source of the protases of omens or signs but not indicating which correlations of protases and apodoses were relevant.

Date-driven Astrology

Although ancient date-driven astrology came to encompass prognostication based on the state of the heavens at dates and times determined by a wide range of criteria, its original and always central mode was 'genethlialogy' or nativity astrology. A memorable description of how the "Chaldean" or nativity

23 D. de S. Price, *Gears from the Greeks: The Antikythera Mechanism—A Calendar Computer from ca. 80 BC* (Philadelphia: American Philosophical Society, 1974), 49; *IAM3* ("Inscriptions of the Antikythera Mechanism. 3. The Front Dial and Parapegma Inscriptions," forthcoming).

24 IMilet inv. 456C, reedited in Lehoux, "The Parapegma Fragments from Miletus."

astrologer originally (ἀρχικῶς) operated is given by the sceptic philosopher Sextus Empiricus (ca. 200 CE):

> By night the Chaldean, they say, sat on some high ridge watching the stars, and another attended upon the woman in labor until she gave birth, and the moment she gave birth he made a sign by means of a gong to the one on the ridge. And he, when he heard, took note himself of the rising zodiacal sign as the ascendant (ὡροσκοποῦν). But by day he paid attention to clocks (τοῖς ὡροσκοπίοις) and to the movements of the Sun.[25]

However, this picture of the astrologer making a 'real-time' observation of the heavens at the moment of birth, though it gives Sextus a convenient starting point for a critique of astrologers' claims to precision in timing, does not correspond to the actual practice of nativity astrology, either in Babylonia, where it originated, or in the Greco-Roman world.

The records of Babylonian nativity astrology are tablets commonly called 'horoscopes' because of their obvious points of resemblance to the horoscopes of the Greco-Roman tradition and its descendants. The term 'proto-horoscopes' more accurately describes them—since they make no mention of the ascendant point of the zodiac, whose Greek name (ὡροσκόπος) is the origin of the term 'horoscope'—but this term quickly becomes cumbersome. Horoscope tablets contain one or occasionally two astral birth records. The record begins with the statement of the birthdate of an individual, who is sometimes named (either here or at the document's end) but more often simply called "the child." Then follows a list of statements of astronomical conditions in effect at or near the birthdate. In a few horoscopes, statements of outcomes pertaining to the individual (for example, "He will have sons") seem to be linked to astronomical statements in the manner of omen texts.

Twenty-eight horoscope tablets are known, pertaining to individuals whose birth years range from 410 BCE through 69 BCE.[26] Most of them are known or presumed to be from Babylon (the earliest 410 BCE, the latest 69 BCE), one is from Nippur (410 BCE), and five are from Uruk (the earliest 263 BCE, the latest 199 BCE). These places of origin are significant. Babylon and Uruk are the two cities from which we have large numbers of astronomical tablets

25 Sextus Empiricus, *Adversus mathematicos* 5.27–28.

26 Rochberg, *Babylonian Horoscopes* (Proceedings of the American Philosophical Society NS 88.1, 1998.) Additionally, four tablets (Rochberg's texts 29–32) that record birthdates unaccompanied by astral data apparently functioned as notes for the preparation of horoscopes.

from the second half of the first millennium BCE, including the remains of a vast archive of observational records from Babylon as well as many tablets of predictive mathematical astronomy from both cities. Nippur is one of a very small number of other cities from which a few astronomical tablets have been identified.[27] All the Nippur tablets are nonmathematical and date from the fifth and fourth centuries BCE. It thus appears that nativity astrology in Babylonia was usually practiced in proximity to centers of astronomical expertise.

