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Saros Cycle Dates and Related Babylonian Astronomical Texts

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I. Introduction

The texts presented here are most probably from Babylon, although their exact provenance is unknown.[1] All concern luni-solar phenomena with the exception of a text on the last visibility of Mercury, which is found on one side of a tablet whose other side deals with lunar eclipse magnitudes and longitudes.

The texts fall into two groups. One comprises what we have called "Saros Cycle Texts," which give the months of eclipse possibilities arranged in consistent cycles of 223 months (or 18 years). Three of the four texts in this group concern lunar eclipse possibilities; the other treats solar eclipse possibilities analogously. Included in this group is B.M. 34597, known as the "Saros Canon," which we republish to correct several errors in previous publications, and to clarify its structure.

The second group of texts contains astronomical functions. Two (Text L and Text F) tabulate lunar longitudes at syzygies in accordance with a relatively crude scheme, which approximates uniform motion and seems designed to facilitate computation. One of these (Text L) also presents a new function which describes lunar eclipse magnitudes with considerable accuracy and includes a correction for zodiacal anomaly. A third text (Text G) is a fragment of a previously published text, which we here call Text S. The fragment enables us to restore the function describing eclipse magnitudes in Text S. This in turn contributes to our (still imperfect) understanding of the analogous, but more sophisticated function in Text L. Finally, the last text in this group (Text M), occupies the obverse of the tablet containing Text L and gives the longitude of Mercury at successive last visibilities (Ω). The writing on it is at right angles to that of Text L on its reverse, and we treat it here as though it were a separate text.

The periods covered by these texts are generally earlier than most of the dates associated with mathematical astronomical texts,

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[1] All the texts are in the British Museum, and we publish them through the courtesy of its trustees. For a discussion of the circumstances of the acquisition of Rassam's "Babylonian Collection" and the problems of establishing the provenance of these texts, see Reade [1986].

although there is some overlap. The Saros Cycle texts include dates from thirteen 18-year cycles, which extend from −490 to −257. Of the texts with astronomical functions, Text S concerns solar eclipse possibilities from −474 to −456; Text M gives calculated positions of Mercury at Ω for the period from −423 to −401; Text L lists lunar eclipse possibilities from −416 to −380; and Text F gives approximate longitudes of full moons from −261 to −256.

It should be unnecessary, but unfortunately is not, to remark that texts presenting dates correctly in several reigns before the Seleucid Era cannot have been composed, at least not in their entirety, in advance of the events they describe. Indeed, we do not know of a single astronomical cuneiform text in which a regnal year exceeds the natural reign of the king before the introduction of a continuing year count in the Seleucid Era. Thus we cannot, alas, be more precise about when our texts were composed or written.

The present paper began with the collaboration of the late A. Sachs* and A. Aaboe around 1970 on Saros texts in the British Museum. The disjointed fragment from the corner of Text L raised difficulties (not yet fully resolved) that brought the enterprise to a prolonged halt. Though questions remain unanswered, we publish the texts so that others may try their hand.

Our paper has been referred to in the literature thrice: first, in Aaboe [1972], n. 9; subsequently, in HAMA, p. 1106 as "Aaboe-Henderson-Neugebauer-Sachs [1975]," and lastly in Britton [1989] as "Aaboe, et al. [1988]."

A. Aaboe's visits to the British Museum in the 1960s and early 1970s, during which most of our texts were first transcribed, were supported by grants from the National Science Foundation and the John Simon Guggenheim Foundation, which support is gratefully acknowledged.

* Abraham Sachs died 22 April 1983. Otto Neugebauer died 19 February 1990, after the present paper was submitted.

II. Saros Cycle Texts

Text A: B.M. 36910 (80-6-17,651) + B.M. 36998 (80-6-17,742)
+ B.M. 37036 (80-6-17,780)

Obv.

PLATE 1.

Rev.

TEXT A

Contents: Regnal years and months of lunar eclipse possibilities for (at least) year 31 of Darius I to year 30 of Artaxerses II (−490 to −374) arranged in 18-year groups.

Previous Publications: Mentioned as Nos. *1422, *1423, and *1424 in LBAT.

Transcription: Table 1; *Translation*: Table 2; *Photograph*: Plate 1

Description of Text:

Text A consists of three rejoined fragments and measures 3½″ by 3½″. While no edges are preserved, traces of line 1 of the obverse appear in columns IV′ and V′, showing that its vertical extent is nearly complete. Horizontally, the text could have contained one or more columns on either side.

The text gives columns of dates in the form of a regnal year number and a month. No instance of a first regnal year is preserved, so we do not know if the kings' names were given.[2] Within each column, successive dates are either six or five months apart, and each column begins after a five-month interval. Successive dates in the same line differ by 223 months between columns. Each column has 38 dates which begin at line 1 of the obverse and carry over the bottom edge to the reverse. There are 21 or 20 lines on the obverse and 17 or 18 on the reverse.

Though Text A leads into, and partly overlaps, the Saros Canon (Text C), it looks quite different: it is less carefully written; it has no vertical rulings separating the columns of dates, nor horizontal lines indicating five-month intervals; and "5 itu" (= five months) is not written after a five-month interval. The dashed lines in Tables 1 and 2 thus have no counterparts in the text. All in all Text A appears much less carefully prepared than Texts B or C.

The character of an intercalary year is indicated by "dir" if the year contains a second *Addaru* (XII_2), and by 2-kám (short for "kin-2-kám") if it has a second *Ululu* (VI_2).[3] This information is mostly written immediately below the year number, except in Obv. 9′,III′ and when the intercalated month itself appears in the text (Obv. 6′,II′ and Rev. 6′,IV′). Month XII_2 is twice written "dir" and once "dir-še" (Rev. 6′,IV′). In the latter case it is the careful

[2] Cf. Text C where they are given and Text D where they are omitted.

[3] In translations such years are indicated by * and ** respectively.

TABLE 1

Text A

	I′	II′	III′	IV′	V′	VI′	VII′
Obverse							
1′)			]	[2]⸢8⸣[ ]	⸢5⸣ ⸢s⸣[ig		
2′)		d][u$_6$]	dir apin	apin	dir ⸢gan⸣	⸢gan⸣[	
3′)	]⸢bar⸣	14 bar	11 ba[r]	29 gu$_4$	6 gu$_4$	5 sig	2⸢3?⸣[
4′)	]du$_6$	du$_6$	du[$_6$]	[di]r apin	apin	dir gan	g[an
5′)	]dir	15 bar	12 bar	[30] bar	7 gu$_4$	6 gu$_4$	24 si[g
6′)	3]⸤3⸥ kin	dir du$_6$	du$_6$	[du]⸤$_6$⸥	dir apin	apin	dir gan[
7′)	]še	dir	13 bar	31 [bar][	8 bar	7 gu$_4$	25 gu[$_4$
8′)	]⸢x⸣	16 kin	du$_6$	du$_6$[	du$_6$	]apin	ap[in
9′)	]	zíz	dir še	še	[še][	]⸢x⸣[	[26][
10′)		17] izi	14 izi	32 kin	9 k[in]	[8 kin	
11′)		] zíz	zíz	dir še	še[ ]	[še	
12′)		18 i]zi	15 izi	33 izi	10 kin	9[kin	
13′)		di]r zíz	zíz	zíz	dir še	še[	
14′)		]19 šu	16 izi	34 izi	11 izi	10 kin	2⸢8⸣[
15′)		] ab	dir zíz	dir zíz	zíz	dir še	[
16′)	]	20 šu	17 šu	35 izi	12 izi	11 izi	29[
17′)		] gan	gan	dir ab	ab	ab	[
18′)		s]⸤ig⸥	18 sig	3⸤6 sig⸥[			
19′)			]⸤gan⸥	[			
20′)				[37			
				[38			
Reverse							
1′)	?– – – –	– –?	]	[d]i[r gan			
2′)				3]9 bar	16 ⸢g⸣[u$_4$		
3′)				]du$_6$	2-kám du$_6$	[	
4′)			]⸢še⸣ dir	40 bar	17 bar	16 [g]u[$_4$	
5′)		]⸢4⸣ kin	22 kin	du$_6$	du$_6$	2-kám du$_6$[	
6′)		]dir še	še	dir š[e	1]8 ⸤bar⸥	17 ⸤bar⸥[	
7′)		]5 kin	23 kin	41 kin[			
8′)		d]ir še	še	⸤š⸥[e			
9′)	9 š]u?	6 izi	24 ⸤kin⸥	⸤i⸥[			
10′)	]ab	ab	⸢d⸣]ir zíz				
11′)	]10 šu	7 [šu]	2⸤5⸥[				
12′)	dir]ab	[a]b]	[				
13′)	11]sig	8 š[u]	[26				
14′)	gan⸢x⸣	⸤ab⸥[ ]	[				
15′)		]	[27				
16′)		]	[				

TABLE 2

Text A

Obv.

I'	II'	III'	IV'	V'	VI'	VII'
(Dar. I) 31 I	13 I	10* II	28 II	5* III	4 III	22 III
VII	VII	VIII	VIII	IX	IX	IX
32* I	14 I	11 I	29* II	6 II	5* III	23 III
VII	VII	VII	VIII	VIII	IX	IX
XII$_2$	15* I	12 I	30 I	7* II	6 II	24* III
33 VI	VII	VII	VII	VIII	VIII	IX
XII	XII$_2$	13* I	31 I	8 I	7* II	25 II
34 VI	16 VI	VII	VII	VII	VIII	VIII
XI	XI	XII	XII	XII	XII$_2$	26* I
35* V	17 V	14 V	32* VI	9 VI	8 VI	VII
XI	XI	XI	XII	XII	XII	XII$_2$
36 IV	18* V	15 V	33 V	10* VI	9 VI	27 VI
X	XI	XI	XI	XII	XII	XII
(Xer.) 1 IV	19 IV	16* V	34 V	11 V	10* VI	28 VI
X	X	XI	XI	XI	XII	XII
2** IV	20 IV	17 IV	35* V	12 V	11 V	29* VI
VIII	IX	IX	X	X	X	XI
3 II	21** III	18 III	36 III	13 IV	12 IV	30 IV
VIII	VIII	IX	IX	X	X	Rest
4* II	(Art. I) 1 II	19* III	37 III	14 III	13* IV	
VIII	VIII	IX	IX	IX	X	

Rev.

I'	II'	III'	IV'	V'	VI'	VII'
5 I	2* II	20 II	38* III	15 III	14 III	destroyed
VII	VIII	VIII	IX	IX	IX	
XII	XII$_2$	21** I	39 I	16** II	15 II	
6 VI	3 VI	VII	VII	VII	VIII	
XII	XII	XII$_2$	40* I	17 I	16** II	
7* VI	4 VI	22 VI	VII	VII	VIII	
XII	XII	XII	XII$_2$	18* I	17 I	
8 V	5* VI	23 VI	41 VI	VII	VII	
XI	XII	XII	XII	XII$_2$	18* I	
9 V	6 V	24* VI	(Dar. II) 1 VI	19 VI	VII	
X	X	XI	XI	XI	XII	
10* IV	7 IV	25 IV	2* V	(Art. II) 1 V	19 V	
X	X	X	XI	XI	XI	
11 III	8* IV	26 IV	3 IV	2* V	20* V	
IX	X	X	X	XI	XI	
12* III	9 III	27* IV	4 IV	3 IV	21 IV	
IX	IX	X	X	X	X	

alignment of the month name which distinguishes it from the several instances of "dir še" (Obv. 9′,III′; 11′,IV′; 13′,V′; and 15′,VI′ and Rev. 8′,II′) where "dir" is written under the year and the meaning is "XII_2 year, month XII."

The text contains three erasures, all of misplaced "dir"s. This, together with the absence of rulings, suggests that the text was not a copy of a finished text, and that the scribe had some difficulty in designating intercalary years. Traces of a "dir" in year 38 of Artaxerxes I, however, show that actual, rather than calculated, intercalations are recorded.[4]

[4] During the reign of Artaxerxes I intercalations occur in the correct sequence required by the nineteen-year cycle, but only month XII_2 is used and VI_2 does not appear. Thus years 19 and 38 have intercalary XII_2's, where we would otherwise expect VI_2's. See PD^3, 6–9.

Text B: B.M. 37044 (80-6-17,788)

Obv.

PLATE 2.

Rev.

TEXT B

Contents: Regnal years and months of lunar eclipse possibilities for (at least) year 10 to year 30 of Artaxerses I (−454 to −434).

Previous Publication: Mentioned as No *1425 in LBAT.

Transcription: Table 3; *Photograph*: Plate 2

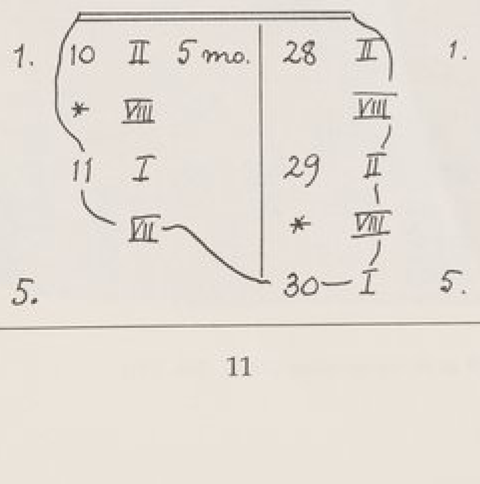
Description of Text:

Text B is a small, well-written fragment with part of the upper edge preserved. The surface of its reverse, where preserved, is blank. A vertical line separates Columns I′ and II′. Text B duplicates the first four or five lines of Columns III′ and IV′ of the obverse of Text A, but with two differences. First, its columns are separated by a vertical ruling and, second, it has the annotation "5 itu" (= five months) in Col. I′, line 1. Thus when complete, Text B probably appeared very much like the Saros Canon (Text C).

TABLE 3

Text B

Obverse	I′		II′	
1)	]10	gu$_4$ 5 itu	28	gu$_4$ {5} itu
2)	]dir	apin		apin[
3)	i]1	bar	29	gu[$_4$
4)	]	du$_6$	dir	ap[in
5)			]30	˻bar˼[



Text C ("Saros Canon"): B.M. 34597[5] (Sp. II,71)

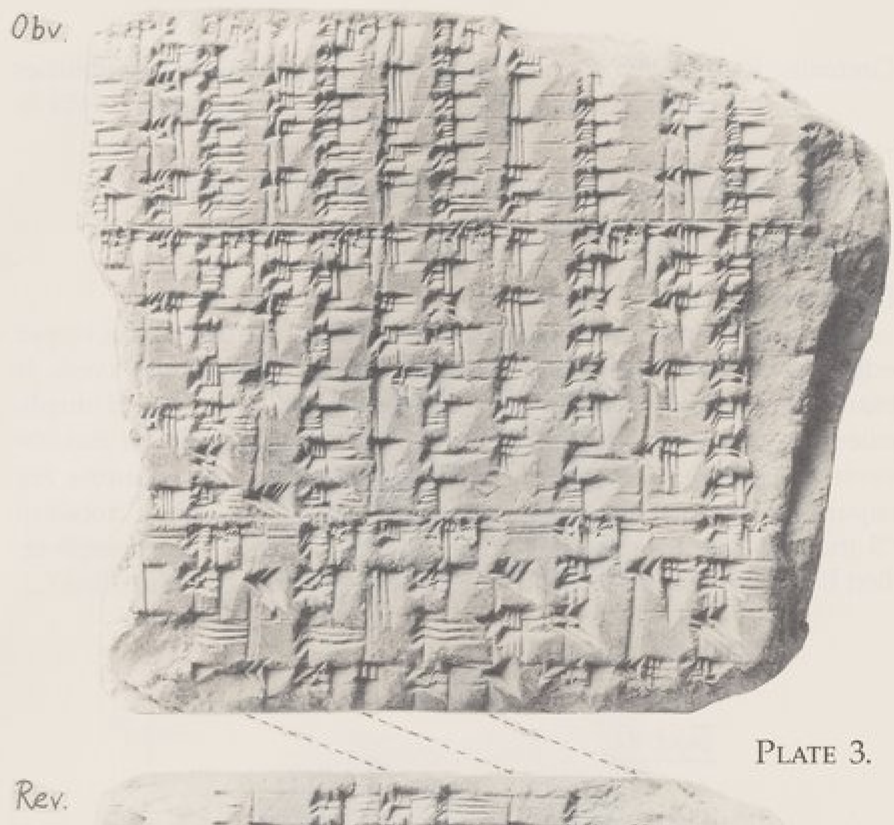


PLATE 3.

[5] Text C Not 34579 as in Neugebauer [1938], 248, 342].

TEXT C

Contents: Regnal years and months of lunar eclipse possibilities for (at least) year 4 of Artaxerxes II to S.E. 40[6] (−400 to −271) arranged in columns of 18 years (223 months).

Previous Publications: Published in hand copy by Strassmaier [1895] and (in Pinches's copy) as No. 1428 in LBAT; and excerpted with revisions in Aaboe [1972]. It has been discussed in, *i.a.*, Epping and Strassmaier [1893], Pannekoek [1917], and Neugebauer [1938].

Translation: Table 4; *Photograph*: Plate 3

Description of Text:

Text C is a handsome fragment 4¾" wide by 4⅛" high. Vertical rulings separate columns of dates, which include abbreviated king names after year 1 of each reign.[7] Horizontal alignment is observed throughout, so that dates in a given line increase by 223 months from one column to the next. Where the interval from one line to the next increases by five months, the entries are separated by a horizontal line, and the second entry carries the annotation "5-itu" as in Text B. These lines continue across the entire text, dividing each column into groups of seven or eight dates separated by six-month intervals.

