Babylonian Lunar Theory in Roman Egypt: Two New Texts

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In 1988 O. Neugebauer published a partial transcription and discussion of a first-century A.D. Greek papyrus fragment in a private collection (*P. Colker*), which as he showed contains a run of values of the function G representing a first approximation to the duration of consecutive synodic months in the Babylonian System B lunar theory.[1] Before this discovery, no one would have expected to find one of the key functions of the Babylonian lunar theories turning up in essentially unmodified form in a Greco-Roman papyrus. A few of the seventy or so astronomical papyri known up to that time showed the influence of Babylonian mathematical astronomy, but none could be reasonably described as an "ACT text in Greek" (where ACT refers by acronym to the kinds of astronomical tablets included in Neugebauer's *Astronomical Cuneiform Texts*). *P. Colker* demonstrated that part of the tradition of astronomical computation practiced by the astrologers—at least, we presume that such were the people who produced most of the Roman-period astronomical papyri—was so close to the Babylonian models that the transmission of methods must have been quite direct: not, for example, through the medium of theoretical handbooks or treatises such as those of Geminus and Ptolemy.

Since the appearance of Neugebauer's article, more has been learned about the practice of ACT-style methods in Roman Egypt. First, from a closer inspection of *P. Colker* it became clear that the very poorly preserved column of numerals to the left of the column for G must contain a function with a periodicity of roughly twelve synodic months (whereas G's periodicity is roughly fourteen months).[2] The most plausible candidate for this function is J, representing a correction to G with an annual period, that is, dependent on the sun's longitude. This confirms that we are dealing with a multi-column table like the Babylonian System B tablets, not some other tabular structure that treats G in isolation; it also points to a possible connection of *P. Colker* with a particular type of System B tablet in which J is tabulated to the left of G instead of occupying its usual position two columns to the right of G.

Secondly, many more astronomical tables came to light among the papyri excavated by B. P. Grenfell and A. S. Hunt at Oxyrhynchus, now kept at the Ashmolean Museum at Oxford. The edition of these papyri that I published in 1999 includes several containing ACT-style tables for planetary phenomena, most of them conforming to known Babylonian arithmetical models.[3] Hence we know now that

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1 NEUGEBAUER (1988).

2 JONES (1997).

3 JONES (1999); see also JONES (1998).

the transmission included a large part of the Babylonian planetary theories as well as part of the System B lunar theory. However, none of the tables in my publication could be certainly identified as pertaining to either of the Babylonian lunar theories.

It was, in fact, just as the edition was going to press that an uninventoried System B lunar table came to light among the unpublished Oxyrhynchus papyri. The text has the inventory number P. Oxy. ined. 23 3B 1/O(1-4)c, and will in due course be published formally with an assigned text number in the *Oxyrhynchus Papyri* series. It comprises three fragments: a larger one (3 cm wide by 3.5 cm tall) that preserves the bottom eleven lines of the table with part of the lower margin below the table and vacant margin to the left of the table, and two smaller fragments belonging above the main one, so that from the top partially preserved line to the bottom would have been twenty lines. There are some slight traces of writing, apparently a document, on the back. The hand of the table appears to belong to the second or third century A.D.; unfortunately, the information surviving in the table cannot be dated astronomically.

In the following provisional translation of the table, brackets enclose restored numerals; all restorations are certain.

i				ii	iii			
[29	14	19	40]	[Pisces]	[1]4	[4]	20	[20]
[28	56	19	40]	[Arie]s	13	[0]	40	[0]
[28	38	19	40]	[Ta]urus	11	38	59	40
[28	20	19	40]	[Gem]ini	9	59	19	20
[28	18	59	40]	[C]ancer	8	18	19	0
[28	36	59	40]	[L]e[o]	6	[55]	18	40
[28	54	59	40]	[Vi]rgo	5	[50]	18	20
[29	12	59	40]	[Libra]	5	[3	1]8	[0]
[29	30	59	40]	[Scorpio]	[4	34	1]7	[40]
[29	48	5]9	40	[Sagittarius]	[4	23	17	20]
[2]9	[56	5]8	20	[Capricorn]	[4	20	15	40]
[2]9	3[8	5]8	20	[Aquarius]	[3	59	1]4	[0]
29	20	58	20	Pisces	3	20	12	20
29	2	58	20	Aries	2	23	10	40
28	44	58	20	Taurus	1	8	9	0
28	26	58	20	Taurus	29	35	7	[20]
28	12	21	[0]	Gemini	27	47	28	20
28	30	21	0	Cancer	26	17	49	[20]
28	48	21	0	Leo	25	6	10	20
29	6	21	0	Virgo	24	12	31	20