A notorious passage from the geographer Strabo (late first century BCE or early first century CE) refers to practitioners of nativity astrology in Babylon:

> A dwelling place is set aside in Babylon for the philosophers of the country, who are called Chaldaioi, and who are for the most part occupied with astronomy (ἀστρονομίαν). Some profess also to interpret nativities (γενεθλιαλογεῖν), but the others do not approve of them (ἀποδέχονται).[28]

At the time Strabo wrote his treatise, there were still scholars in Babylon producing astronomical texts on cuneiform tablets, though we do not know how recent his source was. His allusion to the nativity astrologers indicates that they were part of the scholarly community of astronomers—"philosophers" for Strabo means roughly what we would call "intellectuals"—but that they formed a distinct, not entirely reputable subgroup. Direct proof or disproof of either part of this statement is impossible, because neither the horoscope tablets nor most categories of astronomical tablets from Babylon bear colophons identifying the people who wrote them, and for most of them we have no archeological context.[29] From the colophons of tablets from Uruk, on the other hand, we can establish that astronomical and astrological tablets were written, owned, and presumably also used by the same experts.[30] Again,

27 M. Ossendrijver, *Babylonian Mathematical Astronomy: Procedure Texts* (New York: Springer, 2012), 6 with note 31. The other sites from which we have astronomical tablets are Sippar and Ur (Steele, "The Circulation of Astronomical Knowledge between Babylon and Uruk," in *The Circulation of Astronomical Knowledge in the Ancient World* [ed. J. M. Steele; Leiden: Brill, forthcoming]). They do not include any observational records or tablets of mathematical astronomy.

28 Strabo, *Geography* 16.1.6.

29 For a discussion of the problems involved in establishing the accurate provenance of astronomical tablets from Babylon (mostly in the British Museum), see E. Robson, *Mathematics in Ancient Iraq: A Social History* (Princeton: Princeton University Press, 2008), 220–27.

30 Steele, "Astronomy and Culture in Late Babylonian Uruk," in *"Oxford IX" International Symposium on Archaeoastronomy. Proceedings IAU Symposium No. 278. Proceedings of the*

we cannot prove that any of the Uruk horoscopes were produced by these experts, but it is very likely that a certain Anu-bēlšunu, who was born on 29 December 249 BCE and whose horoscope is preserved in the tablet NCBT 1231 (in the Yale Babylonian Collection), was a prominent scholar of that name who wrote or owned tablets, including both astronomy and astrology, ranging from 229 to 185 BCE.[31] Our single horoscope from Nippur apparently derives from an archive pertaining to the family of one Ninurta-aḫḫê-bulliṭ, a temple brewer, which also contained one of the few astronomical tablets known from Nippur.[32] All in all, we have persuasive circumstantial evidence that the Babylonian horoscopes were produced within the community of scholars engaged in astronomy, whereas it is hard to discern any sign of an internal division between a group of astronomers who practiced nativity astrology and another group hostile to this activity.

A closer examination of the astronomical data in the horoscope tablets strongly confirms the institutional connection between astronomers and nativity astrology while revealing just how astrology depended on that connection. Interestingly, each of the three cities seems to have had its own approach when it came to the astronomical data recorded in horoscopes.

The contents of most of the horoscopes from Babylon are fairly uniform, comprising a birthdate statement and list of astronomical data without astrological interpretations.[33] We can consider them to constitute a distinctive local type. The astronomical data may be grouped according to how their dates relate to the birthdate:

International Astronomical Union 7 (ed. C. Ruggles; Cambridge: Cambridge University Press, 2011), 331–41; Ossendrijver, "Science in Action: Networks in Babylonian Astronomy," in *Babylon—Wissenskultur zwischen Orient und Okzident* (eds. E. Cancik-Kirschbaum, M. van Ess, and J. Marzahn; TOPOI Berlin Studies of the Ancient World 1; Berlin: De Gruyter, 2011), 229–37.

