Babylonian Observations and Greek Science

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Greco-Roman writers of Hellenistic and Imperial times frequently speak of the Babylonians as observers and recorders of astronomical phenomena. There is, however, enormous variation in the specificity and verifiable accuracy of their statements. Consider the case of Simplicius, a Neoplatonist philosopher of the sixth century of our era who had read widely and not unintelligently in the exact sciences and their history. In his huge commentary on Aristotle's *On the Heavens* Simplicius makes three allusions to Babylonian astronomical observations. First, to back up the Aristotelian doctrine of the heavens as a body in eternal circular motion and not subject to generation, corruption, or externally induced change, he says,

> I have heard that the Egyptians are in possession of recorded astral observations covering not less than 630,000 years, and the Babylonians [not less than] 1,440,000 years. From such long intervals, since the time when records were transmitted, nothing is recorded of celestial matters as being in a different condition compared to now, whether with respect to the number of the stars or their magnitude or their color or their periodic motions.

The easy thing for us to do with a passage like this is to pull out of its context the assertion that the Babylonians had kept observations for 1,440,000 years and confront it with what we know from cuneiform texts about the chronological extent of the Babylonian Astronomical Diaries and related texts, a comparison that just

makes Simplicius appear ignorant and absurd. But if we go on to read what he says we learn from those observations, it is not at all clear that Simplicius has anything so specific in mind as the Diaries, which after all do not contain information about the numbers of fixed stars and planets, their colors, or their magnitudes. His appeal is to a vague conception of long, long years of skywatching and writing, calibrated by the traditional chronologies of Mesopotamian literature rather than the contents of a specific astronomical archive.

Elsewhere, Simplicius explains why the modern student should follow the theories of later astronomers rather than Aristotle and the authorities Aristotle relied on for the details of planetary motion. For Aristotle and his sources did not know as many phenomena as their successors,

> because the observations sent by Callisthenes from Babylon at Aristotle's behest had not yet come to Greece, which Porphyry records as covering 31,000 years up to the time of Alexander of Macedon...

Again, a huge time-span—though not quite so huge as before—goes along with hand-waving vague talk of "observations" revealing "phenomena", and one suspects that Simplicius had not tried very hard to imagine what kind of transportable document might have comprised 31,000 years of observation records. In his third reference to Babylonian observers, Simplicius merely asserts that many observations by the Egyptians and Babylonians of occultations of planets by the Moon have been handed down; this, for once, could be seen as a reference to the Diaries, which do contain occultation reports.

By contrast, Ptolemy consistently displays concrete and accurate knowledge of Babylonian observations in his *Almagest*. He quotes literal translations of what are evidently authentic Babylonian reports of planets passing by Normal Stars, as well as somewhat modified and edited versions of Babylonian lunar eclipse reports. Speaking more generally of varieties of planetary observations that he regards as of slight value for astronomical research, he says that the more ancient ones consisted chiefly of records of appearances, disappearances, stationary points, and distances—often comparatively great distances—from fixed stars: though he does not specify the provenance of these observations, his categorization perfectly fits the planetary reports of the Diaries. And Ptolemy identifies the reign of Nabonassar as the "era beginning from which the ancient observations are, on the whole, preserved down to our own time," in accord with the Babylonian tablet series that collected eclipse reports starting with the accession of Nabu-Nasir.

When Simplicius seems to get nearest to the actual Babylonian reports of the Diaries, in his reference to Babylonian observations of lunar occultations of planets, he is thinking of them as counterparts of Aristotle's report of an occultation of Mars: "For we have seen the Moon, half full, pass beneath the planet Mars, which vanished on its shadow side and came forth by the bright and shining part." That is all that Aristotle says about the event. A Diary report would run something like, "Seleucid Era year 180, Month IX, night of the 5th, when the star beta Persei culminated, Saturn entered the southern horn of the Moon." If Simplicius had ever seen an actual Babylonian occultation report, he would not have cared the least about the date and time, but just the fact that an occultation had occurred on *some* occasion, thus

showing that the Moon is closer to us than Saturn. To speak more broadly, most Greco-Roman writers who speak of Babylonian observations show no awareness or interest in the principle of an exactly dated report; for Ptolemy, by contrast, the date was an absolutely essential element of the report, and he not only quotes the date but invariably *uses* it in applying the report towards the deduction of some part of his theories.