Column i is a run of values of System B function A, representing the progress of the moon in longitude since the preceding syzygy, and columns ii and iii give function B, the longitude of the moon at the syzygy calculated as the running total of column i. Since A is smallest when the corresponding longitude is in Gemini or Cancer, the tabulated phenomena are conjunctions rather than full moons. (The ideal maxima and minima of the function have been set to correspond to longitudes such that the midpoint of the shortest possible synodic arc is very near Gemini 11°, and the midpoint of the longest possible arc is very near Sagittarius 11°.) The defining parameters of function A are the unabbreviated ones (employing three sexagesimal fractional places) characteristic of most of the ACT System B tablets from Babylon. In the cuneiform tables, a column providing the year and calendar month of the syzygy regularly appears to the left of A; we may suppose that the corresponding information in the papyrus table was put together with the computed day and time of the syzygy, somewhere in the lost columns to the right. A minor difference of format in comparison to the cuneiform tables is that the zodiacal signs of the longitudes are placed, according to the normal Greek convention, to the left of the degrees.

Both this Oxyrhynchus papyrus and *P. Colker* are easy to identify as pertaining to the Babylonian lunar System B because they preserve substantial parts of actual columns of data. The remaining papyrus to be discussed in this article presents greater difficulties. It was originally intended to appear in volume 15 of the *Papiri della Società Italiana*, the publication of which has unfortunately been long delayed; the papyrus is assigned the publication number *PSI* 1491. Neugebauer, who assisted in preparing a draft text and commentary in 1964, kindly provided me with a copy of his notes and a photograph of the papyrus in 1982. More recently I have been able to study an excellent colour photograph through the kindness of Prof. G. Bastianini.

The fragment has dimensions of approximately 7×16 cm, and preserves part of a single column of text with a bottom margin of about 4.5 cm. The top and both edges of the column are broken off. There is no text on the other side of the papyrus. I would estimate that the hand belongs to the second century A.D.[4] The following is a transcription of the papyrus with the minimal restorations that can be made without understanding the subject of the text:

c]ε̣λί̣[διν	] column [
] ̣ [*c. 5 letters*]´η´ κ[	x]8 …[
δ]ιάcτημα 𐆊 ̣ [	] interval 0 … [
] δεύτερον cε[λίδιν	] second column [
]η̣ν ἐπιcυναγομέ[νην	] accumulated [
τρίτον] cελίδιν ζῳ̣δίω[ν	third] column of zodiacal signs [
τέταρτ]ον cελίδιν οὗ ὅροc ̣ [	fourth] column, of which limit … [
] ̣ οc μοι(ρῶν) κ̅α̅ τίθεται̣ γ̣[ὰρ	] … 21 degrees. For it is placed [
κατ]ὰ τὸν Κρει̣ὸν καὶ τ̣ὸν Ζυ̣[γὸν	at] Aries and Libra [
] ̣ μοι(ρῶν) η̅ ἐλ̣αχίcτην οὐκ ἐ[	] … 8 degrees. Least not … [
] προcθαφαίρεcιc 𐆊 ϛ´ ̣ [	] increment/decrement 0 6 … [
]´ε´ πέμπτον cελίδιν ο̣ῦ̣ [	] … fifth column, of which [
] ̣ μέγιcτόc ἐcτιν λ´β´ ̣ ̣ [	] … greatest is 32 … [
τίθ]εται γὰρ κατὰ τὴν τοῦ Αἰγ[ό–	] For it is placed at Capricorn
κερ]ω καὶ Καρκίνου μοί(ραν) η̅ [	] and Cancer, 8 degrees [

4 The hand is said in NEUGEBAUER (1962), p. 388 to be of the late first or second century, and in NEUGEBAUER (1975), p. 946 to be second century; it is similar in many respects to *P. Bodmer* ii (TURNER (1987), no. 63), which has been variously dated to the second or early third centuries.