As published by Strassmaier and in LBAT, Text C presents elements of seven columns of 38 lines each, beginning and ending in the middle of a group of seven eclipse possibilities. In Strassmaier's copy the columns on obverse and reverse appear in good alignment, whereas Pinches's copy in LBAT shows columns which do not connect cleanly across the tablet's edges, but are somewhat offset. In LBAT the identification of "obverse" and "reverse" was made to minimize this shift.

Subsequently Aaboe [1972] proposed that "obverse" and "reverse" be interchanged, based on the curvature of the tablet. With this identification each column begins just after a five-month interval, and the dates are consistent with those of Text A and Text B

[6] We use "S.E. *N*" to denote year *N* of the Seleucid Era. Month I of S.E. 1 began on April 3, −310.

[7] For the Achaemenid king names see Sachs [1977]. The abbreviations used in the text are: *ú* (Umasu) = Artaxerxes III; *ár* = Arses; *da* = Darius III; *a* = Alexander III (the Great); *pi* = Philip III (Arrhidaeus); and *an* = Antigonus. The entry for 1 Seleucid Era is broken; it probably had *si*.

in the sense that all dates in a given line are separated by a multiple of 223 months. In this arrangement the text preserves traces of eight rather than seven columns, which if complete would have extended from −400 to −257. On the right side the narrowness of the tablet makes it likely that the last preserved column was in fact the last column of the original. To the left, however, at least a third and possibly almost half the tablet appears missing. Thus the complete text probably contained between 13 and 15 columns, extending at least as far back as Text A (−490) and possibly to −526.

As in Texts A and B intercalary years with a XII_2 are designated by a "dir" beneath the year number unless the intercalary month itself appears as an eclipse possibility in that year. An exception is 12 S.E. where the designation is omitted, although it is clear from the months that the year contains a XII_2. Years with a VI_2 are designated by "kin-dir," in contrast to Text A.

The text's use of regnal years after Darius III is as follows:

1 Alexander III (the Great) follows 5 Darius III;
1 Philip IV (Arrhidaeus) follows 7 Alexander III;
1 Antigonus follows 6 Philip IV; and
1 Seleucid Era follows 6 Antigonus.

As discussed more fully below, this rational, but unconventional practice differs from that described in PD[3] and also from that found in Text D. No colophon is preserved, but the text was obviously written after the adoption of the Seleucid Era.[8]

Critical Apparatus:

For our identification of obverse and reverse, see above. All references are to the translation given in Table 4.

Rev. 33, Cols. V′ and VI′ and Rev. 35, Col. VI′: Pinches (LBAT) gives "šu" (month IV) for "du_6" (month VII); this implies that he copied what he saw and not what he thought should be there.

Rev. 37 and 38, Col. I′ : The text (and Pinches) has traces of "izi" (month V) and "zíz" (month XI). Strassmaier restores a "dir" (indicating an intercalary XII_2) in year 20, in agreement with Sp. II 901 = B.M. 35328,[9] which forces the readings "šu" (month IV)

[8] While 1 Seleucid Era begins in −310, Seleucus did not become king until 7 S.E. (−304) (Sachs and Wiseman [1954], 205), and the earliest attested date is 8 S.E. (PD[3], 20). As late as 10 S.E., however, we find the date "year 4" (of Seleucus) in a Diary for −302/301 (Sachs-Hunger [1988], 251). Thus the convention of counting years from 1 S.E. regardless of who was king, must have become general practice between −300 and −280 (31 S.E.), when Antiochus I became sole king.

[9] Published as No. 1394 in LBAT. Translated and discussed by Kugler SSBI, 80–81. The text is a Jupiter observation text, which is explicitly as well as astronomically dated. Obv. 26′ has "dir-še 30" in a section beginning "year 20." This appears to be confirmed by subsequent month names, although poorly preserved.

TABLE 4

Text C	I	II	III	IV	V	VI	VII	VIII
Obv.		22 III 5 mo. IX 23 III IX 24 III * IX 25 II VII	40 IV 5 mo. * X 41 III IX 42 III IX 43 III * IX	12 IV 5 mo. X 13 IV * X 14 III IX 15 III IX	2 IV 5 mo. X 3 IV X 4 IV * X 5 III IX	1 Sel. V 5 mo * XI 2 IV X 3 IV X 4 IV * X	19 V 5 mo. XI 20 V * XI 21 IV X 22 IV X	37 V 5 mo. XI 38 V XI 39 V * XI 40 IV X
		26 I 5 mo VII 27 I VII XII$_2$ 28 VI XII 29 VI	44 I 5 mo. VII 45 I VII XII$_2$ 46 VI XII 1 ArtIII VI	16 II 5 mo. * VIII 17 I VII 18 I VII XII$_2$ 19 VI	6 II 5 mo VIII 7 II * VIII 1 Phil. I VII 2 I VII	5 II 5 mo VIII 6 II VIII 7 II * VIII 8 I VII	23 III 5 mo. * IX 24 II VIII 25 II VIII 26 I VII	
		* XI 5 mo. 30 IV X 31 IV	XI 5 mo. 2 V * XI IV	XI 5 mo. 20 V XI 21 V	* XII 5 mo. 3 V XI 4 V	XII 5 mo 9 VI * XII 10 V	XII$_2$ 5 mo. 27 VI XII 28 VI	
Rev.		X 32 IV * X	X 4 IV X	* XI 1 Arses IV X	XI 5 V (*) XI	XI 11 V XI	* XII 29 V XI	
	18 I VII	33 II 5 mo VIII 34 II VIII 35 II ** VIII 36 I VII	5 III 5 mo * IX 6 II VIII 7 II VIII 8 I ** VII	2 III 5 mo. IX 1 Dar.III III * IX 2 II VIII 3 II VIII	6 III 5 mo IX 1 Antig. III IX 2 III * IX 3 II VIII	12 IV 5 mo. (*) X 13 III IX 14 III IX 15 III * IX	30 IV 5 mo. X 31 IV * X 32 III IX 33 III IX	
	* XII 5 mo. 19 V XI 20 V XI 21 V (*) XI	XII 5 mo 37 VI * XII 38 V XI 39 V XI	XII 5 mo. 9 VI XII 10 VI * XII 11 V XI	4 I 5 mo. VI$_2$ XII 5 VI XII 1 Alex. VI XII	4 I 5 mo. VII 5 I VI$_2$ XII 6 VI XII	16 I 5 mo. VII 17 I VII 18 I VI$_2$ XII	34 II 5 mo * VIII 35 I VII 36 I VII XI$_2$	

and "ab" (month X). The text (with Pinches) implies that the intercalation occurred in year 21*, which agrees with Text L (below). This removes the only meaningful anomaly in the nineteen-year intercalation cycle after −497, and moves the introduction of a consistent nineteen-year intercalation scheme back to the beginning of the fifth century B.C.[10]

Commentary:

Texts A, B and C—despite differences in orthography—all derive from a single, consistent scheme. Each has columns of 38 dates (years and month names), which begin after a five-month interval and run from obverse to reverse. Furthermore, two dates in a given line (counting from 1 to 38) always differ by a multiple of 223 months, whether in the same text or not. As a result the five-month intervals always occur after the same lines, dividing each column into groups of 8-8-7-8-7 dates, where five months separate the groups, while consecutive dates within each group are six months apart.

This arrangement of dates can be derived from the assumptions that: (1) sun, moon and node move uniformly; and (2) the sun returns to its position relative to a node in 223 months.[11] The second assumption corresponds to an eclipse cycle, now generally known as the "Saros," in which 38 eclipse possibilities occur in 223 months.[12] Our texts thus give the months of lunar eclipse possibilities based on this cycle.

By "eclipse possibility" we mean a syzygy at which the sun is within half a month's progress in elongation from a lunar node. At such times solar eclipse possibilities occur at conjunctions and lunar eclipse possibilities at oppositions. By this definition, assuming uniform motion, there will be exactly one solar and one lunar eclipse possibility associated with each passage of the sun by a node.[13] This agrees with the observational fact that for a given location solar eclipses rarely, if ever, occur only one month apart, and lunar eclipses never do.

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[10] The only divergence from the standard nineteen-year intercalation scheme after −497 is the previously noted (Note 3) replacement of VI_2s with XII_2s during the reign of Artaxerxes I. This obviously has no effect on the distribution of intercalary years.

[11] For this derivation from simple arithmetical considerations see Aaboe [1972] and Britton [1989].

[12] See Neugebauer [1957], 141–143, and HAMA, 497 n.2 for the history of the modern use of "Saros" for the 223-month eclipse cycle, beginning with Halley in 1691. In Babylonian texts this cycle was called "18 years." We have used "Saros cycle" to mean 223 months, and "Saros Cycle" to mean 223 months which are also consistent with the arrangement in Texts A–C (i.e., the first month is a multiple of 223 months distant from those in line 1 of Texts A–C).

[13] For a full discussion of the theory presented in System A, where the motion of the sun and moon at syzygy is not uniform, see Aaboe and Henderson [1975].

Lunar		*Solar*		Months
EP	DATE	EP	DATE	
		1	ALEX XI	S = L-1
		2	1 V	"
		3	* XI	"
1	2 IV	4	2 IV	S = L
2	X	5	X	"
3	3 IV	6	3 IV	"
4	X	7	X	"
5	4 IV	8	4 III	S = L-1
6	* X	9	* IX	"
7	5 III	10	5 II	"
8	X	11	VIII	"
9	6 II	12	6 II	S = L
10	VIII	13	VIII	"
11	7 II	14	7 II	"
12	* VIII	15	* VIII	"
13	8 I	16	XII2	S = L-1

(SC 24)

FIGURE 1

There is a simple relationship between lunar and solar eclipse possibilities which, for the Saros cycle, is shown in Figure 1. If lunar eclipse possibilities are associated with a distribution of dates into groups of 8–8–7–8–7 EP,[14] then solar eclipse possibilities will be distributed into groups of 7–8–7–8–8 EP, and the cycle will begin 3 EP earlier than the corresponding lunar cycle.[15]

For solar eclipse possibilities, therefore, the five-month intervals fall in the middle of the (six-month) groups for lunar eclipse possibilities (and vice versa). Consequently, half of all solar eclipse possibilities occur in (i.e., at the end of) the same month as the corresponding lunar eclipse possibility, while the other half occur in the preceding month. This fact, together with the location of the five-month intervals allows us to establish with certainty

[14] For convenience we use the abbreviation "EP" for "eclipse possibility" when referring to some number of them or to a specific one, and use the written-out expression when referring to the general phenomenon.

[15] See Britton [1989], 21–24, for the derivation of these relationships.

that Texts A, B, and C concern lunar, rather than solar, eclipse possibilities.

It is natural to ask how well this simple scheme agrees with the actual record of historical eclipses. Table 5 shows the Julian years of all lunar eclipses visible in Babylon from the beginning of Nabonassar's reign in −746 through −238. The dates are arranged to be consistent with our texts where they overlap, and the Cycles are numbered so that Saros Cycle 1 (SC 1) is the first complete Cycle after the beginning of Nabonassar's reign. Horizontal lines indicate the boundaries between groups of eclipses separated by a multiple of six months, and thus correspond to five-month intervals in our texts.

For 16 complete Saros Cycles, beginning with SC 13 in −526 and extending through SC 27 (−257), the scheme works perfectly in the sense that all lunar eclipses visible in Babylon occurred in the given months.[16] In SC 12 and earlier Cycles, however, eclipses at EP 16 occur one month earlier than in our scheme, which shifts the boundary between Groups II and III one EP earlier. Similar shifts occur in the boundaries between Groups I and II and Groups IV and V in SC7 and between Groups III and IV in SC 4. Thus before SC 5, which began in −670, only the boundary of the Cycles themselves—i.e., the five-month interval between Group V of one Cycle and Group I of the next—is consistent with our scheme. This boundary persists from sometime before Nabonassar (−746) through SC 27. In SC 28 the eclipse of −238:Oct 23 extends Group V, so that subsequent cycles begin 1 EP later.

The last preserved column in the Saros Canon corresponds to the last cycle (SC 27) which is fully consistent with preceding cycles. As we shall see below, a similar list of solar eclipse possibilities also ends with SC 27, although in this case an additional column was ruled off but not filled in. Whether the scheme was continued past the discontinuity at SC 28 remains unknown. Nor is it clear how far the scheme in our texts was extended to earlier periods, especially before −526 (SC 13) when the five-month intervals between groups of actual eclipses are no longer consistent with those in our texts. That some such scheme was used for earlier dates is suggested by the use of the term "5-itu" in several early eclipse reports, since the term can only refer to the interval

16 Lunar eclipses did in fact occur in −274 and −256 (EP 1; SC 27 and SC 28), one month after the indicated date, but neither was visible at Babylon. In the following cycle the corresponding eclipse (−238:Oct 23) was visible at Babylon, thus violating the scheme.

Table 5. Lunar Eclipses Visible at Babylon: −746 to −238

---S.E.-->

<---------------Saros Canon------------------->

Saros Cycle (beginning year) <------------- Text A -----------------> |---------Solar Saros----------| - -

EP	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Grp
		-743	-725	-707	-689	-670	-652	-634	-616	-598	-580	-562	-544	-526	-508	-490	-472	-454	-436	-418	-400	-382	-364	-346	-328	-310	-292	-274	-256	
1		-743		-707	-689	?	-652	?	-616	-598		?	-544			-490												[_{}_	_{}_	
2		-742	-724	?	-688	-670	-652		-616	-598		-562	-544		-508	-490		-454	-436		-400	?	-363	-345		-309	-291			
3		-742	-724	?	-688	-670		-633	-615		-579	-561	?		-507	-489		-453	-435			-381	-363							I
4		-741		-705	-687	-669	?	-633			-579			-525		-489	-471		-435	-417		-381	-363	-344	-326		-290	-272		
5		-741	-723		-687	-669		-632	-614		-578	-560		-524	-506	-488		-452	-434			-380	-362		?	-308	?		-254	
6									-614			-560		?	-506		-470	-452		-416	-398		-362	-344	-325	-307		-271	-253	
7																					-397	-379			-325	-307		-271	-253	
8		-739		-703	-685		?	-631																						
9		-739		-703	?	?	-649		-613	-595		-559	-540		-504	-486		-450	-432		-396	?								
10			-720	-702		-666	-648			-594	-576			-522	?		-468	-450												
11		-738	-720		-684	-666		-630	?	-594	-576		-540	-521		-485	-467		-431	-413		-377	-359		-323	-305		-269	-251	
12			-719	-701		-665	-647			-593	-575		-539	-521	?		-467	-449		-413	-395		-359	-341		-305	-287		-251	
13			-719	-701		-665	-647		-611		-575	-557		-521	-502		-466	-448		-412	-394		-358	-340		-304	-286			II
14													-538	-520		-484	-466			-412	?		-358		-322	-304		-268	-250	
15																										-303			-249	
16		?	-717	-699		-663	-645		-609	-591			-537									-375		-339	?		-285		-249	
17		-735	-717		-681	-663		?	-609			-555		?	-501	?	?	-447	?		-392	?								
18		-735	-716	-698	-680		-644	-626		-590	-572		-536	-518			-464			-410	-392		-356	-338						
19		-734			-680	-662		-626	-608	?		-554	-536	?	-500	-482	-464	-446	?	-409	-391	?	-355	-337	?	-301	-283	-265		
20			-716	?	-679	-661	?	-625	-607		-571	-553		?	-499	?		-445	-427		-391	-373			-319	?		-265	-247	III
21					-679			-625	-607		-571	-553		-517	-499		-463	-445	-427	-409		-372	-354		-318	-300		-264	-246	
22																		?		-408	-390			-336	-318		-282	-264		
23		-732		-696	-678																								-245	
24			-714	-696		-660	-642		-605	-587		-551	-533		-497	-479														
25		-731	-713		-677	-659		-623	-605			-551			-497		?	-443		-407	-389		-353	-335		-298	?			
26			-713	-695		-659	-641	?	-605	-586	?	-550	-532	-514	-496	-478		-442	-424		?	-370			-316	-298				
27			-712	-694		-658	-640			-586			-532			-478	-460		-424	-406		-370	-352		-316	-298	?	-261	-243	IV
28		-730	-712		-676	-658		-622	-604		-567	-549		-513	-495		-459	-441		-405	-387		-351	-333		-297	-279			
29												-549	-531		-495	-477			-423			-369	-351	?	-315	-297	?	-260	?	
30																					-386	?		-332	-314		-278	-260	-242	
31	-746		-710	-692			-638	-620																						
32	-746		-710	-692		-656	-638		-602	-584	-566	-548		-512	-493		-457	-439		-403	-385		-349							
33	-745		-709	-691		-655	-637			-583	-565		-529	-511			-457			-403										
34	-745	-727		-691	-673		-637	-619		-583	-565		-529	-511		-475	-456		-420	-402		-366	-348		?	-294	-276		-240	
35		-726	-708		-672	-654		-618	-600		?	-546		-510	-492	-474		-438	-420		-384	-366		-330	-312		-276	?		V
36				-690			-636	-618		-582	-564		-528	-510		-474	-456		-419	-401		-365	-347		-311	-293	-275		-239	
37													-527			-473	?		-419	-401		-365	-347		-311	-293		-257	?	
38																													-238	
																													-238	

_{}_ : eclipse belonging to previous group, but not visible at Babylon between eclipse possibilities.[17] The term is found in the following list of eclipse reports, where "EP-1" indicates that the five-month interval occurred 1 EP earlier than in our texts. In each case it correctly denotes the boundary between groups as evidenced in Table 5, whether an eclipse was visible or not. This suggests the existence of some scheme similar to that of our texts, but reflecting the actual distribution of eclipses in the earlier period.