Ptolemy's treatment of the Babylonian reports, while obviously far removed from Simplicius' hazy invocations of aeons of observation, is also significantly differentiated from the way the cuneiform tablets present them. In the original Babylonian records, whether we are speaking of the Diaries, the Goal-Year Texts, or the various kinds of excerpt text that seem to be the most likely candidates for the immediate sources of the Greek translations, reports are listed in chronological order and without discussion; the dates are first and foremost a means of organizing and so to speak indexing the reports, and secondarily the means of *seriatim* forecasting of future occurrences of the same kinds of events through established period relations. In the *Almagest* the reports have been isolated and embedded in an analytic, mathematical argument where they function somewhat like postulates, or to put it a bit differently, as agglomerations of data concerning an observed event or configuration of heavenly bodies that is not the object of study in its own right, but conceived as a kind of snapshot of a moment in a continuum of motion and change. The date becomes one part of the data on an equal basis with other recorded information such as an eclipse's magnitude or a distance of a planet from a star.

Ptolemy of course did not invent this manner of presenting and operating with dated observation reports. We find it in a papyrus fragment of an astronomical treatise of unknown authorship composed several decades before the *Almagest*, and Ptolemy provides extensive and credible testimony that Hipparchus followed the same approach in the mid 2nd century BCE in several works on solar and lunar theory that have not come down to us. Can we trace it still further back? I can think of no instance from earlier in the 2nd or from the 3rd century BCE, but we do have testimony claiming its use already in the late 4th century.

In his commentary on the *Almagest*, Theon of Alexandria writes that Hipparchus had said in his book *On Intercalary Months and Days* that Callippus, an astronomer contemporary with Aristotle in the mid-to-late fourth century BCE, had concluded that the length of the year was 365 1/4 days; Theon's words are as follows:

> In his *On Intercalary Months and Days*, Hipparchus first states that Callippus, having compared his own observations with the Chaldean ones, computes the length of the year to be 365 15/60 days, and the length of a month from conjunction to conjunction or from opposition to opposition to be 29 30/60 days.

But this is certainly not a direct quotation from Hipparchus' book, since it echoes almost verbatim a passage much later in Theon's commentary where he recounts how *Hipparchus* obtained an eclipse period embodying accurate periodicities of lunar motion:

> Having compared his own observations with the Chaldean ones, he found from the computations that...

And this in turn proves to be a paraphrase of the counterpart passage in the *Almagest*. So Theon is giving us a stylized representation of whatever Hipparchus wrote about Callippus' methodology, metamorphosed into a mimicry of what *Ptolemy* wrote about Hipparchus' methodology. The parallels confirm that Theon imagined Callippus as proceeding, like Hipparchus, by calculating the time intervals between suitably chosen observations spanning as wide an interval as possible, but his testimony is no satisfactory basis for *our* supposing that Callippus exploited dated Babylonian observation reports. The most one might venture to suggest is that Callippus may have adduced some parameters from Babylonian sources in support of his 76-year calendrical cycle.

Hipparchus thus remains both the earliest Greek astronomer known to have had access to Babylonian dated observation reports and the earliest known to have used them as chronologically fixed data points for establishing theories. The latest Babylonian observation known to have been translated into Greek is a report of Saturn passing by a Normal Star in 229 BCE, so some if not all of the process of selection and translation from the Babylonian tablets must have occurred during the interval between 229 and, say, 140, taking that as roughly the midpoint of Hipparchus' career. The circumstance that the reports of Babylonian origin as preserved in the *Almagest* exhibit differing degrees of divergence from their presumed original forms, for example in the choice of calendars, time reckoning, and stellar nomenclature, could be interpreted as an indication of multiple

transmissions, but other explanations of these inconsistencies are imaginable, and we cannot rule out Gerald Toomer's hypothesis that Hipparchus was himself instrumental in procuring reports from the Babylon archive. The extent of what was transmitted is also uncertain. Clearly there were a lot of lunar eclipse reports, extending back to the earliest records in the eighth century BCE, but how much later did they run than the last preserved one in 382 BCE, and how complete was the set? The preserved planetary observations all come from the mid third century BCE, and there are good reasons to believe that no translations existed of planetary reports from before that century, so that curiously they were all later than the range of preserved eclipse reports.