ἕκτο]ν cελίδιν ἀπὸ Παρθ[ένου	sixth] column from Virgo [
προcθ]αφαίρεcιc ὡc Ἰχθύων [	increment/]decrement to? Pisces [
ἕβδο]μον cελίδιν δρόμοc cε[	] seventh column, course … [
]ηc οὗ ὅροc δ̅ κ΄ε΄ κ΄ζ΄ [	] … of which limit 4 25 27 [
]ην μὲν ἐλαχίcτην η̣ [	] … least …[

The text is obviously a description of a table containing at least seven columns, which are mentioned in order, along with pertinent data including zodiacal signs, degrees, and other numbers. Neugebauer thought that the character of the descriptions was suggestive of a table with columns for several different heavenly bodies: perhaps the sun, moon, and five planets. He further proposed identifying the Cancer and Capricorn of column 5 with the perigee and apogee of Mars, the Virgo and Pisces of column 6 with the apogee and perigee of Jupiter, and the Aries of column 4 with the perigee of Mercury. Since he was unable to recover any continuous sense from the preserved text, however, he remained very circumspect about the interpretation.[5]

The starting point for understanding the papyrus is the very strong impression that only a little text has been lost between consecutive lines. In particular, lines 8-10 are paralleled in construction by lines 14-15, and there seems to be nothing missing except for the completion of partially preserved words. Allowing the margins implied by these restorations to guide us elsewhere, one can obtain a nearly unbroken text over several lines.

The key to understanding the nature of the table might be expected to lie in the remarks on columns four, five, and seven. The fourth column is said to have a greatest (?) limit of 21°, and this (?) is supposed to be placed at the diametrically opposite longitudes, Aries 8° and Libra 8°. Similarly, the fifth column has a greatest limit of 32 units of some kind, perhaps followed by a fraction, at the diametrically opposite points, Capricorn 8° and Cancer 8°. These four longitudes are respectively the equinoctial points and the solstitial points according to the Babylonian System B norm (which is well attested also in Greco-Roman astronomy). They have no relevance for the motion of the planets, which casts doubt upon Neugebauer's hypothesis of a planetary table.

Moreover, the seventh column's "limit" of 4;25,27,[…?] looks suspiciously like a miscopying of 4;29,27,5, which is the upper bound of the function G in a System B lunar table; the problematic digit is an epsilon (5), often mistaken for theta (9) in Greek capital scripts. If we accept this hypothesis, most of the other data in the papyrus quickly fall into place. It is now obvious that the text is a description of a variety of System B table specifically concerned with the prediction of full moons.

5 NEUGEBAUER (1962), p. 388 and (1975), p. 946; further (wrong-headed) embellishment by JONES (1984).

This is what the text now looks like:

πρῶτον c]ε̣λί̣[διν	first] column [
].[ι]΄η΄ κ[	1[?]]8 … [
δ]ιάcτημα ō .[	] Interval 0 … [
] δεύτερον cε[λίδιν	] Second column
ἔχει τ]ὴ̣ν ἐπιcυναγομέ[νην.	has] the running total.
τρίτον] cελίδιν ζῳδίω[ν.	Third] column is for the zodiacal signs.
τέταρτ]ον cελίδιν οὗ ὅροc μ̣[έ–	Fourth] column, of which the maximum
γιc]τ̣οc μοι(ρῶν) κ̅α̅. τίθετα̣ι̣ γ̣[ὰρ	limit is 21 degrees. For it is placed
κατ]ὰ τὸν Κρει̣ὸν καὶ τ̣ὸν Ζυ̣–	at] Aries and Libra
γὸ]ν̣ μοι(ρῶν) η̅. ἐλ̣αχίcτην οὐκ ἐ–	8 degrees. It does not have a minimum.
χει.] προcθαφαίρεcιc ō ϛ΄ μ̣[΄ζ΄ λ΄	Increment/decrement 0;6,4[?][x
]΄ε΄. πέμπτον cελίδιν ο̣ῦ̣ [ὅ–	]… Fifth column, of which
ρο]c̣ μέγιcτόc ἐcτιν λ΄β΄ κ̣[΄η΄.	the maximum limit is 32;2[?][8.
τίθ]εται γὰρ κατὰ τὴν τοῦ Αἰγ[ό–	For it is placed at Capricorn
κερ]ω καὶ Καρκίνου μοί(ραν) η̣̅. [ἕ–	and Cancer 8 degrees.
κτο]ν cελίδιν ἀπὸ Παρθ̣[έ–	Sixth column, from Virgo
νου] ἀφαίρεcιc ὡc Ἰχθύων. [ἕ–	"subtraction" until Pisces.
βδο]μον cελίδιν δρόμοc cε̣–	Seventh column, course of the moon,
λήν]η̣c οὗ ὅροc δ̅ κ΄ε΄ κ΄ζ΄ [ε΄.	of which limit 4;25[?],27,[5
]ην μὲν ἐλαχίcτην ηλ̣[	]… minimum …[