31 Rochberg and P.-A. Beaulieu, "The Horoscope of Anu-bēlšunu," *Journal of Cuneiform Studies* 48 (1996): 89–94.

32 F. Joannès, *Textes économiques de la Babylonie récente* (Paris: Éditions Recherches sur les Civilisations, 1982), 7 note 1; and Joannès, "Les archives de Ninurta-aḫḫê-bulliṭ," in *Nippur at the Centennial* (ed. M. Ellis; Occasional Publications of the Samuel Noah Kramer Fund 14; Philadelphia: University Museum, 1992), 87–100, especially 95.

33 The latest known horoscope, BM 38104 (Text 27 in Rochberg, *Babylonian Horoscopes*, 137–40), cast for an individual born in 69 BCE, is the only one from Babylon to contain an astrological interpretation.

On the birthdate itself

(1) In many horoscopes for birth years down to 142 BCE, the location of the Moon relative to a nearby star in the zodiacal belt ("Normal Star") at the beginning or end of the night of birth or the night preceding the day of birth

(2) The zodiacal sign occupied by the Moon; in some horoscopes from 125 BCE on, the Moon's longitude in degrees

(3) The zodiacal signs occupied by the Sun and any planets that were currently visible at some time of the night (We defer discussion of two late horoscopes from Babylon that give longitudes in degrees for the Sun and planets.)

During the month of the nativity

(4) First and last visibilities of planets

(5) The so-called Lunar Three, comprising an indication of whether the first day of the calendar month coincided with or followed the thirtieth day of the preceding month, the date of the first moonset following sunrise, and the date of the last lunar visibility

Within a few months of the nativity

(6) The date of an equinox or solstice preceding or following the nativity

Within the year of the nativity

(7) Lunar and solar eclipses

Uncertain meaning

(8) In many horoscopes down to 142 BCE, it is stated that the child was born in the *bīt niṣirti* ("secret place") of a specified planet. A planet's *bīt niṣirti* was a constellation or zodiacal sign astrologically associated with that planet. It is not known what criterion determined when a nativity occurred "in" one of these places.

These texts from Babylon offer a range of items of information, among which only the report of the Moon's passage by a Normal Star (item 1) is really specific to the birthdate itself, whereas the zodiacal signs occupied by the heavenly bodies (items 2 and 3) would be valid for intervals of varying length containing the birthdate, and the remaining items (4–7) pertain to dates that are proximate in varying degrees to the birthdate.

It is not difficult to identify plausible sources for most of the astronomical data in the Babylon horoscopes.[34] We can begin by considering the statements of the Moon's position relative to Normal Stars. If these came from any of the known categories of Babylonian astronomical texts, as opposed to the highly improbable alternative that they were products of independent observation or calculation, the only available candidate is the Astronomical Diaries. The Diaries were tablets recording—month-by-month over an interval up to half a year, and day-by-day within each month—a variety of astronomical phenomena and weather conditions, with the day-by-day reports followed by monthly sections summarizing the state of visibility and zodiacal locations of the planets, river levels, commodity prices, and general news. They were compiled in Babylon, apparently without interruption, from at least as early as the mid-seventh century through the mid-first century BCE.[35] In the day-by-day sections, the most numerous astronomical records are observations of the Moon's location relative to Normal Stars, expressed exactly as they appear in the horoscopes. There were twenty-eight Normal Stars in regular use, distributed rather unevenly through the zodiac, so that on a majority of nights the Moon made its closest approach to one of them, and this was recorded whenever the weather permitted an observation.[36] No other known kind of astronomical tablet included these lunar observations. The frequency of occurrence of statements about the Moon's location relative to Normal Stars in the horoscopes from Babylon is consistent with the hypothesis that such a statement was extracted from the Diaries whenever there was one recorded for the birthdate.

The Diaries also contain most of the other varieties of information regularly found in the horoscopes. Dates of first and last visibilities of planets, first moonsets after sunrise, last lunar visibilities, eclipses, and solstices and equinoxes are regularly recorded in the day-by-day sections. The monthly summaries give the zodiacal signs occupied by the planets as well as repeating their

34 See Rochberg, "Babylonian Horoscopes and their Sources," *Orientalia* 58 (1989): 102–23, and Rochberg, "Babylonian Horoscopy: The Texts and their Relations," in *Ancient Astronomy and Celestial Divination* (ed. N. M. Swerdlow; Cambridge, MA: MIT Press, 1999), 39–60, for a broader treatment of this topic.