A particularly interesting problem is to appraise the influence of Babylonian observations on the observations made in the Greco-Roman world. Goldstein and Bowen have drawn attention to the fact that, if we leave aside observations of dates of solstices, Greek scientific records of exactly dated observations begin at the start of the third century BCE in Egypt. Two chronologically overlapping programs of observation can be identified among the records Ptolemy cites in the *Almagest*: that of Timocharis, and that of an unknown astronomer or group of astronomers who employed a distinctive calendrical system devised by one Dionysius. Were these programs inspired by, or influenced by, the continuing program in Babylon? There are important differences between the conventions used in the Greco-Egyptian observations and the Babylonian ones. For example, where a Babylonian report will express a planet's position relative to a fixed star by giving distances in units called cubits and fingers measured parallel to and perpendicular to the ecliptic, a report by

one of the Dionysian observers would give distances in units called Lunar Diameters measured radially from one star and perpendicularly from an imagined line through two stars.

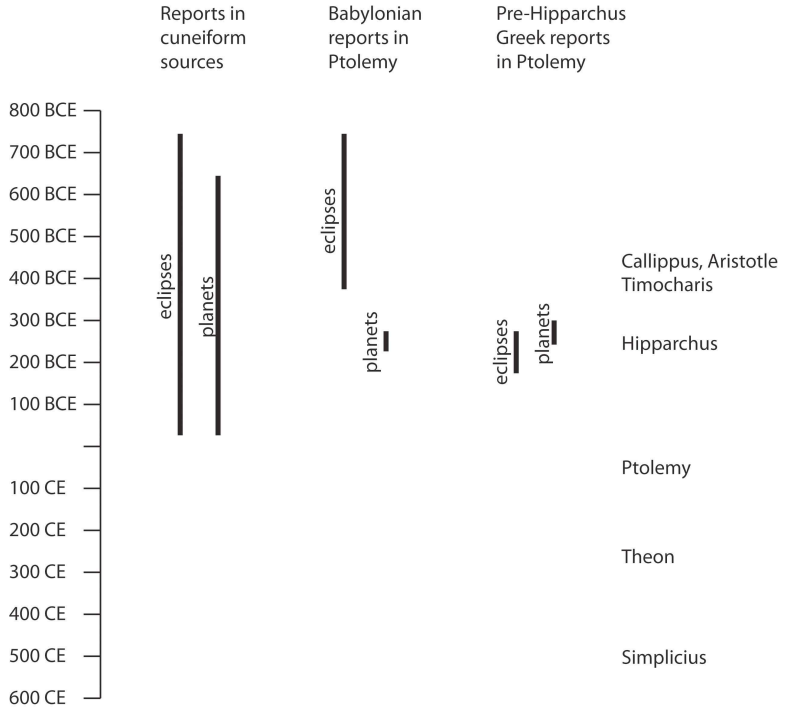
Nevertheless I think there are strong considerations favoring Babylonian influence. Firstly, there is the very notion of recording dated observations, which does not easily explain itself in terms of the concerns of Greek astronomy before the third century. Secondly, the programs involved recording observations made in fairly quick succession, for example observations of the same planet at intervals of a few days, resembling the continuity of the Diary records. Thirdly, Timocharis' program, at least, involved a variety of different kinds of observation with analogues in the Diaries: lunar passages of fixed stars, stellar passages of stars, and lunar eclipses are all attested.

A passage in the *Almagest* recounts how Hipparchus investigated the long term behavior of the position of the bright zodiacal star Spica relative to the nearby autumnal equinoctial point, that is, the intersection of the ecliptic with the celestial equator. This involved analysing a report of an eclipse observation by Timocharis, which Goldstein and Bowen have identified as that of 284 BCE March 17/18. Ptolemy does not quote the original report, but we can deduce that it must have included not only the date but also the time of at least one stage of the eclipse and probably its duration, and the Moon's observed location relative to Spica. With the highly problematic exception of the famous eclipse preceding the battle of Gaugamela in 330 BCE, this is the first known Greek record of an eclipse to have included such details, which were routine in Babylonian eclipse reports. From 201

and 200 BCE Ptolemy preserves, through the intermediary of Hipparchus, anonymous Alexandrian reports of three total eclipses with recorded times of stages of the obscuration; and from 174 BCE he preserves another Alexandrian report of a partial eclipse, with the magnitude expressed in the Babylonian metrology of eclipse digits. Thus Babylonian influence can be indisputably discerned in the practice of eclipse observation at least a generation before Hipparchus.