We may begin the discussion of details with the fourth column (lines 7-12). This column is said in the text to have a maximum of 21 “degrees” at Aries 8° and Libra 8°, no minimum (i.e. a minimum of zero), and an increment/decrement of 0,6,…. This sounds very much like the specification of a linear zigzag function. In a System B table the function H, which represents the month-to-month change in the component of the duration of the synodic month dependent on the sun’s longitude, is a zigzag function, with maximum 21 time-degrees, minimum 0, and increment/ decrement 6;47,30 time-degrees (= 0;6,47,30 “large hours”). The period of H is half a sidereal year, so that the maximum and minimum will be associated with diametrically opposite solar (or lunar) longitudes. There can be no doubt that the fourth column referred to in the papyrus was H.

But what of the statement that the maxima are placed at Aries and Libra 8°? On theoretical grounds H should be synchronized with the function A (the synodic arcs, i.e. progress in longitude from one conjunction or full moon to the next), in such a way that the zero points of H coincide with both the maxima and minima of A.[6] Since A is a measure of the average solar velocity during the synodic month, its extrema correspond to the situations where the sun’s progress during the month straddles the solar apsidal line. Hence the sun’s longitude at the end of a month with

[6] In fact perfect synchronization is not possible because the periodicities of Columns A and H are slightly different.

a maximum or minimum synodic arc (which is the longitude that would be recorded as the running total B on the same line as the maximum or minimum value of A) would be about 15° past the apsidal line. In the Babylonian System B tables these points were generally placed near the beginning of Cancer and Capricorn, and likewise the maxima of H are near the beginning of Aries and Libra.[7] There is no evidence that the Babylonians ever assimilated them to the solstitial and equinoctial points at 8°, but it is not surprising that someone should have done so.

Lines 12-15 of the papyrus describe the fifth column as having maxima of 32,… at Capricorn and Cancer 8°. We have seen that the fourth column was H, and the only conceivable reason for having H is in order to derive from its running totals the function J, the component dependent on the sun's longitude of the duration of the synodic month. This agrees excellently with what the papyrus says. J is computed like a zigzag function, except that the increment/decrements are taken from H instead of being constant. The maximum of J in the Babylonian tables is either 32;28,6 time-degrees or simply 32;28 time-degrees. The minimum is the negative of the maximum; or, equivalently, one may consider the minimum to be zero, with alternate cycles of J taken as additive and subtractive. For the oscillations of J to work properly, it is essential that its zeros coincide as nearly as possible with the maxima of H, so that if H has its maxima at Aries and Libra 8°, the positive and negative extrema of J should be at Capricorn and Cancer 8°.

The papyrus goes on to characterize the sixth column simply as "subtraction from Virgo until Pisces". All this means is that we reserve a column next to Column J in which we note which entries are to be understood as subtractive. This is just what we find in the Babylonian tables, except that an appropriate ideogram is written for both additive and subtractive entries. "From Virgo until Pisces" has to be understood as meaning that J is subtractive between its crossing of zero, which comes *after* the syzygy with a longitude in Virgo, and its next crossing of zero, which comes after the syzygy with a longitude in Pisces. The elliptical use of mere sign names without degrees to specify the zone of slow or fast solar motion in the ecliptic is exactly paralleled in Babylonian procedure texts.[8] In fact J will be *additive* when the sun is in this half of the ecliptic, so the longitudes in question must be those of the moon at opposition—our only indication that the table is for full moons rather than new moons.

The seventh column, unlike the foregoing, is given a name: "course of the moon". This is not, as one might expect, the moon's daily velocity (function F of a System B table), but G, the component of the duration of the synodic month dependent on the moon's anomaly. Only the maximum of this linear zigzag function is specified in the surviving part of our text. As noted above, the correct parameter, 4,29;27,5 time-degrees, has been corrupted through the very common misreading of theta as epsilon.

The first three columns of the table pretty well have to correspond to A and B of the Babylonian System B tables. The description of the first column is very poorly preserved, but it seems at least possible that the number in line 2 was the

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7 For example in ACT 122 the extrema of A are near Cancer and Capricorn 4°, and those of H near Aries 5° and Libra 1°. The procedure text ACT 210, section 5, prescribes that the extrema of Column A should be in Cancer and Capricorn.