35 The datable fragments of Astronomical Diaries are published in the first three volumes of A. J. Sachs and H. Hunger, *Astronomical Diaries and Related Texts from Babylonia* (Oesterreichische Akademie der Wissenschaften; Denkschriften der philosophisch-historischen Klasse, 1988-).

36 For the twenty-eight regularly used Normal Stars (as well as several others that occur more rarely in the observation records), see Jones, "A Study of Babylonian Observations of Planets Near Normal Stars," *Archive for History of Exact Sciences* 58 (2004): 475–536.

visibility dates. Again, it is not just the nature of the data but also the forms of expression in the Diaries that are largely reproduced in the horoscopes. While other categories of astronomical tablet could contain one or another of these kinds of information, economy might suggest that if the authors of the horoscopes had to consult the Diaries for the lunar Normal Star observations, they would also have used them for anything else they contained, at least if the information was comparatively easy to locate in these rather voluminous texts.

On the other hand, it is also likely that another type of astronomical tablet, the so-called Almanacs, were used in conjunction with the Diaries.[37] Almanacs were more compendious compilations of a narrower range of astronomical data, including the Lunar Three, solstices and equinoxes, eclipses, planetary synodic phenomena, and dates when planets moved out of one zodiacal sign into another. Unlike the Diaries, which were predominantly records of observation (though containing predicted data as well), the Almanacs were entirely predicted; the basis of the predictions was the application of recurrence periods to Diary records from earlier years rather than mathematical models involving extensive numerical operations.[38]

The longitudes of the Sun and Moon are not recorded in the Diaries but could have been derived from other information that is recorded there. It would have been easy to determine the Sun's zodiacal sign or even estimate its longitude in degrees by counting the days separating the birthdate from the nearest solstice or equinox and adding to or subtracting from the assumed longitude of the tropical or equinoctial point a proportionate number of degrees. The Moon's zodiacal sign or longitude in degrees could be obtained from an observation relative to a Normal Star, correcting for one or two days' motion if the closest observation report was not from the night of or preceding the

37 Rochberg, "Babylonian Horoscopes and their Sources," 119–23; Rochberg, "Babylonian Horoscopy," 53–54.

38 Rochberg ("Babylonian Horoscopy," 50) notes that the terminology expressing eclipses in the horoscopes is in the form characteristic of predictions rather than observations. In the Diaries, some categories of record (e.g., Normal Star observations) were apparently always observed, some (solstices and equinoxes) were always predicted, and some (e.g., lunar and planetary visibilities) were sometimes observed, sometimes predicted. For the methods of generation of the Almanacs, see J. M. K. Gray and Steele, "Studies on Babylonian goal-year astronomy I: a comparison between planetary data in Goal-Year Texts, Almanacs and Normal Star Almanacs," *Archive for History of Exact Sciences* 62 (2008): 553–600.

birthdate;[39] this calculation would have required a list of longitudes of the Normal Stars, and we have tablets giving such a "star catalogue."[40]

The single extant Nippur horoscope lists dates of astronomical events that occurred during the Babylonian calendar year of the nativity—none of them on the actual birthdate.[41] The following are the events, with their approximate dates in the proleptic Julian calendar, reordered according to chronological sequence:

411 BCE	July 19	Saturn, first appearance in Cancer
	October 13	Jupiter, second station in Aquarius
	November 27	Saturn, first station
	December 5	Mercury, first morning appearance behind Gemini
	December 28	Winter solstice
410 BCE	January 5	Saturn, acronychal rising
	January 13	**birthdate**
	January 14	Moon, last appearance
	January 20	Mercury, last morning appearance in Capricorn
	February 1	Venus, last morning appearance in front of Aquarius
	February 17	Jupiter, last appearance in Pisces