The observation program in Babylon was still fully active at least up to the mid first century BCE, a fact that was known to Strabo and Pliny. Why, then, does Ptolemy cite no Babylonian report after the third century? I can think of several possible answers. First, the translations may have cut off around that point. Secondly, Ptolemy may not have had access to the entire corpus of translated reports, but only to a selection that favored earlier records. Thirdly, he may have judged the Greek reports, once they became available, to be of superior quality. And fourthly, Greek reports may have been easier to work with because their conventions, metrology, and calendar were better understood. It is a pity that we have no other Greek astronomical texts containing embedded Babylonian reports to enable us to gauge the extent to which Ptolemy was in control of his sources and how far he was restricted by them.

Alexander Jones, *Babylonian Observations and Greek Science* (handout)



A. Simplicius (*In Aristotelis quattuor libros de Caelo comm.* ed. Heiberg, *CAG* 7)

(i) (p. 117) ἤκουσα δὲ ἐγὼ τοὺς μὲν Αἰγυπτίους ἀστρῴας τηρήσεις οὐκ ἐλαττόνων ἑξήκοντα τριῶν μυριάδων ἐτῶν ἀναγράπτους ἐσχηκέναι, Βαβυλωνίους δὲ ἑκατὸν καὶ τεσσαράκοντα καὶ τεσσάρων μυριάδων. ἀπὸ δὴ τοσούτων χρόνων, ἀφ᾽ ὧν ἱστορίαι παρεδόθησαν οὐδὲν ἱστόρηται τῶν περὶ τὸν οὐρανὸν ἀλλοίως ἔχον πρὸς τὰ νῦν οὔτε περὶ τὸν ἀριθμὸν τῶν ἀστέρων οὔτε περὶ μέγεθος αὐτῶν ἢ χρῶμα οὔτε περὶ τὰς κινήσεις τὰς ἀποκαταστατικάς.

I have heard that the Egyptians are in possession of recorded astral observations covering not less than 630,000 years, and the Babylonians [not less than] 1,440,000 years. From such long intervals, since the time when records were transmitted, nothing is recorded of celestial matters as being in a different condition compared to now, whether with respect to the number of the stars or their magnitude or their color or their periodic motions.

(ii) (p. 506) ... διὰ τὸ μήπω τὰς ὑπὸ Καλλισθένους ἐκ Βαβυλῶνος ἐκπεμφθείσας τηρήσεις ἥκειν εἰς τὴν Ἑλλάδα Ἀριστοτέλους τοῦτο ἐπισκήψαντος αὐτῷ, ἃς ἱστορεῖ Πορφύριος ἐτῶν εἶναι χιλίων καὶ μυριάδων τριῶν ἕως τῶν Ἀλεξάνδρου τοῦ Μακεδόνος σωζομένας χρόνων...

... because the observations sent by Callisthenes from Babylon at Aristotle's behest had not yet come to Greece, which Porphyry records as covering 31,000 years up to the time of Alexander of Macedon... [William of Moerbeke's Latin version has "1,903 years", evidently arising from a misreading of numerals.]

(iii) (p. 481) ... καὶ περὶ τοὺς ἄλλους δὲ ἀστέρας τὸ αὐτὸ συμβὰν τοὺς ἀνωτέρω ἐτήρησαν Αἰγύπτιοί τε καὶ Βαβυλώνιοι, ὡς πολλὰς αὐτῶν περὶ ἑκάστου τῶν ἀστέρων τηρήσεις παραδεδόσθαι.

... and concerning the other stars the Egyptians and Babylonians have observed the same thing taking place, so that many of their observations concerning each of the stars has been handed down.

B. Callippus' alleged use of Babylonian observations.

(i) Theon on Hipparchus on Callippus' determination of periods (*Comm. in Ptol. syntaxin math.* III, ed. Rome 838-839)

πάλιν ἐν τῷ περὶ ἐμβολίμων μηνῶν τε καὶ ἡμερῶν, προειπὼν ὅτι ὁ μὲν Κάλλιππος συγκρίνας τὰς ἑαυτοῦ τηρήσεις πρὸς τὰς Χαλδαικὰς συνάγει τὸν ἐνιαύσιον χρόνον ἡμερῶν τξε ιε...