Lunar Eclipse Reports with "5-itu"

Date	SC:EP	Visible?	"5-itu"	Reference
−746:Feb 6	0:31	Yes	EP-1	LBAT 1413
−685:Apr 22	4: 8	Yes	EP-1	LBAT 1416
−667:May 2	5: 8	No	EP-1	LBAT 1416
−649:May 13	6: 8	Yes?	EP-1	LBAT 1416
−631:Jun 4	7: 8	Yes	EP-1	LBAT 1416
−598:Feb 19	9: 1	Yes	EP	LBAT 1420*
−591:Apr 2	9:16	Yes	EP-1	LBAT 1420*
−588:Jul –	9:23	No	EP-1	LBAT 1420*
−577:Jun –	10: 8	No	EP-1	LBAT 1420*
−526:Apr –	13: 1	No	EP	B.M. 37276*
−422:Aug –	18:31	No	EP-1	LBAT 1426

* = unpublished

The (unpublished) text B.M. 37276 contains brief observational reports at consecutive eclipse possibilities, beginning with EP 1; SC 13 (3** Cambyses = −526). Only the top of the first column is preserved, so it is impossible to tell the structure and full extent of the text. Nevertheless, it begins with the earliest Saros Cycle for which the five-month intervals in our texts agree with the eclipse record.

The earliest use of the term "5-itu" to designate the beginning of a new group of eclipse possibilities occurs in the report of the eclipse of −746:Feb 6. This eclipse was the first in Nabonassar's reign and is the earliest detailed eclipse report which we have from Babylon.[18]

The scheme underlying our texts is consistent with the histor-

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[17] While theoretically possible, eclipses separated by five months are seldom, if ever, observed and eclipses separated by eleven months are rare. In the 500 odd years covered by Table 5 there is only one instance of two eclipses separated by five months which might have been visible in Babylon (EP 16 & 17; SC 21). The first of these had a magnitude of only 0.1[d], while the second was only marginally visible, if at all, before sunrise.

[18] The eclipse occurred in month XII of the accession year of Nabonassar (i.e., at EP 31; SC 0) and begins a series of consecutive eclipse reports covering at least Group V of SC 0.

TABLE 6. Saros Cycle Dates—Lunar Eclipse Possibilities

<----I'-----------II'----------III'------Saros Canon------V'----------VI'-----------VII'----------VIII'->

<----I'-----------II'------------III'-------- Text A -------V'------------VI'-----------VII'-->

EP#	SC = 13 EP# 1 = 3 CAMBS -526: 4/4		SC = 14 EP# 1 = 13 DARI1 -508: 4/14		SC = 15 EP# 1 = 31 DARI1 -490: 4/25		SC = 16 EP# 1 = 13 XERXS -472: 5/6		SC = 17 EP# 1 = 10 ARTX1 -454: 5/17		SC = 18 EP# 1 = 28 ARTX1 -436: 5/26		SC = 19 EP# 1 = 5 DARI2 -418: 6/8		SC = 20 EP# 1 = 4 ARTX2 -400: 6/18		SC = 21 EP# 1 = 22 ARTX2 -382: 6/29		SC = 22 EP# 1 = 40 ARTX2 -364: 7/9		SC = 23 EP# 1 = 12 ARTX3 -346: 7/21		SC = 24 EP# 1 = 2 ALEX -328: 7/31		SC = 25 EP# 1 = 1 S.E. -310: 8/11		SC = 26 EP# 1 = 19 S.E. -292: 8/22		SC = 27 EP# 1 = 37 S.E. -274: 9/2	
	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo	Yr	Mo
1	3**	I	13*	I	31	I	13	I	10*	II	28	II	5*	III	4	III	22	III	40*	IV	12	IV	2	IV	1*	V	19	V	37**	V
2		VI2		VII		VII		VII		VIII		VIII		IX		IX		IX		X		X		X		XI		XI		XI
3		XII		XII2	32*	I	14	I	11	I	29*	II	6	II	5*	III	23	III	41	III	13*	IV	3	IV	2	IV	20*	V	38	V
4	4	VI	14	VI		VII		VII		VII		VIII		VIII		IX		IX		IX		X		X		X		XI		XI
5		XII		XII		XII2	15*	I	12	I	30	I	7*	II	6	II	24*	III	42	III	14	III	4*	IV	3	IV	21	IV	39*	V
6	5*	VI	15	VI	33	VI		VII		VII		VII		VIII		VIII		IX		IX		IX		X		X		X		XI
7		XII		XII		XII		XII2	13**	I	31	I		I	7*	II	25	II	43*	III	15	III	5	III	4*	IV	22	IV	40	IV
8	6	V	16*	VI	34	VI	16	VI		VI2		VII	8	VII		VIII		VIII		IX		IX		IX		X		X		X
9		X		XI		XI		XI		XII		XII		XII		XII2	26*	I	44	I	16*	II	6	II	5	II	23*	III	41	III
10	7	IV	17	IV	35*	V	17	V	14	V	32*	VI	9	VI	8	VI		VII		VII		VIII		VIII		VIII		IX		IX
11		X		X		XI		XI		XI		XII		XII		XII		XII2	45*	I	17	I	7*	II	6	II	24	II	42*	III
12	8*	IV	18	IV	36	IV	18*	V	15	V	33	V	10*	VI	9	VI	27	VI		VII		VII	PHIL4	VIII		VIII		VIII		IX
13	DARI1	X		X	XERX	X		XI		XI		XI		XII		XII		XII		XII2	18*	I	1	I	7*	II	25	II	43	II
14	1	III	19**	IV	1	IV	19	IV	16*	V	34	V	11	V	10*	VI	28	VI	46	VI		VII		VII		VIII		VIII		VIII
15		IX		IX		X		X		XI		XI		XI		XII		XII	ARTX3	XII		XII2	2*	I	8	I	26*	II	44	II
16	2	III	20	III	2**	IV	20	IV	17	IV	35*	V	12	V	11	V	29*	VI	1	VI	19	VI		VII		VII		VIII		VIII
17		VIII		VIII		IX		IX		IX		X		X		X		XI		XI		XI		XII		XII		XII2	45*	I
18	3**	II	21	II	3	III	21**	III	18	III	36	III	13*	IV	12	IV	30	IV	2*	V	20	V	3	V	9*	VI	27	VI		VII
19		VII		VIII		IX	ARTX1	VIII		IX		IX		X		X		X		XI		XI		XI		XII		XII		XII2
20	4	I	22*	II	4*	III	1	II	19*	II	37	III	14	III	13*	IV	31	IV	3	IV	21*	V	4	V	10	V	28*	VI	46	VI
21		VII		VIII		IX		VIII		IX		IX		IX		X		X		X	ARSES	X		XI		XI		XII		XII
22	5*	I	23	I	5	II	2*	II	20	II	38*	III	15	III	14	III	32*	IV	4	IV	1	IV	5*	V	11	V	29	V	47*	VI
23		VII		VII		VIII		VIII		VIII		IX		IX		IX		X		X		X		XI		XI		XI		XII
24		XII		XII		XII		XII2	21*	I	39	I	16**	II	15	II	33	II	5*	III	2	III	6	III	12*	IV	30	IV	48	IV
25	6	V	24*	VI	6	VI	3	VI		VII		VII		VII		VIII		VIII		IX	DARI3	IX	ANTIG	IX		X		X		X
26		XI		XII		XII		XII		XII2	40*	I	17	I	16**	II	34	II	6	II	1*	III	1	III	13	III	31*	IV	49	IV
27	7	V	25	V	7*	VI	4	VI	22	VI		VII		VII		VII		VIII		VIII		IX		IX		IX		X		X
28		XI		XI		XII		XII		XII		XII2	18*	I	17	I	35**	II	7	II	2	II	2*	III	14	III	32	III	50*	IV
29	8*	V	26	V	8	V	5*	VI	23	VI	41	VI		VII		VII		VII		VIII		VIII		IX		IX		IX		X
30		XI		XI		XI		XII		XII	DARI2	XII		XII2	18*	I	36	I	8**	II	3	II	3	II	15*	III	33	III	51	III
31	9	IV	27*	V	9	V	6	V	24*	VI	1	VI	19	VI		VII		VII		VII		VIII		VIII		IX		IX		IX
32		IX		X		X		X		XI		XI	ARTX2	XI		XII		XII		XII	4**	I	4	I	16	I	34*	II	52	II
33	10	III	28	III	10*	IV	7	IV	25	IV	2*	V	1	V	19	V	37*	VI	9	VI		VI2		VII		VII		VIII		VIII
34		IX		IX		X		X		X		XI		XI		XI		XII		XII		XII	5**	I	17	I	35	I	53*	II
35	11**	III	29*	III	11	III	8*	IV	26	IV	3	IV	2*	IV	20(!)	V	38	V	10*	VI	5	VI		VI2		VII		VII		VIII
36		IX		IX		IX		X		X		X		X		XI		XI		XII	ALEX3	XII		XII	18**	I	36	I	54	I
37	12	II	30	II	12*	III	9	III	27*	IV	4	IV	3	IV	21*!	IV	39	V	11	V	1	VI	6	VI		VI2		VII		VII
38		VIII		VIII		IX		IX		X		X		X		X		XI		XI		XII		XII		XII		XII2		XII2

ical eclipse record for fifteen Saros Cycles beginning with SC 13 and extending through SC 27. Table 6 gives the dates of all lunar eclipse possibilities for this period, arranged as in our texts. Rather tidily, the table begins with an eclipse possibility in month I of 3** Cambyses (−526) and ends with one in month XII_2 of 54 S.E. (−256). It is not impossible that the Saros Canon originally covered this same period.

Text D ("Solar Saros"): B.M. 36754 (80-6-17, 488 + 564)

Obv.

Plate 4.

Rev.

TEXT D

Contents: Regnal years and months of solar eclipse possibilities for, at least, year 11 Artaxerxes III to S.E. 53 (−347 to −258), arranged in eighteen-year groups.

Previous Publication: mentioned as LBAT *1430.

Transcription: Table 7; *Translation*: Table 8; *Photograph*: Plate 4

Colophon: *ki-ṣa-ri šá* [. . .] which means "the knots (i.e., nodes) for [solar eclipses?]."[19]

Description of Text:

Text D is a single fragment 5¼" wide by 3¼" high. Parts of the top, right and left edges are preserved, although the surface itself is destroyed near the edges. The surface is divided into six columns of 38 lines which continue from obverse to reverse and are marked by vertical rulings. The columns are of uneven widths, ranging from ¾" (Cols. I and IV obv.) to 17/16" (Col. IV rev.), and the text is generally less well finished than the Saros Canon. Column VI is blank where preserved, and the vertical ruling separating Columns V and VI is not continued on the reverse. It seems likely that Column VI was left blank throughout.

The format of the text is similar to that of the Saros Canon (Text C). The obverse begins at the beginning of a group (i.e., after a five-month interval) and contains 20 lines, the reverse containing 18 lines. Horizontal alignment is observed throughout, so that dates in a given line increase by 223 months from one column to the next. Five-month intervals are designated by "5 itu" and by horizontal lines which extend across the tablet from edge to edge, so the distribution of eclipse possibilities is the same within each Saros.

The text's use of regnal years is as follows: it begins with years 10–21 of Artaxerxes III followed by years 1–2 of Arses and years 1–5 of Darius III. Beginning with Column II we have years 1–7 of Alexander III (the Great), followed by years 1–8 of Philip III (Arrhidaeus). So far no king's name has been preserved, but following year 8 of Philip we have years 3–6 of Antigonus, year-number "3" being followed by a small "*an*"; then years 6–11 of Alexander IV, but without his name; and finally year 7 of the Seleucid Era, the

[19] See Aaboe [1972], note 22.

TABLE 7

Text D

Obv.

I	II	III	IV	V	VI
[10 še 5 itu]	[5 zíz 5 itu]	[5 zíz 5 itu]	[17 še 5 itu]	[35 še 5 itu]	[ ]
[11 šu]	[1] ⸢izi⸣	⸢6⸣ [izi]	[18 kin]	[36 kin]	[ ]
[ab]	[ ] zíz	zíz	zí[z]	[še]	[ ]
12 šu	2 šu	6 izi	19 izi	⸢37⸣ [kin]	[ ]
ab	ab	zíz	zíz	zíz	[ ]
13 šu	3 šu	7 šu	20 izi	38 izi	[ ]
ab	ab	ab	zíz	zíz	[ ]
[1]⸤4⸥ sig	4 šu	8 šu	21 šu	39 izi	
[ap]in 5 itu	gan 5 itu	gan 5 itu	gan 5 itu	ab 5 itu	
[15 gu]$_4$	5 gu$_4$	9 sig	22 sig	40 sig	
[apin]	apin	gan	gan	gan	
[16 gu$_4$]	6 gu$_4$	10 gu$_4$	23 sig	41! sig	
[apin]	apin	apin	gan	gan	
[17 bar]	7 gu$_4$	11 gu$_4$	24 gu$_4$	42 sig	
[kin 5 it]u	du$_6$ 5 itu	du$_6$ 5 itu	du$_6$ ‹5 itu›	⸤apin 5 itu⸥	
[še]	dir	7 se bar	25 bar	43 [bar]	
[18 kin]	[1 ki]⸤n⸥	du$_6$	du$_6$	[du$_6$]	
[še]	[še]	dir	26 bar	[44 bar]	
[19 izi]	[2 kin]	⸤8⸥ ⸤kin⸥	du$_6$	[du$_6$]	
[zíz]	[še]	[še]	[ ] ⸤dir⸥ [ ]	[45 bar]	

Rev.

I	II	III	IV	V	VI
[20 izi]	[3 izi]	[9 kin]	[27 kin]	[du$_6$]	[ ]
[zíz]	[zíz]	[še]	[še]	[dir]	[ ]
[21 šu 5 itu]	[4 šu 5 itu]	[10 šu 5 itu]	[28 izi 5 itu]	[46 izi 5 itu]	[ ]
[ab]	[ab]	[ab]	[zíz]	[zíz]	[ ]
[1 sig]	[5 šu]	[11 šu]	[29 šu]	[47] ⸢izi⸣	
[gan]	[ab]	[ab]	[ab]	[zí]z	
[2 sig]	[6 sig]	12 ⸢šu⸣	30 ⸢šu⸣	[4]⸢8⸣ šu	
[gan]	[ ] ⸢gan⸣	ab	ab	ab	
[1 sig]	7 sig	13 sig	31 šu	49 šu	
[gan]	gan	gan	ab	ab	
[2 bar 5] itu	8 gu$_4$ 5 itu	14 gu$_4$ 5 itu	32 gu$_4$ 5 itu	50 sig 5 itu	
[du$_6$]	apin	apin	apin	gan	
[3 bar]	3^{an} bar	15 gu$_4$	33 gu$_4$	51 gu$_4$	
[du$_6$]	du$_6$	apin	apin	apin	
[4 bar]	4 bar	16 bar	34 gu$_4$	52 gu$_4$	
[kin-2-kám]	du$_6$	du$_6$	apin	apin	
[še]	5 bar	17 bar	35 bar	53 gu$_4$	
[5 kin]	kin-2-kám	du$_6$	du$_6$	apin	

[illegible] [. . . . .]

ki-ṣa-ri šá [. . . . .]

Table 8

Text D

Obv.	I	II	III	IV	V	VI
1.	Art. III 10 XII 5 mo.	5 XI 5 mo.	5 XI 5 mo.	17 XII 5 mo.	35 XII 5 mo.	
	11 IV	[Alex.] 1(*) V	6 V	18(*) VI	36 VI	
	X	XI	[Alex. IV] XI	XI	XII	
	12 IV	2 IV	6(*) V	19 V	37(*) VI	
5.	X	X	XI	XI	XI	
	13(*) IV	3 IV	7 IV	20(*) V	38 V	
	X	X	X	XI	XI	
	14 III	4(*) IV	8 IV	21 IV	39(*) V	
	VIII 5 mo.	IX 5 mo.	IX 5 mo.	IX 5 mo.	X 5 mo.	
10.	15 II	5 II	9(*) III	22 III	40 III	
	VIII	VIII	IX	IX	IX	
	16(*) II	6 II	10 II	23(*) III	41 III	
	VIII	VIII	VIII	IX	IX	
	17 I	7 II	11 II	24 II	42(*) III	
15.	VI 5 mo.	VII 5 mo.	VII 5 mo.	VII	VIII 5 mo.	
	XII	[Phil.] XII_2	7(*) se I	25 I	43 I	
	18(*) VI	1 VI	VII	VII	VII	
	XII	XII	XII_2	26(*) I	44 I	
	19 V	2(*) VI	8 VI	VII	VII	
20.	XI	XII	XII	XII_2	45(*) I	
Rev.						
21.	20 V	3 V	9(*) VI	27 VI	VII	
	XI	XI	XII	XII	XII_2	
	21(*) IV 5 mo.	4 IV 5 mo.	10 IV 5 mo.	28(*) V 5 mo.	46 V 5 mo.	
	[Arses] X	X	X	XI	XI	
25.	1 III	5(*) IV	11 IV	29 IV	47(*) V	
	IX	X	X	X	XI	
	2 III	6 III	12(*) IV	30 IV	48 IV	
	[Dar. III] IX	IX	X	X	X	
	1(*) III	7 III	13 III	31(*) IV	49 IV	
30.	IX	IX	IX	X	X	
	2 I 5 mo.	8(*) II 5 mo.	14 II 5 mo.	32 II 5 mo.	50(*) III 5 mo.	
	VII	VIII	VIII	VIII	IX	
	3 I	3an I	15(*) II	33 II	51 II	
	VII	VII	VIII	VIII	IX	
35.	4(*) I	4 I	16 I	34(*) II	52 II	
	VI_2	VII	VII	VIII	IX	
	XII	5(*) I	17 I	35 I	53(*) II	
	5 VI	VI_2	VII	VII	VIII	

"7" being followed by "*se.*" The Seleucid Era is then used to the end of the text.