For the Sun and Moon, only one event is listed: the winter solstice that fell a few days before the birthdate, and the Moon's last visibility that fell a few days later, respectively. For the planets, the text lists some or all the synodic phenomena that took place within the calendar year; it is not clear on what basis the selection was made (or why no phenomena for Mars are listed at all), though there seems to have been some preference for events that fell near the

39 In two of the horoscopes that give the Moon's longitude in degrees, it is expressly stated to apply to the stage of night when a Normal Star observation would be possible, a strong hint that the longitude was obtained from such an observation.

40 N. A. Roughton, Steele, and C. B. F. Walker, "A Late Babylonian Normal and *Ziqpu* Star Text," *Archive for History of Exact Sciences* 58 (2004): 537–72.

41 Rochberg, *Babylonian Horoscopes*, 51–55 (Text 1 = Louvre AO 17649); see also Rochberg, "Babylonian Horoscopes and their Sources," 111–14.

birthdate.[42] Nevertheless, if the birthdate had not been recorded, we would at best be able to guess that it fell somewhere within a three-month range that covers eight of the ten recorded events; in other words, an astrological interpretation based purely on the astronomical data in this kind of horoscope would not have been able to differentiate between individuals born quite far apart in the same calendar year.

The astronomical data in the Nippur horoscope are all such as could have been found observed or predicted in a Diary or predicted in an Almanac. On the other hand, the restriction of statements concerning the planets to the dates of their synodic phenomena (sometimes accompanied by an indication of the zodiacal constellation occupied by the planet on the date of the phenomenon) and the complete absence of a positional statement for the Moon might suggest not just that the author had a different conception of the kinds of astronomical circumstances that were pertinent to nativity astrology, but also that he had access to astronomical records constituting a subset of the contents of the Diaries. The source was definitely Diary-like and not of a purely predictive variety, such as an Almanac, since Saturn's first appearance is given both an observed date ("high and faint") and a corrected, "ideal" date, and the presence of dense cloud cover is mentioned in the statement of Mercury's last morning appearance.

The Uruk horoscopes again form a distinct group. All of them intermix apodosis statements (e.g., "he will find favor wherever he goes") with the astronomical statements, and all the astronomical statements are indications of the position of the Sun, the Moon, or a planet on the birthdate, or of a planet's invisibility on that date. The earliest two (263 and 249 BCE) give the Sun's and Moon's longitudes in degrees but the planets' positions only in relation to zodiacal signs without degrees. The others give degrees for all the heavenly bodies, and additionally the trend of the Moon's latitudinal motion. Nothing in any of the Uruk horoscopes appears characteristic of an origin in observational records. A point of particular interest in the latest tablet (containing a pair of horoscopes for 199 and 200 BCE) is that the individual planets are characterized as "present" or "not present," apparently meaning that they were above or below the horizon at the time of birth. These statements imply that the author calculated or estimated the rising and setting points of the ecliptic for the time of birth—data not known to have been taken into account in any

42 Following the usual practice in Babylonian astronomy, the recognized synodic phenomena of Mercury and Venus are the first and last visibilities in the morning and evening, while those for the superior planets include the first and last visibilities, the two stations, and the sunset rising.

other Babylonian horoscopes, but that acquired central importance in Greek horoscopy.

The longitudes in degrees for the planets in the later Uruk horoscopes could not have been derived, directly or indirectly, from the Diaries, the Almanacs, or the other classes of observational or predictive tablets dependent on the Diaries; they must have been calculated by mathematical methods. In Babylonian mathematical astronomy, however, a planet's longitude on an arbitrary date was only obtainable indirectly, by interpolation between computed longitude-date pairs for consecutive synodic phenomena. While we have an abundance of tabular texts giving the computed synodic phenomena, tablets presenting sequences of day-by-day longitudes interpolated between the phenomena are comparatively rare. Both linear interpolation and more sophisticated approaches employing sequences with constant third differences to produce the effect of acceleration and deceleration are attested. These may, however, have been scholastic exercises, since making them involved an expense of labor seemingly out of proportion to the occasional need for just one longitude; the actual interpolations leading to the longitudes in the horoscopes could have been done by a more direct calculation on ephemeral media.