8 See, e.g., ACT 204 §7 with Neugebauer's commentary, and AABOE and HENDERSON (1975), p. 192.

increment/decrement of the zigzag function for A, 0;18° per synodic month. The second column is clearly B, i.e. the longitude of the full moon, computed as the running total of A. Just as in the Babylonian tables, but unlike the usual Greek practice, the zodiacal sign of the longitude was written *to the right of* the degrees, in what the papyrus calls the third column.

The table, then, comprised Columns A, B, H, J, and G in that order. Most of the Babylonian System B tables that have these columns place H and J after G, and insert other columns between B and G; but the order HJG does occur in ACT 119, and we have already seen that *P. Colker* apparently had J to the left of G. Moreover, there are several cuneiform tables, which Neugebauer calls "auxiliary" tables (ACT 170-174), in which the only columns are T (the year and lunar month), B, J, G, K (= J + G, the duration of the synodic month over 29 days in time-degrees), and L (the date of syzygy, as the running total of K). Except that it incorporates the columns (A and H) from which B and H are derived, the table of the papyrus follows this pattern so far as it goes. The purpose of such a table would be to calculate the exact longitudes, dates, and times of opposition, without further concern for eclipse or visibility phenomena such as are predicted in the fuller System B tables. A text such as the present papyrus would definitely not have provided enough information to teach one how to generate a System B table of full moons; it might have been an *aide-mémoire* for an experienced scribe.

Two further points deserve to be mentioned. One is the conservative character of the tradition. The System B tables surviving in cuneiform fall within an interval of two centuries, from about 250 B.C. to about 50 B.C. Now after a documentary gap of two hundred years or more, in a different region and a different language, we encounter tables not only based on the same astronomical theory and mathematical methods, but even preserving such details of format as placing the names of zodiacal signs following the degrees and the indications of subtractive quantities following the quantities. This fact demonstrates, overriding all the historian's *a priori* assumptions about the difficulty of deep cultural contacts between Mesopotamia and the classical world, that an unbroken practical tradition at a high technical level led from the scribes of Babylon and Uruk to those of provincial Egypt.

Secondly, we have to confess that we do not know why these tables were being produced. To be sure, our position with respect to the Babylonian lunar tables is not much better, but there at least we can appeal vaguely to the use of a lunar calendar, the ominous significance of sightings of the new and full moon, and the—itself not adequately explained—practice of regularly measuring the time intervals between moonrise or moonset and sunrise or sunset close to the syzygies. In the Greco-Egyptian context there is no obvious application for precisely computed syzygies, except perhaps in the compiling of eclipse canons as part of general astrology.

Abbreviations

ACT = NEUGEBAUER (1955).

References

AABOE, Asger, and HENDERSON, Janice A. 1975. “The Babylonian Theory of Lunar Latitude and Eclipses According to System A”. *Archives internationales d’histoire des sciences* 25: 188–222.

JONES, Alexander. 1984. “A Greek Saturn Table”. *Centaurus* 27: 311–317.

— 1997. “A Greek Papyrus Containing Babylonian Lunar Theory”. *Zeitschrift für Papyrologie und Epigraphik* 119: 167–172 and plate II.

— 1998. “Studies in the Astronomy of the Roman Period. III. Planetary Epoch Tables”. *Centaurus* 40: 1–41.

— 1999. *Astronomical Papyri from Oxyrhynchus* (Memoirs of the American Philosophical Society 233). Philadelphia: American Philosophical Society.

NEUGEBAUER, Otto. 1955. *Astronomical Cuneiform Texts*. 3 vols. London: Lund Humphries (Reprint New York: Springer 1983).

— 1962. “Astronomical Papyri and Ostraca: Bibliographical Notes”. *Proceedings of the American Philosophical Society* 106: 383–391.

— 1988. “A Babylonian Lunar Ephemeris from Roman Egypt”. In: Erle LEICHTY, Maria de J. ELLIS, and Pamela GERARDI (eds.), *A Scientific Humanist: Studies in Memory of Abraham Sachs* (Occasional Publications of the Samuel Noah Kramer Fund 9): 301–304. Philadelphia: Samuel Noah Kramer Fund.

TURNER, Eric G. 1987. *Greek Manuscripts of the Ancient World.* Revised edition. London: University of London.