Commentary:

Our text, which we call the "Solar Saros," gives the months of solar eclipse possibilities for 5 (solar) Saros Cycles beginning with SC 23 and extending through SC 27. That it concerns solar rather than lunar eclipse possibilities can be seen from Table 9, which compares the dates from column VI' of the Saros Canon (SC 25) with those from column III of the Solar Saros. The column from the Solar Saros begins correctly 3 EP earlier than that from the Saros Canon. Indeed, the five-month intervals in the Solar Saros are half a group out of phase with those of the Saros Canon while the relationship between the months is just what we would expect for solar eclipse possibilities (Figure 1, p. 17). Finally, in Table 9 we show dates of lunar and solar eclipses, taken from Oppolzer [1887]. In every case but one, dates from the Solar Saros correspond to dates of actual solar eclipses (not necessarily visible at Babylon), just as dates of lunar eclipses correspond to dates from the Saros Canon.

The one exception to the agreement between the Saros Canon and the Solar Saros is that the latter contains groups of 8-6-8-8-8 EP, whereas we would expect groups of 7-8-7-8-8 EP. This anomaly also accounts for the sole inconsistency between the dates in our text and those of actual solar eclipses, wherein all of the dates in line (EP) 15 are one month too early. The simplest explanation is that both boundaries of Group II are (consistently) in error by 1 EP—i.e., EP 8 should occur 1 month earlier and EP 15 one month later. This would restore the expected distribution of 7-8-7-8-8 EP and leave all dates in our (emended) text in agreement with dates of actual solar eclipses—the first eclipse possibility in each group corresponding in each instance to the earlier of the two "one-month" eclipses listed by Oppolzer.

The purpose of texts such as the Lunar or Solar Saros is not clear to us. They are obviously not observational records, since at a given location eclipses materialize at only a fraction of the eclipse possibilities. Nor are they forecasts containing eclipse warnings for the future for the trivial reason that texts which give dates in several reigns cannot have been written in advance of the events they describe, at least not in their entirety.

One possibility is that the texts served as a guide to observational data on eclipses in the corpus of Astronomical Diaries, although the use of different dates than those used in the Diaries is difficult to understand in this context. Another is that such texts

TABLE 9

Oppolzer, Lun. Ecl. No.	Date	Lunar Saros
		S.E. 1 V 5 mo.
1381	-309 Feb 4	* XI
		2 IV
1382	-308 Jan 25	X
1383	Jul 19	3 IV
1384	-307 Jan 13	X
1385	Jul 9	4 IV
		* X
		5 II 5 mo.
		VIII
1386	-305 May 20	6 II
1387	Nov 12	VIII
1388	-304 May 8	7 II
1389	Oct 31	* VIII
1390	-303 Apr 28	8 I
1391	Oct 21	VII
		XII 5 mo.
		9 VI
1392	-301 Mar 7	* XII
1393	Sep 1	10 V
1394	-300 Feb 25	XI
1395	Aug 20	11 V
		XI
		12 IV 5 mo.
1396	-298 Jan 4	(*) X
1397	Jun 30	13 III
1398	Dec 25	IX
1399	-297 Jun 19	14 III
1400	Dec 14	IX
1401	-296 Jun 8	15 III
		* IX
		16 I 5 mo.
		VII
1402	-294 Apr 18	17 I
1403	Oct 12	VII
1404	-293 Apr 7	18 I
1405	Oct 2	VI_2
1406	-292 Mar 26	XII

Solar Saros	Date (Oppolzer, Solar Eclipses)	No. (Oppolzer, Solar Eclipses)
[Antig. 5 XI 5 mo.]	-311 Mar 13	2144
6 V	Sep 5	2145
XI	-310 Mar 2	2146
(Alex. h.s)6 V	Aug 25	2147
XI	-309 Feb 20	2148
7 IV	Aug 15	2149
X	-308 Feb 9	2150
8 IV	Jul 5/Aug 4	2151/2
IX 5 mo.	Dec 29	2153
9 III	-307 Jun 25	2154
IX	Dec 18	2155
10 II	-306 Jun 14	2156
VIII	Dec 8	2157
11 II	-305 Jun 3	2158
VII 5 mo.	Nov 28	2159
S.E. 7 I	-304 Apr 23/May 22	2160/1
VII	Oct 17	2162
XII_2	-303 Apr 12	2163
8 VI	Oct 6	2164
XII	-302 Apr 2	2165
[9] :	Sep 25	2166
:	-301 Mar 23	2167
[10] :	Sep 15	2168
:	-300 Feb 10	2169
[11] :	Aug 5	2170
:	-299 Jan 29	2171
12 IV	Jul 26	2172
X	-298 Jan 18	2173
13 III	Jul 15	2174
IX	-297 Jan 8	2175
14 II 5 mo.	Jun 5/Jul 4	2176/7
VIII	Nov 29	2178
15 II	-296 May 24	2179
VIII	Nov 17	2180
16 I	-295 May 13	2181
VII	Nov 7	2182
17 I	-294 May 3	2183
VI	Oct 27	2184
	-293 Mar 24/Apr 22	2185/6

served to identify eclipse possibilities which were similarly affected by lunar anomaly. This arises from the fact that 223 (synodic) months very nearly equal 239 anomalistic months, so that each line in our texts—comprised of syzygies separated by 223 months—designates eclipse possibilities with roughly the same lunar anomaly. Finally, texts like these may have served as either

TABLE 10. Babylonian Years According to:

Julian Year	PD-3	SOLAR SAROS	SAROS CANON	PTOLEMAIC CANON (Alexandria)	NOTES
-334	1 DARI3	1 DARI3	1 DARI3	1 DARI3	
-333	2	2	2	2	
-332	3	3	3	3	D -322: 3 DARI3
-331	4	4	4	4	
-330	5	5	5	1 ALEX3	D -330: VI - Alexander enters Babylon
-329	7 ALEX3	1 ALEX3	1 ALEX3	2	D -329; LBAT 1397 and BM 37043: 7 ALEX3
-328	8	2	2	3	D -328: 8 ALEX3
-327	9	3	3	4	
-326	10	4	4	5	
-325	11	5	5	6	
-324	12	6	6	7	D -324: 12 ALEX3
-323	13	7	7	8	
-322	14	1 PHIL3	1 PHIL3	1 PHIL3	D -322: 1 PHIL3 !; II/29 Alexander dies.
-321	2 PHIL3	2	2	2	D -321: 2 PHIL3
-320	3	3	3	3	
-319	4	4	4	4	
-318	5	5	5	5	DC: 5 PHIL3
-317	6	6	6	6	
-316	7	7	1 ANTIG	7	
-315	8	8	2	1 ALEX4	DC: 8 PHIL3
-314	2 ALEX4	3 ANTIG	3	2	ST: 3 ANTIG
-313	3	4	4	3	
-312	4	5	5	4	
-311	5	6	6	5	
-310	1 S.E.	6 ALEX4	1 S.E.	6	
-309	2	7	2	7	DC: 7 ALEX4
-308	3	8 *	3	8 *	D -308: 8 ALEX4; Seleucus = General
-307	4	9 *	4	9 *	DC: 9 ALEX4
-306	5	10 *	5	10 *	
-305	6	11 *	6	11 *	SKL: Last year (?) of ALEX4
-304	7	7 S.E.	7	12 *	SKL: 7 S.E. = 1st yr. Seleucus = King
-303	8	8	8	1 PTOL1	CT IV: 8 S.E. (earliest dated text)
-302	9	9	9	2	D -302: 9 S.E.
-301	10	10	10	3	D -302/301: 'Year 4' (of Seleucus)
-300	11	11	11	4	
-299	12	12	12	5	D -299: 12 S.E.

Abbreviations: *: Posthumous

Ct IV: Cuneiform Texts from Babylonian Tablets etc. in the British Museum, vol. IV.

D -XXX: Diary for the year -XXX; Sachs - Hunger [1988].

DC: Diadochi Chronicle; Grayson [1975].

SKL: Seleucid King List; Sachs and Wiseman [1954].

ST: Saros Tablet; BM 34576.

aids or exercises in establishing fairly long stretches of local chronology in antiquity, as they have in modern times.

Excursus—Post Achaemenid Dates:

Before Alexander, Babylonian dates reflected a simple and consistent practice with respect to regnal years: namely that a regnal year, once begun, continued even when a new king acceded to the throne in that year. Thus a king's accession year was counted as his predecessor's last, so that his first year was his first full year as king. The practice avoided ambiguity with respect to regnal years.

Macedonian usage, in contrast, was that a king's first year began with his accession. Thus when a king died or was overthrown, an event could be assigned to either the last year of the departed king or the first year of the new king.

Compounding the confusion in the period from the end of the reign of Darius III (−330) until ca. S.E. 11 (−300) was the absence of a single convention on when reigns began, or even on who was king. This is reflected in Table 10, which describes three different methods of dating from Babylon, together with that preserved in Ptolemy's "King List."

The first column of dates are those used in PD³, which agree with those found in Diaries and the Diadochi Chronicle (Grayson [1975]) at least through the reign of Philip III (Arrhidaeus). By this convention year 7 of Alexander III (the Great) follows year 5 of Darius III,[20] and the reign of Philip III extends through year 8 (−315). For at least the first six years of the Seleucid Era, however, the Diaries and the Diadochi Chronicle date in years of Alexander IV, in contrast to the convention used in PD³. Indeed, even as late as S.E. 10 (−301) we find a Diary reference to "Year 4" of Seleucus, suggesting that the inception of the reign of Seleucus had not been firmly settled.

In our texts the dates from the Solar Saros are the least consistent, the reigns of Antigonus, Alexander IV, and Seleucus beginning in years 3, 6, and 7 respectively. Such confusion seems unlikely to have been wholly invented, suggesting that this convention reflected some contemporary practice. In contrast, the Saros Canon begins each reign including the Seleucid Era with year 1. This rational approach seems likely to be the farthest removed from contemporary practice, and may simply reflect a later attempt to establish a coherent chronology.

[20] This implies that Alexander's reign began with his Macedonian accession in −335 and thus avoids the problem that by Macedonian convention Alexander's accession (and thus first year) in Babylon occurred in year 5 of Darius III. See PD³, 19–21.

III. Texts Containing Astronomical Functions

Text E ("Text M" and "Text L")

Text E_1: B.M. 36651 (80-6-17,383) + B.M. 36719 (80-6-17,452) +
B.M. 37032 (80-6-17,776) + B.M. 37053 (80-6-17,797)

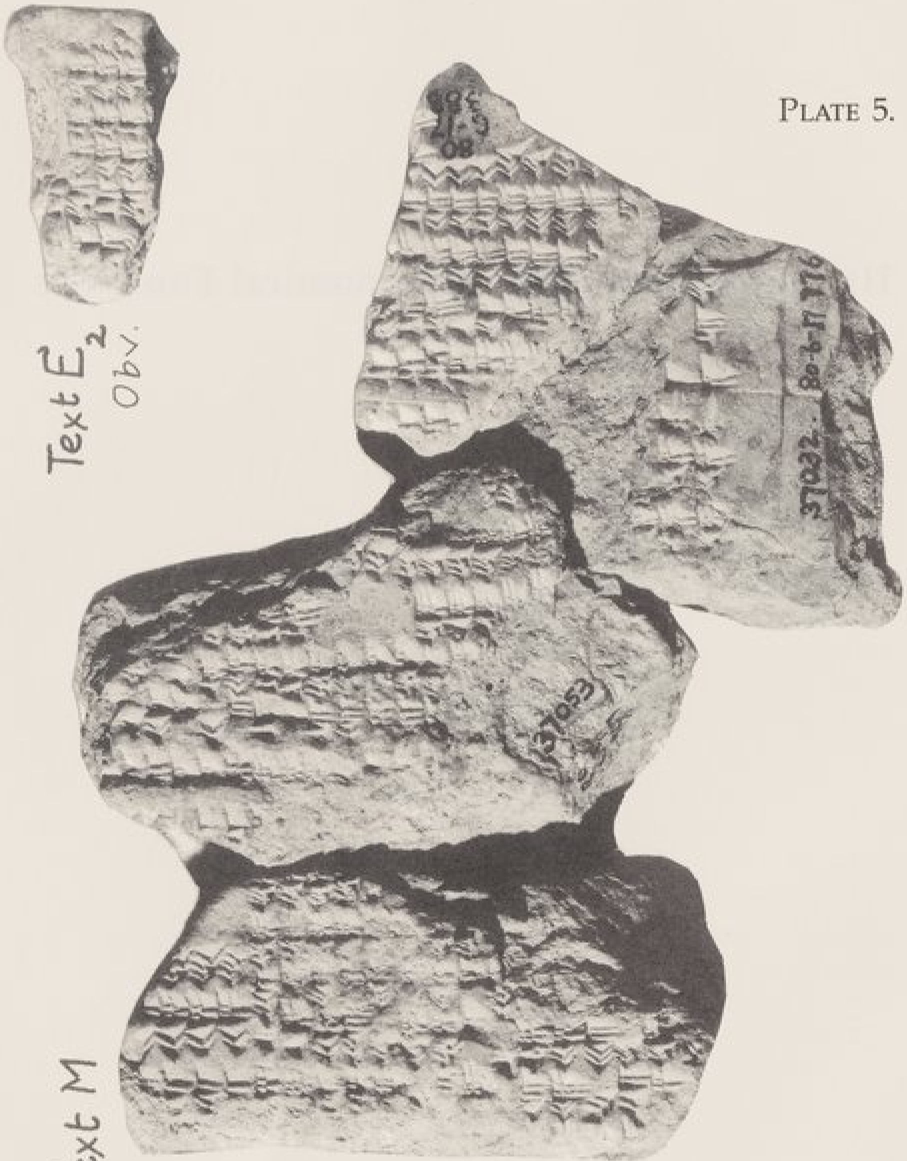

PLATE 5.

TEXT E

Contents:

Obverse ("Text M"): Regnal years and longitudes of 69 consecutive synodic phenomena for Mercury (most likely its last appearances as an evening star, Ω), beginning in year 41 of Artaxerxes I and continuing through year 2 of Artaxerxes II (−423 to −401).

Reverse ("Text L"): Regnal years, months, longitudes, and eclipse magnitudes of lunar eclipses for 36 years, from year 7 of Darius II to year 24 of Artaxerxes II (−416 to −380)).

Transcriptions: Text M, Table 7; Text L, Tables 13, 14 and 15.

Photograph: Plates 5 and 6.

Description of Text:

An extraordinary feature of our text is that the writing on the obverse is at right angles to that on the reverse. In the astronomical cuneiform literature this has been met twice before.[21] In all three cases the contents of obverse and reverse are diverse: in our text, the obverse concerns Mercury while the reverse has to do with eclipses.

There are several indications that the text is a copy of older originals. In Reverse IIa, 28, we see what is most likely *hi-pí, hi-pí* (broken, broken), very small and shallow, written through a very faint horizontal line. In Reverse Ib, 31, 32, and possibly in Obverse II, 13, we find "UR," the older form of Leo, while Reverse IIb, 31 and 33 have the later "A." In the material related to ACT this usage has been encountered only once before, *viz.* in B.M. 37024, a procedure text for Mars, System A (Aaboe [1987], 3), where both are also attested. Further, the dates of both the Mercury and the lunar-eclipse data are in the neighborhood of −400. On the obverse, the writing of 9 in the older nine-wedge form or the more recent three-diagonal form is unstable. The reverse employs AB for ABSIN (*Virgo*), a usage without precedent. Finally, the procedure text ACT No. 816, which is intimately related to the Mercury side of this text, is clearly a copy, as is indicated by the presence of [*hi-p*]*í eš-šú* ("recent break") in Section 5, and contains features which seem to be non-standard.

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[21] Text J (B.M. 36744) in Neugebauer and Sachs [1969] and Texts G and H in Aaboe and Sachs [1966]. In addition, the so-called "Saros Tablet" (B.M. 34576) has what may be an eclipse report written at right angles to the main text at the bottom of the reverse (private communication, C.B.F. Walker).