At this point, we should take a second look at the Babylon horoscopes. The last known horoscope tablet from Uruk, in terms of birthdate, is the one with the pair of horoscopes for 200 and 199 BCE; speaking more generally, Uruk appears to have ceased to be a center of astronomical and astrological scholarship after the Parthian conquest in 141 BCE.[43] Horoscope production in Babylon continued until at least the mid-first century BCE, and it is noteworthy that among the ten known Babylon horoscope tablets for birthdates later than the middle of the second century, there are two (for 87 and 69 BCE) that give longitudes in degrees for all currently visible planets as well as for the Sun and Moon—clear evidence that mathematical astronomy was coming to be used in Babylon as a source of horoscopic data. Unlike the Uruk horoscopes, however, this pair contain lunar visibility, eclipse, and solstice reports, so that they should be considered rather as a modification of the Babylon type of horoscope than as an importation of the Uruk type. Furthermore, there was still some dependence on Almanacs, if not on Diaries.

43 H. Hunger and T. de Jong ("Almanac W22340a from Uruk: The Latest Datable Cuneiform Tablet," *Zeitschrift für Assyriologie und Vorderasiatische Archäologie* 104 [2014]: 182–94) have dated a problematic fragmentary Almanac tablet from Uruk to 79/80 CE, more than two centuries after the latest securely dated astronomical tablets from Uruk—a circumstance that renders the dating doubtful at best.

Horoscopy in the Greek (and the related Egyptian) tradition has long been known to have depended exclusively on predicted astronomical data. These data constitute a detailed description of the configuration of the heavenly bodies in relation to both the zodiac and the local horizon and meridian at the moment of birth; occasionally, reference was also made to the conjunction or opposition of the Sun and Moon immediately preceding the birthdate. At the conceptual level, the predominant frame of reference for a horoscope is defined by the horizon and meridian, whose intersections with the zodiac are the four cardines—called ascendant or "hour watcher" (ὡροσκόπος), midheaven (μεσουράνημα), setting (δύσις), and lower midheaven or "under-Earth" (ὑπὸ γῆν)—which in turn determine a division of the zodiac into twelve sectors called places (τόποι) associated with various aspects of one's life.[44] In practice, however, the division of the zodiac into twelve signs of 30° each, defined either sidereally in relation to fixed stars or tropically in relation to the solstitial and equinoctial points, served as the scale in relation to which the locations of not only the heavenly bodies but also the cardines were calculated. Hence a Greek horoscope minimally consists of a statement of the birthdate followed by the longitudes of the Sun, Moon, planets, and the ascendant. Most of the more than two hundred extant horoscopes preserved on papyri and ostraca from Roman Egypt keep to this minimum or go barely beyond it, and the great majority of these give all the longitudes as zodiacal signs without degrees.[45] At the other extreme, we have a few 'deluxe' horoscopes that present additional astronomical and astrological data, typically embedded in a prose exposition instead of the usual list format.

Practices of astronomical observation were far more limited in the Greco-Roman context than in Babylon. The reports of observations by Greek astronomers preserved in Ptolemy''s *Almagest* and a very few other sources are not excerpts from records comparable in breadth, consistency of method, and chronological span to the Babylonian Diaries. Each astronomer seems to have chosen to observe particular types of phenomena or configurations, using varying metrological and calendrical conventions, with a view to theoretical

44 These are the 'houses' of modern astrological terminology, but in Greek astrology the word 'house' (οἰκός) meant a zodiacal sign as the domicile of a ruling heavenly body.