In his *On Intercalary Months and Days*, Hipparchus first states that Callippus, having compared his own observations with the Chaldean ones, computes the length of the year to be 365 15/60 days...

(ii) Theon on Hipparchus' determination of periods (*Comm. in Ptol. syntaxin math.* IV, ed. Rome 991-992)

συγκρίνας γὰρ τὰς ἑαυτοῦ τηρήσεις πρὸς τὰς Χαλδαικὰς εὗρεν ἐκ τῶν ἐπιλογισμῶν ὅτι...

Having compared his own observations with the Chaldean ones, he found from the computations that...

(iii) Ptolemy on Hipparchus' determination of periods (*Alm.* 4.2, ed. Heiberg 1.270)

ἤδη μέντοι πάλιν ὁ Ἵππαρχος ἤλεγξεν ἀπό τε τῶν Χαλδαικῶν καὶ τῶν καθ᾽ ἑαυτὸν τηρήσεων ἐπιλογιζόμενος...

But again, Hipparchus, calculating on the basis of the Chaldean observations and those of his own time, refuted...

Selective references

p. 1

Simplicius on *De Caelo*: CAG 7.117 (handout A i).

p. 2

Simplicius on *De Caelo*: CAG 7.506 (handout A ii); cf. C. F. Lehman, *Zwei Hauptprobleme der altorientalischen Chronologie und ihre Lösung*, Leipzig, 1898, 109–110 and 210, and S. M. Burstein, "Callisthenes and Babylonian Astronomy: A Note on *FGrHist* 124 T 3," *Echos du monde classique/Classical News and Views* 28, n.s. 3, 1984, 71–74 for the possibility that the number of years of observations reported by Porphyry *via* Simplicius was not 31,000 (as written in the Greek manuscripts) but 1903 (as in William of Moerbeke's Latin translation). Burstein further suggests that 1903 was calculated as the interval between the foundation date of Babylon as given by Ctesias and the death of Alexander. Whether or not this plausible explanation is correct, Callisthenes certainly did not have had access to Babylonian observation reports going that far back, and for that matter Porphyry's claim was not necessarily referring to the specific set of reports that Callisthenes allegedly sent to Greece.

Simplicius on *De Caelo*: CAG 7.481 (handout A iii).

p. 3

Ptolemy, *Almagest* 9.2, ed. Heiberg 2.209; 3.7, ed. Heiberg 1.254.

Aristotle, *De Caelo* 292a3.

"Diary report" of occultation: not an actual quotation, but similar wording in *ADART* 3 text –124 B obv. 24' for S.E. 187 X 5.

p. 5

P.Oxy. astr. 4133 in A. Jones, *Astronomical Papyri from Oxyrhynchus*, Philadelphia, 1999. Cf. A. Jones, "A Likely Source of an Observation Report in Ptolemy's *Almagest*," *Archive for History of Exact Sciences* 54, 2000, 349–373.

Theon of Alexandria on *Almagest*, ed. Rome 3.838–839 (handout B i).

p. 6

Theon of Alexandria on *Almagest*, ed. Rome 3.991–992 (handout B ii).

Ptolemy, *Almagest* 4.2, ed. Heiberg 1.270 (handout B iii).

p. 7

G. J. Toomer, "Hipparchus and Babylonian Astronomy," in *A Scientific Humanist: Studies in Memory of Abraham Sachs*, ed. E. Leichty *et al.*, Philadelphia, 1998, 353–362.

B. R. Goldstein and A.C. Bowen, "The introduction of dated observations and precise measurement in Greek astronomy," *Archive for History of Exact Sciences* 43, 1991, 93–132.

p. 8

Ptolemy, *Almagest* 3.1, ed. Heiberg 1.198.

Eclipse of 330 BCE: Ptolemy, *Geography* 1.4; Pliny, *N.H.* 2.180; cf. J. L. Berggren and A. Jones, *Ptolemy's Geography: A Translation of the Theoretical Chapters*, Princeton, 2000, 29–30.

p. 9

Eclipses: Ptolemy, *Almagest* 4.11, ed. Heiberg 1.344–346; 6.5, ed. Heiberg 1.477.