Text E_2: B.M. 37162 (80-6-17,912)

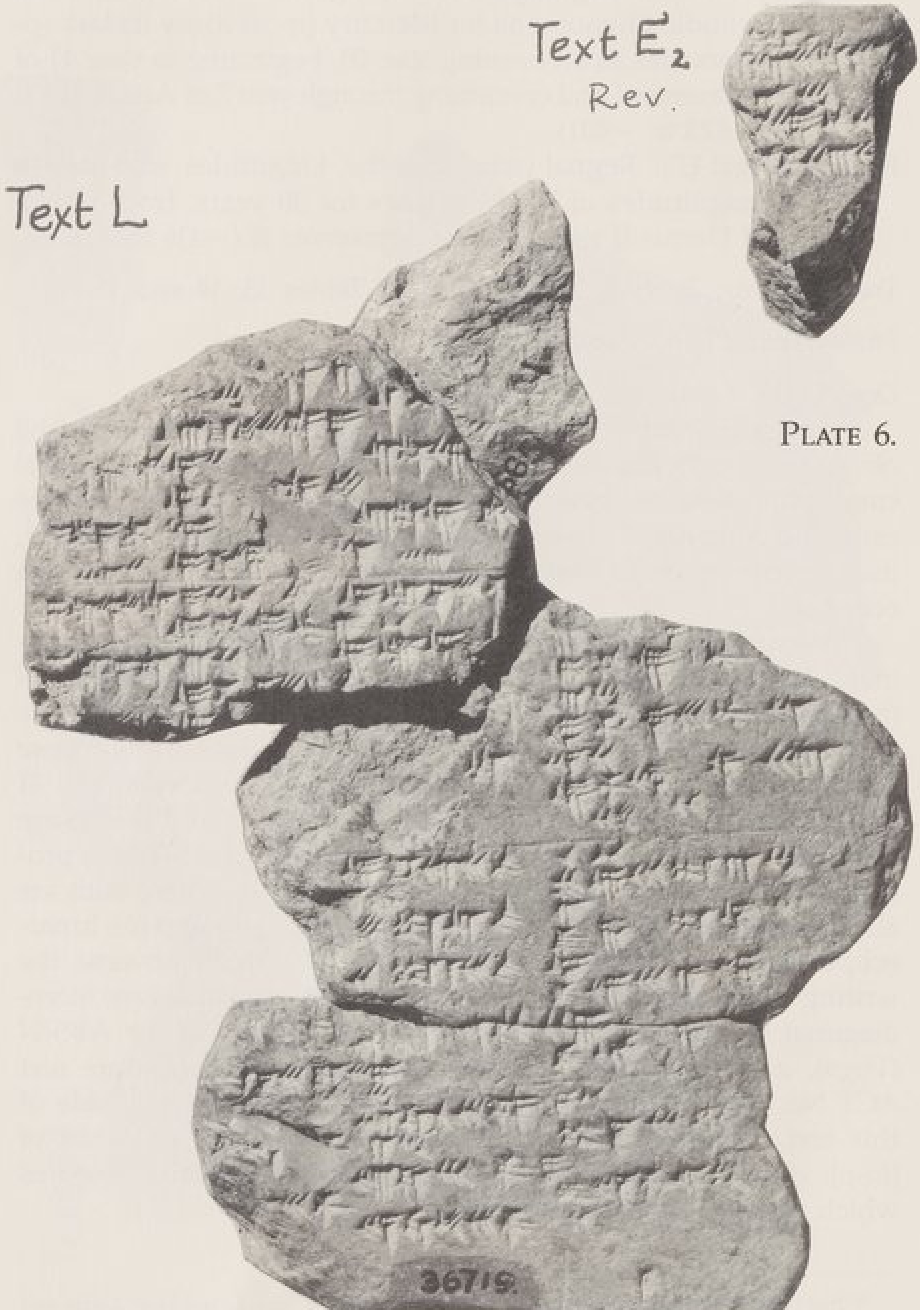

PLATE 6.

All joins were executed by us; though too much clay is missing for a physical join there is no doubt that the fragment B.M. 37162 (Text E_2) derives from the same tablet as Text E_1. Since Text E_2 preserves the upper right-hand corner of the obverse (as well as of the reverse) and since both obverse and reverse are preserved almost to their bottom edges, we can estimate the original extent of the text with confidence. Its dimensions, when unbroken, were 5½ by 6½ inches.

On the obverse horizontal and vertical alignments are strictly obeyed, even by sexagesimal digits in their proper places.

Critical Apparatus:

The digit 9 is written in the older nine-wedge form in obverse I,17, II,10, and II,15 while the cursive three-wedge form is used in I,19 and III,12. As noted, the 9 in I,17 is an error for 8.

For Leo we find the older UR in Reverse Ib, 31, 33, and possibly in Obverse II,13, while the later A is used in reverse IIb, 31, 33.

Obv. I,17: 13,1$\underline{9}$,2,48,45: the nine-wedge 9 should be 8, an isolated error without consequence.

Obv. II,14–18: 24,51,4$\underline{8}$,48,45 in II,15: 8 should be 7, and this error is repeated in the next four lines, that is, as far as Column II is preserved in this sexagesimal place. If this is not merely a copyist's error, it would show clearly that each column is computed independently from its initial value, for the values in the same lines of Column III are correct. Where Column II is not preserved we have restored the correct 7, though it is likely that the text had 8.

Rev. Ia,14: 1$\underline{6}$,30: should be 1$\underline{5}$,30, an isolated error without consequence.

Rev. IIa,20: 15 Taurus (Taurus very damaged) should be 24 Taurus.

Rev. Ia,20 and Ib,19: The traces of Month VIII (APIN) of year 16 Darius II should read Month VII (DU_6). Alternatively year 16 of Darius II would have to have a month XII_2, whereas Text A explicitly gives VI_2 (Rev. VI′, 5′) as noted in PD^3.

Rev. IIa,32,34 and IIb,31,33: Year 20 of Artaxerxes II must here be normal, while year 21 must have a month XII_2. As noted above, this agrees with the evidence of the Saros Canon and conflicts with B.M. 35328. PD^3 makes year 20 an intercalary year, based partly on Strassmaier's misreading of the Saros Canon.

Rev. Ib,33: 3$\underline{5}$ should be 3$\underline{6}$.

Commentary—Text M (Obverse):

The obverse of our text concerns Mercury, and we shall treat it here as though it were a separate text. The fragmentary state of the preserved surface and the unprecedented arrangement and structure of the table would have been insurmountable obstacles to our penetration into the contents, were it not for the procedure text ACT No. 816.

In this procedure text are set forth several schemes of the System A variety concerning Mercury. The first, which we shall call Model I, is given in Section 1; it serves to determine the longitude of Mercury at moments three synodic periods apart, or year by year, as the text apparently has it, for three synodic periods of Mercury fall only little short of one year. The parameters of the generating function of this scheme are:

$$\begin{array}{lcl} \text{Aries } 30^\circ \text{ to Leo } 30^\circ & : & w_1 = -16;52,30^\circ \\ \text{Leo } 30^\circ \text{ to Cancer } 20;37,30^\circ & : & w_2 = -16^\circ \\ \text{Cancer } 20;37,30^\circ \text{ to Aries } 30^\circ & : & w_3 = -10^\circ \end{array}$$

$$P = \frac{\Pi}{Z} = \frac{6,37,43}{19,12} = 20;42,51,52,30\,.$$

Since the w's are negative, the zodiacal signs are here, as in the text, to be taken in the sense opposite to their usual order.

The scheme is based upon a distribution of intervals in the three zones of length

$$I_1 = 0;0,52,44,3,45 \qquad I_2 = 0;0,50^\circ \qquad I_3 = 0;1,2,30^\circ$$

and, as characteristic of System A, one step corresponds to $Z = 19,12$ intervals, of whatever length.[22]

Since

$$21 \cdot Z = \Pi + 5,29\,,$$

21 steps, each corresponding to three synodic periods, lead to a total lag of 5,29 intervals, which, in their respective zones amount to

$$\begin{aligned} 5,29 \cdot I_1 &= 4;49,9,36,33,45^\circ \\ 5,29 \cdot I_2 &= 4;34,10^\circ \\ 5,29 \cdot I_3 &= 5;42,42,30^\circ\,. \end{aligned}$$

These are convenient checking parameters and, indeed, 21 triple synodic periods are very nearly 20 years. Section 4 of ACT

[22] See Aaboe [1964], 219.

No. 816 is, as a matter of fact, concerned with precisely these corrections for 20 years, but gives them as

$$4;49,17^\circ \qquad 4;34,15^\circ \qquad 5;32,51,30^\circ$$

though the zones are explicitly described and identical with those of Model I. This is not the only instance of internal inconsistency in this text.

In Section 3, which is only partly preserved, are found elements of a scheme, called System A_3, for producing longitudes of characteristic phenomena of Mercury one synodic period apart. Because the preserved parameters are incomplete, we have no indication of the extent of the zones. As we shall see, however, the parameters of this scheme—we call it Model I—must have been:

$$\begin{aligned} &\text{Leo } 30^\circ \text{ to Aries } 30^\circ &: w_1 &= 1,50;56,15^\circ \\ &\text{Aries } 30^\circ \text{ to Cancer } 20^\circ &: w_2 &= 2,11;28,53,20^\circ \\ &\text{Cancer } 20^\circ \text{ to Leo } 30^\circ &: w_3 &= 1,45;11,6,40^\circ \end{aligned}$$

$$P = \frac{\Pi}{Z} = \frac{18,39}{5,55} = 3;9,7,36,20, \ldots$$

This model is based on a distribution of 18,39 intervals of length, in the respective zones,

$$I_1 = 0;18,45^\circ \qquad I_2 = 0;17,46,40^\circ \qquad I_3 = 0;22,13,20^\circ$$

to be taken 5,55 at a time.

Since for Model II

$$3 \cdot Z = -54 \ (\mathrm{mod}\ \Pi),$$

the application of three consecutive synodic arcs leads to a lag of 54 intervals. Indeed, the intervals of Model II multiplied by 54 are precisely the w's of Model I, but the period of this derived model:

$$\frac{\Pi}{\Pi - 3 \cdot Z} = \frac{18,39}{54} = \frac{6,13}{18} = 20;43,20$$

is different from that of Model I because of the displacement of one endpoint of a zone from Cancer 20° of Model II to Cancer 20;37,30° of Model I. Models I and II are thus not strictly compatible. Neugebauer [ACT, 428] resolved this difficulty by assuming that Cancer 20;37,30° was probably an error for Cancer 20° which, indeed, seemed a very plausible assumption until the present text was understood.

For quite surprisingly, the structure of Text M turns out to be such that each column, by itself, is computed strictly in accordance with Model I, while the first line obeys the rules of Model

II. Specifically, the entries of the first line of the text—i.e., I(1), II(1), III(1), where I(1) means Column I, line 1, etc.—give longitudes of consecutive synodic phenomena of Mercury computed according to Model II, while each of the columnar sequences

(i) I(1), I(2), I(3), I(4), . . .
(ii) II(1), II(2), II(3), II(4), . . .
(iii) III(1), III(2), III(3), III(4), . . .

denotes longitudes of synodic phenomena of Mercury three synodic periods apart computed strictly according to Model I.

Thus it is clear that the 69 entries, read in the order

(iv) I(1), II(1), III(1), I(2), II(2), III(2), I(3), . . .,

give longitudes of synodic phenomena of Mercury one synodic period apart, and that they would represent them systematically, obeying a rather simple period relation, if Model I and Model II were truly compatible. Indeed, the sequence (iv) above conforms precisely to the rules of Model II until we reach the transition from III(3) to I(4) which is the first place where the disparity between the two models, *viz.*, whether a discontinuity of the generating functions is at Cancer 20° or 20;37,30°, becomes relevant. Model II, hitherto having employed the discontinuity at Cancer 20° several times, would yield Cancer 2;35,12,30° as a successor to III(3) while our text has Cancer 2;25,50° as the entry in I(4).

Similar discrepancies occur at II(10) and III(17). This last entry yields explicit and complete evidence for the discontinuity at Cancer 20;37,30°, while the situation at II(10) is only partially, though sufficiently, preserved. (See Table 11.)

It is clear, then, that the procedure text ACT No. 816 must not be tampered with despite internal inconsistencies, for it is precisely followed in the present text, where relevant. We have failed to discover any justification, astronomical or otherwise, for employing incompatible schemes in a single text when consistent and simple alternatives were so close at hand.

It remains to explain the integers preceding the longitudes in Text M. At first they presented quite an obstacle for, wherever preserved, they are written so close to the following number that we initially read them as first digits. When this proved wrong we thought they might be line numbers, since a continuous run from 1 to 17 is preserved in Columns II and III. This assumption, however, was contradicted by the corner piece (E_2), which shows that one line precedes the line numbered 1 in Column II, as well as

TABLE 11

Text M — B.M. 37053 — B.M. 37162 = L_b

Obv.		I			II			III		
1.	…	24,4,10	♌	…	14,40,57,25,18,45	♐	…	5,37,12,25,18,45	♈	1.
	…	8,4,10	♌	1	27,48,27,25,18,45	♏	…	18,44,42,25,18,45	♓	
	…	22,4,10	♋	2	10,55,57,25,18,45	♏	…	1,52,12,25,18,45	♓	
	…	2,25,50	♋	3	24,3,27,25,18,45	♎	…	14,59,42,25,18,45	♒	
5.	…	12,25,50	♊	4	7,10,57,25,18,45	♎	…	28,7,12,25,18,45	♑	5.
	…	22,25,50	♉	5	20,18,27,25,18,45	♍	…	11,14,42,25,18,45	♑	
	…	2,25,50	♉	6	3,25,57,25,18,45	♍	…	24,22,12,25,18,45	♐	
	…	15,10,32,48,45	♈	7	17,15,16,40	♌	…	7,29,42,25,18,45	♐	
	…	28,18,2,48,45	♓	8	1,15,16,40	♌	…	20,37,12,25,18,45	♏	
10.	…	11,25,32,48,45	♓	9	13,54,43,20	♋	…	3,44,42,25,18,45	♏	10.
	…	24,33,2,48,45	♒	10	23,54,43,20	♊	…	16,52,12,25,18,45	♎	
	…	7,40,32,48,45	♒	11	3,54,43,20	♊	11	29,59,42,25,18,45	♍	
	…	20,48,2,48,45	♑	…	13,54,43,20	♉	12	13,7,12,25,18,45	♍	
	…	3,55,32,48,45	♑	…	24,51,48,48,45	♈	13	26,26,23,20	♌	
15.	…	17,3,2,48,45	♐	…	7,59,18,48,45	♈	14	10,26,23,20	♌	15.
	…	10,32,48,45	♐	…	21,6,48,48,45	♓	15	24,26,23,20	♋	
	[illegible]	13,19,2,48,45	♏	…	4,14,18,48,45	♓	16	5,23,36,40	♋	
	[illegible]	26,25,32,48,45	♎	…	17,21,48,48,45	♒	17	15,23,36,40	♊	
	[illegible]	9,33,2,48,45	♎	…	29,17,48,45	♒	…	25,23,36,40	♉	
20.	[illegible]	22,40,32,48,45	♍	…	13,36,47,48,45	♑	…	5,23,36,40	♉	20.
	…	5,48,2,48,45	♍	…	26,44,17,48,45	♐	…	17,40,32,48,45	♈	
	…	19,30	♌	…	9,51,47,48,45	♐	1	48,2,48,45	♈	
	…	3,30	♌	…	22,59,17,48,45	♏	2	13,55,32,48,45	♓	

B.M. 36719 — B.M. 37032 — B.M. 36651

by the numbers 1 and 2 in Column III, lines 22 and 23, for there is no very good reason to use a numbering modulo 20.

Our investigation of the only remaining possibility, namely, that these numbers indicate regnal years from three consecutive reigns, enabled us to date the contents of Text M with high plausibility. Between −750 and 0 there are only two situations that would fit the regnal years for a Mercury phenomenon. The earlier solution would have the first line begin in year 13 of Esarhaddon (−645), and here the phenomenon must be the first visibility of Mercury as a morning star (Γ). The later possibility would assign the first line to year 41 of Artaxerxes I (−423) and identify the phenomenon as the last visibility of Mercury as an evening star (Ω).

TABLE 12

Line		~λ☿	~Text	Text minus λ☿		~λ☿	~Text	Text minus λ☿		~λ☿	~Text	Text minus λ☿
	Artaxerxes I				Artaxerxes I				Artaxerxes I			
1	41ʸ IV 10 = −423 Jul 27	139°	144°	5°	41ʸ VIII 3 = −423 Nov 15	245°	255°	10°	41ʸ XI 28 = −422 Mar 8	355°	6°	11°
	Darius II				Darius II				Darius II			
2	1ʸ IV 3 = −422 Jul 10	121	128	7	1ʸ VII 23 = −422 Oct 26	229	238	9	1ʸ XI 19 = −421 Feb 17	337	349	12
3	2 III 28 = −421 Jun 24	103	112	9	2 VII 13 = −421 Oct 5	210	221	11	2 XI 14 = −420 Feb 1	320	332	12
4	3 II 21 = −420 Jun 5	84	92	8	3 VI 4 = −420 Sep 15	192	204	12	3 X 8 = −419 Jan 15	303	315	12
5	4 II 13 = −419 May 17	64	72	8	4 V 30 = −419 Aug 31	178	187	9	4 X 2 = −419 Dec 29	286	298	12
6	5 II 4 = −418 Apr 28	44	52	8	5 V 29 = −418 Aug 19	165	170	5	5 IX 25 = −418 Dec 12	270	281	11
7	5 XII_2 24 = −417 Apr 8	24	32	8	6 IV 26 = −417 Aug 5	149	153	4	6 VIII 20 = −417 Nov 26	254	264	10
8	6 XII 14 = −416 Mar 18	6	15	9	7 IV 20 = −416 Jul 19	132	137	5	7 VIII 11 = −416 Nov 6	238	247	9
9	7 XII 6 = −415 Feb 27	347	358	11	8 III 14 = −415 Jul 3	114	121	7	8 VII 2 = −415 Oct 17	221	231	10
10	8 X 29 = −414 Feb 10	330	341	11	9 III 8 = −414 Jun 16	95	104	9	9 VI 21 = −414 Sep 26	202	214	12
11	9 X 24 = −413 Jan 25	312	325	13	10 II 30 = −413 May 29	76	84	8	10 VI 14 = −413 Sep 8	185	197	12
12	10 X 19 = −412 Jan 9	295	308	13	11 I 22 = −412 May 9	56	64	8	11 V 12 = −412 Aug 26	172	180	8
13	11 IX 11 = −412 Dec 21	280	291	11	12 I 13 = −411 Apr 19	36	44	8	12 V 10 = −411 Aug 13	159	163	4
14	12 IX 5 = −411 Dec 5	264	274	10	13 I 3 = −410 Mar 30	17	25	8	13 V 7 = −410 Jul 30	142	146	4
15	13 VIII 28 = −410 Nov 18	248	257	9	13 XII 24 = −409 Mar 11	358	8	10	14 IV 1 = −409 Jul 13	124	130	6
16	14 VII 19 = −409 Oct 29	231	240	9	14 XI 15 = −408 Feb 20	340	351	11	15 III 25 = −408 Jun 26	106	114	8
17	15 VII 9 = −408 Oct 7	213	223	10	15 XI 9 = −407 Feb 3	323	334	11	16 III 17 = −407 Jun 8	87	95	8
18	16 VI_2 1 = −407 Sep 18	195	206	11	16 X 5 = −406 Jan 18	305	317	12	17 II 8 = −406 May 20	67	75	8
19	17 V 25 = −406 Sep 2	180	190	10	17 IX 28 = −405 Jan 1	289	300	11	18 II 1 = −405 May 2	47	55	8
20	18 V 25 = −405 Aug 22	168	173	5	18 IX 22 = −405 Dec 15	274	284	10	18 XII_2 21 = −404 Apr 10	28	35	7
21	19 IV 21 = −404 Aug 7	152	156	4	19 VIII 17 = −404 Nov 28	257	267	10	19 XII 11 = −403 Mar 21	8	18	10
	Artaxerxes II				Artaxerxes II				Artaxerxes II			
22	1ʸ IV 16 = −403 Jul 22	135	140	5	1ʸ VIII 9 = −403 Nov 10	241	250	9	1ʸ XII 4 = −402 Mar 3	350	1	11
23	2 IV 11 = −402 Jul 6	117	124	7	2 VII 28 = −402 Oct 20	224	233	9	2 XI 25 = −401 Feb 12	333	344	11

A comparison of the longitudes in the text with modern computations[23] shows that only the later possibility need be considered. Specifically, for the earlier dating we find

$$-3° \leqslant \lambda_{\text{text}} - \lambda_{\text{mod.}} \leqslant +16°$$

which is not acceptable, though a systematic difference between Babylonian and modern longitudes of some 5°–10° is to be expected. For the later dating the relevant data are displayed in Table 12, and the differences now vary smoothly, and all lie in the interval

$$+4° \leqslant \lambda_{\text{text}} - \lambda_{\text{mod.}} \leqslant +13° .$$

Text L (Reverse):

Text L contains two double-columns, each of which presents data for 38 lunar eclipse possibilities or one Saros. For each eclipse possibility we are given the regnal year and month, longitude of the corresponding full moon, and a number closely related to the "magnitude" of that eclipse possibility.