45 The principal collections of Greek documentary horoscopes are: Neugebauer & H. B. van Hoesen, *Greek Horoscopes* (Philadelphia: American Philosophical Society, 1959); D. Baccani, *Oroscopi greci: documentazione papirologica* (Messina: Sicania, 1992); and Jones, *Astronomical Papyri from Oxyrhynchus*. At the date of writing, 250 Greek and Demotic Egyptian horoscopes on papyri and ostraca are inventoried in the Trismegistos database (www.trismegistos.org). An extremely small number of documentary horoscopes are known from sites outside of Egypt (e.g., graffiti at Dura Europos) and on small unprovenanced objects.

astronomical investigations. The lack of Diary-like observational corpora also rendered impracticable the composition of nonmathematical predictive corpora like the Babylonian Almanacs, since their predicted data were more or less direct extrapolations from observations by means of recurrence periods.

All Greek horoscopes thus depended for their data on mathematical models expressed in the form of numerical tables. Two categories of table were required: tables for computing the positions of the Sun, Moon, and planets for a given date, and ascension tables correlating degrees of the ecliptic with the degrees of the celestial equator that simultaneously cross the horizon or meridian (used for determining the longitudes of the cardines). Among the two hundred or so horoscopes preserved in Greek or Demotic Egyptian on papyri and ostraca, a very small number—all of them specimens of the deluxe type—explicitly refer to tables. The introductory section of *PLond*. 1.130, a horoscope for a birthdate in 81 CE, identifies the source of its longitudes of the heavenly bodies as αἰώνιοι κανόνες, "Aeon tables."[46] Ptolemy (*Almagest* 9.2) and Vettius Valens (*Anthologiae* 6.2) also allude to these tables, and it is clear from Ptolemy's uncomplimentary description of them that the designation applied to a whole class of tables by various authors, not to a specific set.[47] Ascension tables are indicated as the source of the computed ascendant in *PLond*. 98 (95 CE) and *POxy. astron*. 4276 (second or third century CE), in the latter instance with an attribution to or at least association with Hipparchos (Ἱππαρχικοῦ συντάγματος).[48] Numerous fragments of tables for computing positions of the heavenly bodies according to mathematical models are extant on papyrus.[49] They fall into two groups, according to whether they are based on Babylonian-style arithmetical models or geometrical models assuming combinations of uniform circular motions treated trigonometrically; among the latter group, fragments of Ptolemy''s *Handy Tables* and adaptations of Ptolemy's tables predominate. Surprisingly, the only ascension tables attested in papyri are parts of the *Handy Tables*, though we have abundant indirect evidence that astrologers also used arithmetically structured tables ultimately derived from Babylonian mathematical astronomy.

46 Neugebauer and van Hoesen, *Greek Horoscopes*, 21–28.

47 Ptolemy employs the variant expression αἰώνιος κανονοποιία; the collective noun, difficult to render in English, is roughly equivalent to the German *Tafelwerk*.

48 Neugebauer and van Hoesen, *Greek Horoscopes*, 28–38; Jones, *Astronomical Papyri from Oxyrhynchus*, 1.282–283 and 2.418–419.

49 For the various formats of astronomical tables found in Greek papyri, see Jones, "A Classification of Astronomical Tables on Papyrus," in *Ancient Astronomy and Celestial Divination*. (ed. N. M. Swerdlow; Cambridge, MA: MIT Press, 1999), 299–340.

It is likely that any astrologer who professed to do high-quality work—the kind who produced the deluxe horoscopes, for example—would have owned and known how to use at least one set of numerical tables. The most elaborate horoscopes report more astronomical information than just the longitudes of the heavenly bodies on the birthdate. The current stage of each planet's synodic cycle may be indicated, the convention being to identify the stage by the synodic phenomenon that immediately preceded the date. The latitudes of the Moon and planets are also sometimes given, as well as the names of nearby stars in the zodiacal belt. Ptolemy's *Handy Tables*, which incorporates tables for computing both longitudes and latitudes as well as for determining whether a planet is visible and whether it is stationary, plus a catalogue of zodiacal stars, turns out to constitute a more or less complete package of astronomical resources for the most ambitious astrologer.