Within each Saros the data for successive eclipse possibilities at the same node are presented in separate sub-columns. (We call the double-columns I and II and their parts Ia, Ib, IIa and IIb.) Columns Ia and IIa concern eclipse possibilities at the descending node, while Columns Ib and IIb concern eclipse possibilities at the ascending node. Five-month intervals between successive eclipse possibilities are marked in the text by a horizontal line that runs across both columns where preserved. For the sub-columns (i.e., eclipse possibilities at the same node) such a line indicates an eleven-month interval.

The regnal year numbers alone allow us to date the contents of the text to the 36 years from year 7 of Darius II (−416) to year 24 of Artaxerxes II (−380). Thus Text L begins with EP 6 of Saros Cycle 19 (see Table 6, page 21), in contrast to Text S,[24] which begins with EP 1 of (solar) Saros Cycle 16. No king name is preserved in text L_1, but text L_2 (which was identified as part of Text L only after we had dated L_1) has a small *ár-šú* following year 7 of Artaxerxes II, whose name also appears elsewhere as *Aršu*.[25]

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[23] The approximate dates of the Mercury phenomena were computed from Schoch's tables in Langdon, Fotheringham, and Schoch [1928], 103–105 and X, with the corrections proposed by van der Waerden [1942].

[24] Text S gives computed and observational data for the 38 solar eclipse possibilities comprising (solar) Saros Cycle 15 (−474 to −456). It was originally published by Aaboe and Sachs [1969], and is augmented by Text G here. It is discussed in HAMA, 525–528; Moesgaard [1980], 78–79; and most recently Britton [1989].

[25] See Sachs [1977].

This chronological support was, of course, welcome. However, the corner piece L_2 raised problems which we have failed to resolve to our satisfaction. To set these problems in relief we present first our reconstruction of the text from the evidence provided in L_1, ignoring the added evidence from L_2 except for the suggested position of the uppermost eleven-month line. Table 13 gives our transcription of L_1, while in Table 14 we have separated the columns more clearly and reconstructed the longitudes and magnitudes from the data preserved in L_1.

Longitudes:

Within each sub-column the longitudes are computed according to the rules that to a twelve-month interval corresponds an effective decrease in longitude of 10;30° and to an eleven-month interval a decrease of 10;30° and an additional full sign.

The solar travel according to this scheme corresponding to these time intervals is, therefore:

$$\text{(in 12 months)}\ d_{12}\lambda = 1 \text{ rotation} - 10;30°;\ \text{and}$$
$$\text{(in 11 months)}\ d_{11}\lambda = 1 \text{ rotation} - 10;30° - 1 \text{ sign}$$

Furthermore, since a Saros contains 14 twelve-month intervals and 5 of the other kind, we get for the total solar progress during one Saros:

$$\text{(in 223 months)}\ d_{223}\lambda = 14 \cdot d_{12}\lambda + 5 \cdot d_{11}\lambda$$
$$= 19 \text{ rotations} - 5{,}49;30°$$
$$= 18 \text{ rotations} + 10;30°.$$

This leads to a solar progress in 19 years of

$$d_{235}\lambda = d_{12}\lambda + d_{223}\lambda$$
$$= 19 \text{ rotations} + 0;0°,$$

which is a precise statement of the nineteen-year cycle.

This relation, we are sure, is the basis of the scheme, which represents a simple, but clever, device to avoid using mean motion which, incidentally, would lead to non-terminating sexagesimal fractions. It can be summarized thus:

$$d_{223}\lambda = -\, d_{12}\lambda = 10;30° \ (\text{mod. } 360°) \text{ and} \qquad \text{(A)}$$
$$d_{11}\lambda = d_{12}\lambda - 1 \text{ sign } (\text{mod. } 360°). \qquad \text{(B)}$$

One consequence of the scheme is that for each line the longitudes in our text should increase by 10;30° from Column I to Column II. This is true for Columns Ib and IIb. In Columns Ia and IIa, however, the difference is 10;0°, which suggests an error in at least one of these columns.

TABLE 13

Text L

11.	]⌈30⌉ ⌈máš⌉ 5 [BE]	
12.	3],40 11 x [	
13.	] 13 šu 19,30 máš 7 [	
14.	[x 13] ⌈ab⌉ 16,30 alla$_x$ 14,20 [illegible] 12 ab 26	
15.	14 sig [9] máš 19 [	
16.	[1]4 gan 5 alla$_x$ 25 13 ab 15 alla$_x$ [	
17.	[ ] 32,20 15 sig 28,30 pa] 31 33 [	
18.	15 apin 24,30 múl 7,20 BE 14 apin 4,30 maš [	
19.	16 gu$_4$ 18 gír 2 BE	
20.	16 apin 14 múl 3,20 15 apin 15 múl [	
21.	17 bar x 14 gír x	16 gu$_4$ 18 gír [
22.	x 3,30 múl x [	x 13,40
23.		17 bar 7,30 gír 21
24.		] múl 24,20
25.		] 18 bar 27 rín 33
25a.		29,20
26.		18 kin 22,30 zib 10 BE
27.		x šè 16,30 ab 3,40
28.		]9 izi 12 zib 2
		ḫi-pí ḫi-pí
29.		zíz 6 ab 14,20
30.		]20 izi 1,30 zib 14
31.		zíz 25,30 A 25
32.	] x UR ⌈21⌉ [illegible] 21 gu 26	
33.	ab 4,30 UR 35	zíz 15 A 3[5,40]
33a.	— x 40	
34.	22 sig 10,30 máš 4 BE	
35.	x x 2,40	gan 4,30 alla$_x$ [2]
36.	23 sig 30 pa 8	
37.	] x ,30 maš	gan 24 maš 12,40
38.	24 sig 19,30 pa 20	

So far these rules are identical with those encountered in Text S for computing the longitude of conjunction at solar eclipse possibilities. To test the connectibility of the texts we first transform the

TABLE 14

Text L	Ia	Ib	IIa	IIb
Dar. II	[8 I 18,30 ♏]	[*7 III 22,30 ♉]	[*7 I 28,30 ♏]	[6 VII 3 ♊]
	[8 XII 8 ♎]	[8 II 12 ♉]	[7 XII₂ 18 ♎]	[7 VI 22,30 ♉]
	[9 XI 27,30 ♍]	[9 II 1,30 ♈]	[8 XII 7,30 ♎]	[8 VI 12 ♈]
	[*10 XII 17 ♍]	[10 II 21 ♓]	[9 XI 27 ♍]	[9 VI 1,30 ♈]
	[11 XI 6,30 ♍]	[11 I 10,30 ♓]	[*10 XI 16,30 ♍]	[*10 V 21 ♓]
	[12 X 26 ♋ 3,40 [	[12 XII 30] ♑ 5 [BE]	11 X [6 ♌]	[11 IV 10,30 ♒]
	[*13] X 16,30 ♋ 14,20	13 XI 19,30 ♑ 7	12 X 25 [30 ♋]	[12 IV 30 ♑]
	[14 IX 5 ♋ 25 32,20	14 X [9] ♑ 19	13 X 15 ♋	[*13 IV 19,30 ♑]
	15 VIII 24,30 ♉ 7,20 BE	15 IX 28,30 ♐] 31 33	14 VIII 4,30 ♊	[14 III 9 ♑]
	(*) 16 VII 14 ♉ 3,20	(*) 16 IX 18 ♏ 2 BE	15 VIII 15 ♉	[15 II 28,30 ♏]
	[17 VI] 3,30 ♉ 14	17 VIII 7,30 ♏ 10	[16 VII 13,30 ♉ 13,40	(**) 16 II 18 ♏ [ ]
	[*18 VI 23 ♈ 24,40]	[18 VII 27 ♎]	[17 VII 3] ♉ 24,20	17 I 7,30 ♏ 21
	[19 VI 12,30 ♓]	[18 VI₂ 16,30 ♎]	(*) 18 VI 22,30 ♓ 10 BE	(*) 18 I 27 ♎ 33 29,20
Art. II	[1 V 2 ♓]	[19 VI 6 ♍] 4	[19 V 12 ♓ 2	⟨18⟩ XII 16,30 ♍ 3,40
	[*2 V 21,30 ♒]	[1 V 25,30 ♌]	20 V 1,30 ♓ 14	⟨19⟩ XII 6 ♍ 14,20
	[3 IV 11 ♒]	[*2 V 15 ♌	(*) 21 [IV 21 ♒ 26	⟨20⟩ XI 25,30 ♌ 25
	[4 III 30 ♑]	[3 IV 4,30 ♌ 35	22 III 10,30 ♑ 4 BE	⟨21⟩ XI 15 ♌ 3[6,40]
	[*5 III 20 ♐]	[4 III] 24 ♊ 2,40	23 III 30 ♐ 8	⟨22⟩ X 4,30 ♋ [ ]
	[6 II 9,30 ♐]	[5 II 13,30 ♊	24 II 19,30 ♐ 20	⟨23⟩ IX 24 ♊ 12,40

longitudes of conjunction in Text S into lunar longitudes at the corresponding lunar eclipse possibilities by adding or subtracting (depending on the eclipse possibility) the solar progress in half a month to or from the longitude of conjunction, plus 180°. If we assume that the semi-monthly solar motion is 14;40°,[26] and allow for an advance of 10;30° per Saros as required by the scheme, we can connect the longitudes in Columns Ib and IIb of Text L precisely to their counterparts in Text S. In contrast, the longitudes in Columns Ia and IIa are 1;0° and 0;30° higher than the values which agree with Text S.

In Text S the lunar longitude at conjunction increases in six months by 175° from ascending to descending node and by 174;30° from descending to ascending node. In Text L the corresponding

26 A more accurate value of the semi-monthly solar motion implicit in the 12, 223, or 235 month relationships reflected in the longitude scheme is 14;33, . . .°. Since the value 14;40° results in longitudes at lunar eclipse possibilities which end in whole or half degrees, its use may simply reflect a desire to distinguish easily longitudes of lunar and solar eclipse possibilities, while retaining simple fractions.

motions are 176° and 173;30° in Column I and 175;30° and 174° in Column II. The latter values are consistent with six months' progress at 29;15° per month and six months at 29° per month. These motions are also found in Text F (below), where several values are connectible with Column II of Text L. Thus it seems likely that the difference between Text S and Column II of Text L was intended, and also that the longitudes in Column Ia of Text L are in error and 0;30° too high.

The relation

$$\begin{aligned} 1 \text{ Saros} &= 223 \text{ months} \\ &\cong 18 \text{ revolutions of the sun} + 10;30° \end{aligned}$$

implies a value of the year of

$$1 \text{ year} = \frac{223 \cdot 360}{18 \cdot 360 + 10;30} \text{ months} \cong 12;22,7,51, \ldots \text{ months},$$

which is fairly close to the standard value in System A of 12;22,8. It is even closer to one of the year lengths implied by Lunar System B, *viz.*

$$\frac{6,0}{\mu_A} = 12;22,7,51, \ldots \text{ months}$$

where μ_A is the mean value of Column A, the monthly solar progress. To put the comparison another way, we have

$$\mu_A = 29;6,19,20^{\circ/m}$$

whereas our present scheme implies a mean monthly progress of

$$\mu = \frac{18 \cdot 6,0 + 10;30}{223} = 29;6,19,22, \ldots^{\circ/m}.$$

We may here have a justification of μ_A.

Text L_2:

There can be no doubt that the fragment E_2 (of which L_2 is the reverse) was once the upper right-hand corner of Text M, and thus also of Text L. The ductus is much the same in E_1 and E_2, except for the somewhat cramped writing on the reverse of E_2; the writing on the obverse is athwart that of the reverse; and indeed, the obverse of E_2 fits precisely in our reconstruction of Text M as indicated in Table 11, page 41. The reverse of E_2, however, presents problems which we have been unable to reconcile with our reconstruction of Text L (Table 14).

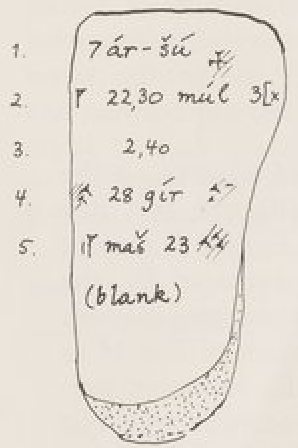
In Table 15 we show a transcription (A) and translation (B) of the cornerpiece L_2, together with what we would expect from our reconstruction (C). In the last we have included restored magnitudes and have let 1′, 2′, . . . denote the line numbers of our reconstructed text as they appear in Table 14, though it clearly does not represent the top of the actual text correctly.

The top edge of the fragment is preserved, leaving no room for additional lines before line 1, which reads "(year) 7 Artaxerxes II." The difficulties begin immediately with line 2, where we find traces of month VIII followed by 22,30 Taurus followed in turn by a number which begins with 30. This is precisely the entry we find in the reconstructed text, but in line 3′ instead of line 2. In line 3 (of the fragment) we find 2,40, the magnitude we would expect to find at the end of line 4′, Col. IIa. Thus far the fragment appears simply to be missing the first two lines of our reconstructed text, although we would also expect a horizontal line denoting a five-month interval between lines 2 and 3.

More severe difficulties occur in line 4 where we find traces of month II followed by 28 Scorpio, followed in turn by an illegible sign. The longitude, 28 Scorpio, is close to that found in line 2′ (Col. IIa) of the reconstructed text (28,30 Scorpio). It is also connectible with the longitudes in Text S, unlike the other longitudes in Column IIa.

Table 15

Text L_2 A



B

7 Artaxerxes II
VIII] 22,30 ♉ 30+x
2,40
II 28 ♏ [
3 ♊ 23,[40?]
(blank)

C

1′	6 VIII 3 II 24
2′	7 II 28,30 ♏ [33]
3′	7 VIII 22,30 ♉ 34,40
4′	7 XII_2 18 ♎ [2,40]
5′	8 VI 12 ♈ [ ]
6′	8 XII 7,30 ♎ [13,20]
7′	9 VI 1,30 ♈ [ ]

Finally, in line 5 we find traces of 3 Gemini followed by 23 and what could be 40. This longitude is found in line 1′ of our reconstructed text, where we would expect, however, 24 for the magnitude. Following line 5 the fragment is blank for at least two and possibly three lines.

Our fragment thus gives jumbled data for the first four dates in Column II corresponding to lines 3′, 4′, 2′, and 1′ of our reconstructed text. Furthermore, the blank lines in the fragment show that the entries were not continued and imply that at least some of the entries in Table 14 were omitted. Finally, two data disagree by small amounts with our reconstructed text.

We have no satisfactory explanation for this anomalous fragment, apart from speculating that all or most of the top of the original was broken away somewhere above line 11′. If so, then the corner fragment could simply reflect calculations of some of the missing entries for the top of Column II set down in wrong order.