However, among the astronomical papyri, the fragments of such 'primary' tables are greatly outnumbered by fragments of almanac-style tables that gave precomputed positions of the heavenly bodies for a series of dates at regular or irregular intervals. The most common format tabulated the dates in each calendar year when each of the five planets was predicted to enter a new zodiacal sign. This type of 'sign-entry' almanac would have sufficed for the majority of horoscopes that only specified positions according to zodiacal sign without degrees. Other almanacs gave computed dates and longitudes of the planets at their synodic phenomena as well as their sign-entries, allowing for the possibility of interpolating longitudes for intermediate dates. Starting in the third century CE, one begins to encounter almanacs tabulating planets' longitudes in degrees, computed at fixed intervals, such as every fifth day. A numerically skilled astrologer could have computed an almanac for himself, but it appears probable that many of the almanacs we have were produced commercially for the astrological trade by specialists. For an individual astrologer, the labor involved in computing a few years' worth of an almanac would probably have far exceeded the labor of directly computing the horoscopes of those clients whose birthdates fell within the almanac's span.

Ephemerides—that is, tables listing computed positions of the heavenly bodies at intervals of single days within a calendrical structure—constitute a special category of almanac. Some ephemerides gave daily longitudes only for the Moon, accompanied by an almanac giving the planets' longitudes only at their synodic phenomena and sign-entries. Others laid out the longitudes of the Moon, Sun, and five planets in parallel columns. While astrologers certainly could have employed ephemerides for composing horoscopes, there was also a broader market of nonexperts who consulted ephemerides to determine auspicious and inauspicious days for various activities, according to the configurations of the Moon relative to the other heavenly bodies. In the latest examples we have on papyrus, from the fifth century CE, such astrological appraisals are explicitly provided in a separate column.

For a sophisticated astrologer, almanacs were a time-saving and labor-saving resource to be called upon when imprecise astronomical data were sufficient for an astrological interpretation. In precision work involving numerical tables, an astrologer had to possess mathematical skills different from the knowledge of metrology, mensurational formulas, and problem-solving algorithms that were the substance of common mathematical education, and also different from the deductive theoretical mathematics of the Euclidean kind. In particular, he had to understand and know how to perform arithmetical operations—addition, subtraction, occasional multiplication, and tabular interpolation—with sexagesimal fractions. Almanacs would have made it possible to dispense with most of the sexagesimal arithmetic, at least so far as the planets are concerned, and it is conceivable that some astrologers managed to carry on a low-end practice with slender mathematical skills, relying on ephemerides, almanacs, and crude rule-of-thumb algorithms. No systematic study of the errors in the preserved horoscopes has yet been made, but even a superficial survey suggests that gross mistakes were not uncommon.

Astrological practice called for only a rather superficial knowledge of theoretical astronomy. An astrologer obviously would have needed to know the identities of the heavenly bodies, their apparent patterns of movement through the zodiac, and the elementary concepts of the celestial sphere underlying the definitions of the cardines. Even comparatively complex astronomical tables like Ptolemy's, however, can be used by someone who has no deep understanding of the theory behind the tables, so long as one has clear instructions and the requisite arithmetical skills. Although the prevailing rationale for Greco-Roman astrology appealed to a vaguely Aristotelian cosmology of revolving heavenly spheres influencing the sublunary world and its denizens, the detailed geometrical models of epicyclic and eccentric motions played no significant role in astrology. We should not be surprised, therefore, that among the abundant remains of astrologers' resources found among the papyri, fragments of works on theoretical astronomy are exceedingly rare.

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