Eclipse Magnitudes:

Following each longitude in Text L is a number which expresses the distance of the moon at conjunction from the inferior eclipse limit—i.e., the extreme negative nodal elongation at which a lunar eclipse is possible. The units of this function, which we shall call Ψ(L), are equal to 1/46th of the monthly progress in nodal elongation ($d_1\eta$), and derive from a function where $d_1\eta$ = 30;40° making 1 unit of Ψ(L) equal to 0;40° of nodal elongation.[27] For convenience (and to be consistent with the terminology of ACT) we shall use the term "eclipse magnitude" to describe Ψ(L) and its values, although strictly speaking the function describes nodal elongations rather than magnitudes in the modern sense.

Underlying Ψ(L) is a function, Ψ(6), which reflects uniform motion and is based on an eclipse cycle comprising 46 EP over 270 months arranged in six groups separated by five-month intervals. The period of this cycle,

$$P(6) = \frac{270}{46} = 5;52,10,26,\ \ldots\ \text{(months/EP)},$$

is poorer than that of the Saros,

$$P(5) = \frac{223}{38} = 5;52,6,18,\ \ldots\ \text{(months/EP)}.$$

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[27] Britton [1989], 14 ff., discusses Ψ(6), Ψ(S), and related functions. A demonstration of the correspondence between units of magnitude and units of nodal elongation is given on page 25.

However, unlike the Saros, it leads to units which convert conveniently into degrees of nodal elongation, η, by the relation

$$\eta = 0;40°(\Psi - 18); \ \Psi = \frac{3}{2}\eta + 18. \qquad \text{(C)}$$

For this reason (at least we can think of no other) $\Psi(6)$, rather than the corresponding function based on the Saros, was used as the basis for both $\Psi(L)$ and $\Psi(S)$, a related magnitude function found in Column III of Text S.

The principal parameters of $\Psi(6)$ are:

Parameter	Description	Units of Ψ	Nodal Elongation
$d_1\Psi(6)$	Monthly change	46	30;40°
$d_{12}\Psi(6)$	12-month change	12	8;0°
$d_{11}\Psi(6)$	11-month change	−34	−22;40°
$d_{223}\Psi(6)$	223-month change	−2	−1;20°
Eclipse limits		0 and 36	±12;0°

In Text L we find that $d_{12}\Psi(L)$ is always 12 at one node and 10;40 at the other for an entire group. These motions switch nodes at between lines 25 and 26 which is the boundary between Groups IV and V (Table 16). The preserved values of $d_{11}\Psi(L)$ range from −29;20 to −34;20. Thus $\Psi(L)$, though related, is clearly different from $\Psi(6)$.

Because its period is poor, $\Psi(6)$ requires some adjustment to be used as the basis of a more accurate theory. Thus fitting it to a Saros cycle ($d_{223} = 0$) requires a cumulative adjustment of +2 units of magnitude to offset the fact that $d_{223}\Psi(6) = -2$. This is very nearly what we find in $\Psi(S)$, where the cumulative adjustment is +2;40 units and the fraction seems to have resulted from a desire to preserve integral values in a related function.

If we examine the changes in $\Psi(L)$ from one column to the next—i.e., in 223 months—we find that when

$$d_{12}\Psi(L) = 12: \quad d_{223}\Psi(L) = -1 \text{ (Group V)},$$

but that when

$$d_{12}\Psi(L) = 10;40: \ d_{223}\Psi(L) = -0;20 \text{ (Groups IV, V) or } -0;40 \text{ (Group I)}.$$

If we assume that $d_{223}\Psi(L) = -0;20$ whenever $d_{12}\Psi(L) = 10;40$ except in Group I (see Table 16), and that $d_{223}\Psi(L) = -1$ whenever

$d_{12}\Psi(L) = 12$, the resulting sum of all such $d_{223}\Psi(L)$ over 38 EP is $-26;40$, so that the average value of

$$d_{223}\Psi(L) = -26;40 \div 38 = -0;42,6, \ldots, \text{ or}$$
$$d_{223}\Psi(L) - d_{223}\Psi(6) = +1;17,53, \ldots$$

Since $d_{223}\Psi(5) = 0$ and $d_{223}\Psi(6) = -2$, this implies an underlying eclipse period of

$$P(L) = \frac{26;40}{2\cdot 28}\{P(6) - P(5)\} + P(5) = \frac{1}{38}\left(223 + \frac{20}{69\cdot 19}\right)$$
$$= 5;52,7,45, \ldots$$

which corresponds to a monthly progress in nodal elongation of

$$d_1\eta = 30;40,13,58, \ldots^\circ.$$

As shown in the following table these parameters are virtually identical with those found in System B (and indeed also with modern values). Furthermore, if we subtract the monthly progress in nodal elongation found above from the average monthly solar progress implicit in Text L (29;6,19,22, . . .°), we find for the monthly motion of the node

$$d_1N = -1;33,54,36, \ldots^\circ,$$

which also agrees much better with System B than with System A.

	P	$d_1\eta$	d_1N
System A	5;52,7,39, . . .	30;40,14,30°	−1;33,55,30°
System B	5;52,7,44, . . .	30;40,14,4, . . .°	−1;33,54,44, . . .°
Text L	5;52,7,45, . . .	30;40,13,58, . . .°	−1;33,54,36, . . .°
Modern	5;52,7,45, . . .	30;40,14,1, . . .°	−1;33,53,49, . . .°

For $\Psi(L)$ to agree precisely with (the period of) System B, the sum of all 38 values of $d_{223}\Psi(L)$ would have to equal −26;18 instead of −26;40. While better agreement (−26;20) could have been obtained by assigning −0;40 as the sarosly difference to Group III rather than Group I, $P(L)$ is nearly as close to the period of System B as can be arranged with units of 0;20 and the requirement that all differences within a group be the same. In contrast, equivalence with the period of System A would require that the total of the sarosly differences be −24;48, or that the average sarosly difference for 10;40 velocities be −0;18, which is inconsistent with any combination of −0;20 and −0;40. This suggests that the intended period of $\Psi(L)$ was the same as that of System B, and that the sarosly difference −0;40 in Group I was introduced to accomplish this.

Using the twelve-month and 223-month differences described above, we can reconstruct all of Ψ(L) except for Group II, Cols. Ib and IIb. The result is shown in Table 16, where (+) and (−) indi-

TABLE 16

Text L EP#	Grp #	Ψ (L) Ia (-)	Ib (+)	IIa (-)	IIb (+)	d(223) (II-I)	Saros Cycle EP#
1			[24;40]		24;0	[-0;40]	6
2	I	[34]		[33]		[-1;0]	7
3			[35;20]		34;40	[-0;40]	8
4		[3;0]		2;40		[-0;20]	9
5			[ ]		[ ]	[-1;0]	10
6		[13;40]		13;20		[-0;20]	11
7	II		[ ]		[ ]	[-1;0]	12
8		[24;20]		24;0		[-0;20]	13
9			[ ]		[ ]	[-1;0]	14
10		[35;0]		34;40		[-0;20]	15
11			-5		[-6]	[-1;0]	16
12		3;40		[3;20]		[-0;20]	17
13			7		[6]	[-1;0]	18
14	III	14;20		[14;0]		[-0;20]	19
15			19		[18]	[-1;0]	20
16		25;0		[24;40]		[-0;20]	21
17			31		[30]	[-1;0]	22
18		-7;20		-7;40		-0;20	23
19			-2		-3	-1;0	24
20		3;20		3;0		-0;20	25
21	IV		10		9	-1;0	26
22		14;0		13;40		-0;20	27
23			22		21	-1;0	28
24		24;40		24;20		-0;20	29
25			34		33	-1;0	30
26		[-9]		- 10		[-1;0]	31
27			4;0		3;40	-0;20	32
28		[3]		2		[-1;0]	33
29	V		14;40		14;20	-0;20	34
30		[15]		14		[-1;0]	35
31			25;20		25;0	-0;20	36
32		[27]		26		[-1;0]	37
33			36;0!		35;40	-0;20	38
34		[-3]		-4		[-1;0]	1
35			2;40		2;0	-0;40	2
36	I	[9]		8		[-1;0]	3
37			13;20		12;40	-0;40	4
38		[21]		20		[-1;0]	5
					Total =	- 26;40	

cate ascending and descending nodes. Values which have been reconstructed assuming only that values of $d_{12}\Psi(L)$ are constant within a group are shown without [ ], while those derived from the postulated values of $d_{223}\Psi(L)$ are shown in [ ]. The groups are numbered after our Saros scheme for lunar eclipses described above. Only the boundaries between Groups I/II and Groups V/I agree with that scheme; the rest are shifted upwards by 1 EP, thus distributing the eclipse possibilities into groups of 8–7–7–8–8 EP.

To reconstruct the remaining values of Group II+ (Cols. Ib and IIb) we need to understand the structure of the discontinuities at the boundaries between groups, or, more precisely, how $d_{11}\Psi(L)$ varies. Table 17a shows the known values of $d_{11}\Psi(L)$, while 17b shows the difference between these values and the corresponding value for uniform motion, $d_{11}\Psi(6) = -34$.

We begin by noting that over 223 months the sum of the differences between the twelve-month and eleven-month changes in $\Psi(L)$ and the corresponding values for the uniform motion function, $\Psi(6)$, must cumulatively equal the difference between the 223-month changes in the two functions—i.e.,

$$\Sigma\{d_{12}\Psi(L) - d_{12}\Psi(6)\} + \Sigma\{d_{11}\Psi(L) - d_{12}\Psi(6)\} = d_{223}\Psi(L) - d_{223}\Psi(6),$$

where both sums are taken over 223 months. Substituting the appropriate values of $d\Psi(6)$ yields

$$\Sigma\{d_{11}\Psi(L) + 34\} = d_{223}\Psi(L) + 2 - \Sigma\{d_{12}\Psi(L) - 12\}, \qquad \text{(D)}$$

where

$$d_{223}\Psi(L) + 2 = +1, \text{ when } d_1\Psi(L) = 12 \text{ and}$$
$$= +1;40 \text{ or } +1;20, \text{ when } d_1\Psi(L) = 10;40.$$

In columns Ia and IIa of Table 17 there are, excluding the boundaries between groups, eight intervals where $d_{12}\Psi(L) = 10;40$, or where $d_{12}\Psi(L) - 12 = -1;20$. In these intervals $\Psi(L)$ will fall $8 \times (-1;20) = -10;40$ behind where it would be if $d_{12}\Psi(L) = d_{12}\Psi(6) = 12$. To compensate for this slower progress, the boundary jumps must reflect a cumulative correction of +10;40 relative to $d_{11}\Psi(6)$. Furthermore, to this must be added an amount corresponding to $d_{223}\Psi(L) - d_{223}\Psi(6)$, which here equals +1, since $d_{12}\Psi(L) = 12$ in Group I, Column Ia. Thus over 223 months the five boundaries must include a total correction of +11;40 relative to the eleven-month change of $\Psi(6)$, if the function is to return to its initial value plus $d_{223}\Psi(L) = -1$. As shown in Table 17b, this is exactly what we find in columns Ia and IIa.

At the ascending node, columns Ib and IIb, there are six intervals, excluding the boundaries, where $d_{12}\Psi(L) = 10;40$. Further-

Table 17a. $d_{11}\Psi(L)$

Boundary	Ia (−)	Ib (+)	IIa (−)	IIb (+)
Groups I/II	−31		−30;20	
Groups II/III	−31;20		−31;20	
Groups III/IV	−32;20	−33	−32;20	−33
Groups IV/V	−33;40	−30	−34;20	−29;20
Groups V/I	−30	−33;20	−30	−33;40
Total	−158;20		−158;20	

Table 17b. $d_{11}\Psi(L)$ +34

Boundary	Ia (−)	Ib (+)	IIa (−)	IIb (+)
Groups I/II	+3	[+1;40]	+3;40	[+1;20]
Groups II/III	+2;40	[+2]	+2;40	[+2]
Groups III/IV	+1;40	+1	+1;40	+1
Groups IV/V	+0;20	+4	−0;20	+4;40
Groups V/I	+4	−0;40	+4	+0;20
Total	+11;40	[+9;20]	+11;40	[+9;20]

more, in Group I, Column Ib $d_{223}\Psi(L)$ = −0;40, which is +1;20 greater than the corresponding difference of $\Psi(6)$. Thus in columns Ib and IIb the total correction at the boundaries relative to $d_{11}\Psi(6)$ is +1;20 − (6 × −1;20) = 9;20. This means that the combined correction from the two unknown boundaries must equal +3;40 in column Ib and +3;20 in column IIb. Since $d_{11}\Psi(L)$ must be an integer at the boundary between Groups II and III, there are four pairs of corrections which might serve. For column Ib these are:

Groups I/II	−0;20	+0;40	+1;40	+2;40
Groups II/III	+4	+3	+2	+1.

If we now consider the combined boundary corrections at both nodes, we find that these are most nearly uniform and symmetrical if we choose +1;40 and +2 from the above pairs. Table 18 shows the resulting corrections. Any other choice yields a combined correction of at least +5;40 at either the first or second boundary of column I, which is higher than any attested value and not symmetrical. These therefore seem the most probable corrections, and we have used them to reconstruct the missing values of $\Psi(L)$ in Group II+, although tentatively, since we still do not understand how the individual boundary jumps were derived.

The values of $\Psi(L)$, as reconstructed, are presented in column

TABLE 18. $d_{11}\Psi(L)$ +34

Boundary	Column I	Column II
Groups I/II	+4;40	+5;0
Groups II/III	+4;40	+4;40
Groups III/IV	+2;40	+2;40
Groups IV/V	+4;20	+4;20
Groups V/I	+4;40	+4;20
Total	+21;0	+21;0

(1) of Table 19 with the longitudes from Text L in column (2). The velocities, represented by the twelve-month changes in Ψ, are fixed relative to eclipse groups as follows: $d_{12}\Psi(L) = 12$ at the ascending node (Cols. Ib and IIb) in Groups II, III, and IV and at the descending node (Cols. Ia and IIa) in Groups I, and V. Conversely $d_{12}\Psi(L) = 10;40$ at the descending node of Groups II, III, and IV and at the ascending node of Groups I and V.

For a given velocity (progress in nodal elongation) the longitudes in Groups I and V fall within those in Groups II–IV, so the latter groups determine the range of the two velocities. These ranges are as follows:

$d_{12}\Psi(L) = 12$:
Col. I: 196;30° to 3;30° (*Libra* 16;30° to *Aries* 1;30°)
Col. II: 207;0° to 12;0° (*Libra* 27° to *Aries* 12°).

$d_{12}\Psi(L) = 10;40$:
Col. I:[28] 23;0° to 188;0° (*Aries* 23° to *Libra* 8°)
Col. II: 33;0° to 198;0° (*Taurus* 3° to *Libra* 18°).

Interzone midpoints:[29]
Col. I: 12;[0]° and 192;[0]° (*Aries, Libra* 12°)
Col. II: 22;30° and 202;30° (*Aries, Libra* 22;30°).

Ignoring the small error in Col. Ia, each zone of constant velocity extends for 165°, and the two are separated by a gap of 15° at each end.[30] The midpoints of these gaps are separated by 180°, so there can be no doubt that the scheme assumes two equal zones of constant velocity, each covering half the zodiac, but fixed relative to the Saros Cycle rather than to the ecliptic, and thus ad-

[28] As given in the text. Correcting the longitudes in Col. Ia as discussed above would reduce these values by 0;30°.

[29] Assuming corrected values for the longitudes in Column Ia.

[30] This may explain the anomalous distribution of eclipse possibilities into groups of 8-7-7-8-8 EP. The standard distribution would add 1 EP to Groups II–IV in Text L and thereby cause the velocity zones to overlap.

TABLE 19

Text L EP#	Grp #	(1) Ψ(L) Ia (-)	Ib (+)	IIa (-)	IIb (+)	(2) Longitude Ia (-)	Ib (+)	IIa (-)	IIb (+)	(3) dΨ(L) Ia (-)	Ib (+)	IIa (-)	IIb (+)	(4) dΨ(L) - d (6) Ia (-)	Ib (+)	IIa (-)	IIb (+)
1			[24.7]		24.0		52.5		63.0		9.3		9.0		3.3		3.0
2	I	[34.0]		[33.0]		228.5		238.5		1.3		1.7		-4.7		-4.3	
3			[35.3]		34.7		42.0		52.5		-32.3		-32.0		1.7		2.0
4		[3.0]		2.7		188.0		198.0		0.0		-0.7		-6.0		-6.7	
5			[3]		[2]		1.5		12.0		10.7		11.3		4.7		5.3
6		[13.7]		13.3		177.5		187.5		1.3		0.7		-4.7		-5.3	
7	II		[15]		[14]		351.0		1.5		9.3		10.0		3.3		4.0
8		[24.3]		24.0		167.0		177.0		2.7		2.0		-3.3		-4.0	
9			[27]		[26]		340.5		351.0		8.0		8.7		2.0		2.7
10		[35.0]		34.7		156.5		166.5		-40.0		-40.7		-6.0		-6.7	
11			-5		[-6]		300.0		310.5		8.7		9.3		2.7		3.3
12		3.7		[3.3]		116.0		126.0		3.3		2.7		-2.7		-3.3	
13			7		[6]		289.5		300.0		7.3		8.0		1.3		2.0
14	III	14.3		[14.0]		106.5		115.5		4.7		4.0		-1.3		-2.0	
15			19		[18]		279.0		289.5		6.0		6.7		0.0		0.7
16		25.0		[24.7]		95.0		105.0		6.0		5.3		0.0		-0.7	
17			31		[30]		268.5		279.0		-38.3		-37.7		-4.3		-3.7
18		-7.3		-7.7		54.5		64.5		5.3		4.7		-0.7		-1.3	
19			-2		-3		228.0		238.5		5.3		6.0		-0.7		0.0
20		3.3		3.0		44.0		[54.0]		6.7		6.0		0.7		0.0	
21	IV		10		9		217.5		228.0		4.0		4.7		-2.0		-1.3
22		14.0		13.7		33.5		43.5		8.0		7.3		2.0		1.3	
23			22		21		207.0		217.5		2.7		3.3		-3.3		-2.7
24		24.7		24.3		23.0		33.0		9.3		8.7		3.3		2.7	
25			34		33		196.5		207.0		-43.0		-43.0		-9.0		-9.0
26		[-9]		-10		342.5		352.5		13.0		13.7		7.0		7.7	
27			4.0		3.7		156.0		166.5		-1.0		-1.7		-7.0		-7.7
28		[3]		2		332.0		342.0		11.7		12.3		5.7		6.3	
29	V		14.7		14.3		145.5		156.0		0.3		-0.3		-5.7		-6.3
30		[15]		14		321.5		331.5		10.3		11.0		4.3		5.0	
31			25.3		25.0		135.0		145.5		1.7		1.0		-4.3		-5.0
32		[27]		26		311.0		321.0		9.0		9.7		3.0		3.7	
33			36.0		35.7		124.5		135.0		-39.0		-39.7		-5.0		-5.7
34		[-3]		-4		270.5		280.5		5.7		6.0		-0.3		0.0	
35			2.7		2.0		84.0		94.5		6.3		6.0		0.3		0.0
36	I	[9]		8		260.0		270.0		4.3		4.7		-1.7		-1.3	
37			13.3		12.7		73.5		84.0		7.7		7.3		1.7		1.3
38		[21]		20		249.5		259.5		3.0		3.3		-3.0		-2.7	

vancing by 10;30° each Saros. This effectively (if erroneously) implies that the variation in velocity is associated with either lunar anomaly or nodal elongation, rather than with longitude, since both of the former return very nearly to their starting points in one Saros.

To see the full effect of the variation in velocity we look at the change in Ψ(L) at successive eclipse possibilities, where it is large, rather than at twelve and eleven month intervals where it is not. Column (3) of Table 19 shows this change, while column (4) shows it net of the mean motion in nodal elongation, represented by dΨ(6). Column (4) thus presents the inequality in nodal elongation implicit in Ψ(L), expressed in units of Ψ.

Table 20 rearranges the data from column (4) of Table 19 in order of increasing longitude. Data marked by an * occur at boundaries which have beeen shifted 1 EP from the pattern characteristic of Ψ(6), and thus are likely to be distorted.

The remaining data are graphed in Figure 2, where they are compared with the theoretical inequality resulting from the sun's zodiacal anomaly,[31] expressed in units of Ψ. For −400 this inequality can amount to as much as ±4.07°, equivalent to ±6.1 units of magnitude. The theoretical inequality is zero at Babylonian longitudes[32] of roughly 74° and 254° and reaches its minimum and maximum at longitudes of 164° and 344° respectively. An additional inequality of ±1.5 units arises from the lunar anomaly. While individual values fall outside this band by up to 1.5 units (1°), the inequality in Ψ(L) clearly parallels the zodiacal inequality very closely. In particular, the extreme values derived from the text occur at very nearly the same longitudes as those of the theoretical inequality, while the zero values—although more dispersed—almost precisely bracket their counterparts in the theoretical function. Finally, it is noteworthy that the maximum inequality in Ψ(L), ±7;40 units = ±5.1°, agrees very closely with the theoretical amplitude, ±5.07° = ±7.6 units, obtained by combining the maximal inequalities due to zodiacal and lunar anomalies.

Ψ(L) thus describes an inequality in nodal elongation which is very nearly in phase with the zodiacal inequality for the two Cycles covered by our text, but whose amplitude appears to reflect

[31] As remarked by Aaboe and Henderson [1975], 194, the nodal elongation of the moon at syzygy is mainly determined by the sun's position. Consequently, its principal inequality is due to the sun's zodiacal anomaly.

[32] We have assumed the System A norm in which the vernal point occurs at Aries 10°. Thus by "Babylonian longitudes" we mean modern longitudes less 10°.

TABLE 20

INEQUALITY IN Ψ(L) (units of Ψ)			
----- Col I -----		----- Col II -----	
Bab. Long.	dΨ(L) minus dΨ(6)	Bab. Long.	dΨ(L) minus dΨ(6)
1.5	4.7	1.5	4.0
23.0	3.3	12.0	5.3
33.5	2.0	33.0	2.7
42.0	1.7	43.5	1.3
44.0	0.7	52.5	2.0
52.5	3.3	54.0	0.0
54.5	-0.7	63.0	3.0
73.5	1.7	64.5	-1.3
84.0	0.3	84.0	1.3
95.0	0.0	94.5	0.0
106.5	-1.3	105.0	-0.7
116.0	-2.7	115.5	-2.0
124.5	-5.0	126.0	-3.3
135.0	-4.3	135.0	-5.7
145.5	-5.7	145.5	-5.0
156.0	-7.0	156.0	-6.3
156.5 *	-6.0 *	166.5	-7.7
167.0	-3.3	166.5 *	-6.7 *
177.5	-4.7	177.0	-4.0
188.0	-6.0	187.5	-5.3
196.5 *	-9.0 *	198.0	-5.3
207.0	-3.3	207.0 *	-9.0 *
217.5	-2.0	217.5	-2.7
228.0	-0.7	228.0	-1.3
228.5	-4.7	238.5	0.0
249.5	-3.0	238.5	-4.3
260.0	-1.7	259.5	-2.7
268.5 *	-4.3 *	270.0	-1.3
270.5	-0.3	279.0 *	-3.7 *
279.0	0.0	280.5	0.0
289.5	1.3	289.5	0.7
300.0	2.7	300.0	2.0
311.0	3.0	310.5	3.3
321.5	4.3	321.0	3.7
332.0	5.7	331.5	5.0
340.5	2.0	342.0	6.3
342.5	7.0	351.0	2.7
351.0	3.3	352.5	7.7

the combined effects of the zodiacal and lunar anomalies. The relationship of the inequality to lunar anomaly is also evident in the basic structure of the text and especially in the constancy of the twelve- and 223-month changes within eclipse groups. Ψ(L) thus appears to antedate the clear separation of the two anomalies,

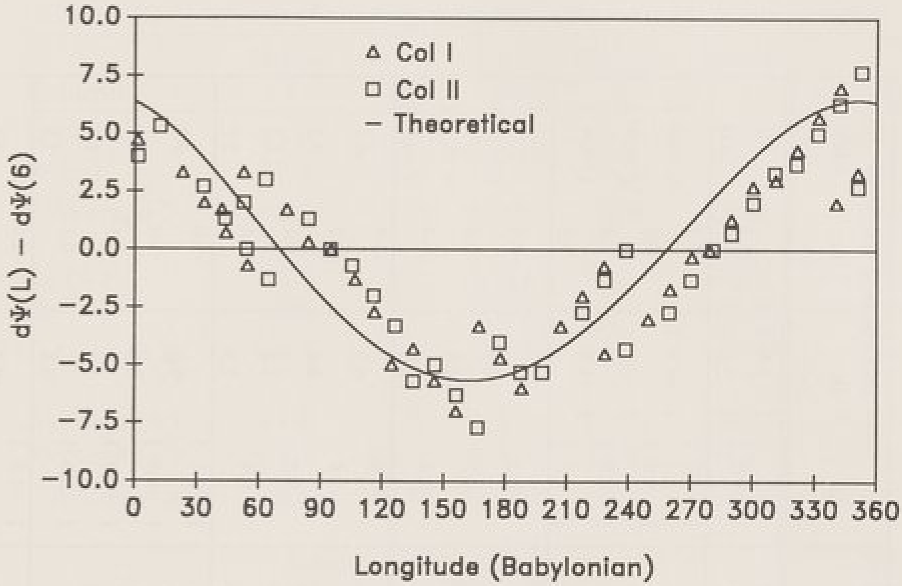


FIGURE 2. Inequality in Ψ(L)

while representing an improvement over the more elementary function, Ψ(S).

Table 21 shows (1) Ψ(L) as reconstructed; (2) the nodal elongation (in degrees) at syzygy, computed from P.V. Neugebauer [1929]; and (3) the resulting error in (correction to) Ψ(L). These errors are evenly distributed and relatively small, indicating that Ψ(L) is generally quite good.

The average error for each group is shown in Table 22. In every instance the errors at opposite nodes cancel, so the errors for the entire group are small. Only Group III has an average error greater than ±0.5 units; it is also the group with the distinctive correction to $d_{11}\Psi(6)$ shown in Table 18.

The mean error for all 76 values of Ψ(L) is negligible and less than the uncertainty of modern calculations. The probable error of a single value is ±93 units (0;37°). This shows that Ψ(L) is extremely well centered and better than Ψ(S), whose mean and probable errors are +0.65 ± 2.0 units (Britton [1988], 67). Finally, the accuracy of Ψ(L) is also remarkably consistent from group to group, which suggests that empirical adjustments—rather than purely theoretical considerations—may have influenced the choice of values at the group boundaries.

Ψ(L) differs from later functions in appearing to have been specifically fitted to the period covered by the text. We infer this from the general accuracy of the function, which depends on its close

TABLE 21

Text		(1)				(2)				(3)			
		Ψ(L)				ELONGATION				ERROR in Ψ (L)			
L EP#	Grp #	Ia (-)	Ib (+)	IIa (-)	IIb (+)	Ia (-)	Ib (+)	IIa (-)	IIb (+)	Ia (-)	Ib (+)	IIa (-)	IIb (+)
1			[24.7]		24.0		5.5		5.3		[1.6]		2.0
2	I	[34.0]		[33.0]		10.4		9.5		[-0.4]		[-0.8]	
3			[35.3]		34.7		13.3		13.1		[2.6]		3.0
4		[3.0]		2.7		-11.0		-11.8		[-1.5]		-2.4	
5			[3.0]		[2.0]		-10.6		-11.1		[-0.9]		[-0.6]
6		[13.7]		13.3		-2.5		-3.1		[0.6]		0.0	
7	II		[15.0]		[14.0]		-3.0		-3.6		[-1.5]		[-1.4]
8		[24.3]		24.0		5.9		5.2		[2.5]		1.8	
9			[27.0]		[26.0]		4.8		4.3		[-1.8]		[-1.6]
10		[35.0]		34.7		14.0		13.4		[4.0]		3.4	
11			-5.0		[-6.0]		-16.9		-17.8		-2.3		[-2.7]
12		3.7		[3.3]		-9.7		-10.0		-0.2		[-0.3]	
13			7.0		[6.0]		-8.4		-9.1		-1.6		[-1.6]
14	III	14.3		[14.0]		-2.6		-2.5		-0.2		[0.3]	
15			19.0		[18.0]		0.2		-0.7		-0.7		[-1.1]
16		25.0		[24.7]		5.4		5.3		1.1		[1.3]	
17			31.0		[30.0]		8.5		7.6		-0.3		[-0.6]
18		-7.3		-7.7		-17.3		-18.4		-0.6		-1.9	
19			-2.0		-3.0		-13.2		-14.1		0.2		-0.1
20		3.3		3.0		-10.4		-10.6		-0.9		-0.9	
21	IV		10.0		9.0		-4.9		-5.8		0.6		0.3
22		14.0		13.7		-2.5		-2.8		0.2		0.1	
23			22.0		21.0		3.6		2.7		1.4		1.1
24		24.7		24.3		4.9		4.6		0.7		0.6	
25			34.0		33.0		12.2		11.5		2.3		2.3
26		[-9.0]		-10.0		-18.8		-19.3		[-1.2]		-1.0	
27			4.0		3.7		-9.6		-10.1		-0.4		-0.8
28		[3.0]		2.0		-10.7		-11.3		[-1.0]		-1.0	
29	V		14.7		14.3		-1.7		-2.1		0.8		0.5
30		[15.0]		14.0		-2.3		-2.9		[-0.4]		-0.3	
31			25.3		25.0		5.9		5.5		1.5		1.3
32		[27.0]		26.0		6.2		5.5		[0.3]		0.3	
33			36.0		35.7		12.4		13.1		0.6		2.0
34		[-3.0]		-4.0		-15.0		-16.0		[-1.5]		-2.0	
35			2.7		2.0		-10.4		-10.6		-0.3		0.1
36	I	[9.0]		8.0		-6.8		-7.8		[-1.2]		-1.7	
37			13.3		12.7		-2.6		-2.6		0.8		1.4
38		[21.0]		20.0		1.3		0.3		[-1.1]		-1.6	

TABLE 22. Average Errors in Ψ(L) by Group (units of magnitude)

Column	Group I	Group II	Group III	Group IV	Group V	Average
Ia (+)	−1.0	+1.4	+0.2	−0.2	−0.6	−0.047
Ib (−)	+1.2	−1.4	−1.2	+1.1	+0.6	+0.137
Average I	+0.1	+0.2	−0.6	+0.5	0.0	+0.045
IIa (+)	−1.5	+0.7	+0.4	−0.5	−0.5	−0.321
IIb (−)	+1.6	−1.2	−1.5	+0.9	+0.7	+0.168
Average II	+0.1	−0.1	−0.7	+0.2	+0.1	−0.074
Average (+)	+1.4	−1.3	−1.4	+1.0	+0.7	+0.155
Average (−)	−1.3	+1.1	+0.3	−0.3	−0.6	−0.183
Average ALL	+0.06	+0.04	−0.65	+0.33	+0.06	−0.014
	Groups II, III, and IV					−0.095
	Groups V and I					+0.064
	Positive Errors		35			
	Negative Errors		41			
	Standard Deviation		±1.38 units			
	Probable Error		±0.93 units			

correlation with the zodiacal inequality, and which gets worse as one moves forwards or backwards in time. This apparent specificity is further emphasized by the fact that in the entire period from the beginning of the reign of Nabonassar to the beginning of the Seleucid Era, there were only two triplets of eclipses visible at Babylon, which exhibit the maximal inequality in nodal elongation due to the combined effects of both the zodiacal and lunar anomalies.

Both sets of eclipses occur in Column I of our text. The first comprises EP's 7, 8, and 9 in Group II and begins with the eclipse of −413:Sep 8. The second comprises EP's 26, 27, and 28 in Group V and begins with the eclipse of −403:Feb 23. The longitudes and (modern) magnitudes for these eclipses are:

Date	Long.	Mag.	Date	Long.	Mag.
−413:Sep 8	339.89°	14.7	−403:Feb 23	150.41°	3.9
−412:Mar 4	159.51°	10.5	−403:Aug 18	319.93°	1.0
−412:Aug 28	329.03°	13.1	−402:Feb 13	139.59°	19.1

In both cases the inequality in elongation is $\pm 5.06°$, equivalent to ± 7.6 units of magnitude. In the first case, however, the inequality acts to minimize the variation in magnitude, while in the second case the variation in magnitude is maximized. The second group of eclipses is also that for which we find the maximal inequality in $\Psi(L)$, namely $\pm 7;0$ units in Column I and $\pm 7;40$ units in Column II.

In sum, we find in $\Psi(L)$ a function which describes the variation in nodal elongation with a relatively high degree of accuracy but in a manner which does not separate the independent components due to the lunar and zodiacal anomalies. $\Psi(L)$ thus appears to antedate both System A and System B, while possessing attributes which appear related to each. In particular, the period relation which underlies $\Psi(L)$ appears identical with that of System B, as does the implicit magnitude for a central eclipse, $\Psi(L) = 18$. In contrast the two zones of constant twelve-month progress in nodal elongation point towards System A's treatment of the zodiacal anomaly. Finally, the excellence of $\Psi(L)$ as reflected in the accuracy of its amplitude, phase (in relation to the zodiacal inequality), and above all the mean position of its implicit node, points to a serious and painstaking effort in its construction and appears to exclude the possibility that it was merely a pedagogical excercise.

Text F: B.M. 36400 (80-6-17,176)

Contents: Full-moon longitudes monthly for S.E. 46–51 (−264 to −258).

Transcription: Table 23.

Description of Text:

B.M. 36400 lists lunar longitudes of full moons monthly for five years beginning with S.E. 46,VI, and ending with S.E. 51,VI. Obverse and reverse contain two columns each. Contrary to normal practice, the order of the columns on the reverse is from left to right. Years are separated by horizontal rulings except in obverse I; the only preserved year number is a "50" on the left edge corresponding to reverse I,13, as indicated in the transcription in Table 23.

In the last line the "9" is written with nine wedges (although as three diagonals everywhere else), and the zodiacal sign Taurus as "gu_4" (an abbreviation of the earlier notation "gu_4-an") in obverse I,15 and reverse I,8 and II,4, in contrast to the normal Seleucid convention of rendering Taurus as "múl-múl" or "múl." In astronomical diaries, "gu_4-an" virtually disappears as the designation of the zodiacal sign by the beginning of the Seleucid Era. One of the latest occurrences is from S.E. 56 in a statement of Mercury Ξ (A. Sachs), but it may well have been an anachronism by then; the event had to be predicted from the corresponding phenomenon that the scribe would have had to find in a diary dating 46 years before, in this way introducing the likelihood of contamination by the older terminology.

In the absence of an explicit year number in the text, these instances might well have been taken as formal indications of a probable pre-Seleucid date. On the lower edge are what appear to be something like the numbers 24 and 2 written in a wettish, shallow fashion, possibly even erased.

About half of the surface of the obverse is destroyed. The two groups that remain in the first column, amounting to seven lines in all, present problems which we shall discuss later. From the first preserved line of obverse II to the very end of the text, however, the longitudes follow a clear and consistent pattern.

Commentary:

The longitude scheme is very primitive: six months with a monthly lunar progress of 29°, followed by a six-month increase

Text F

Obv.

I

1)	[		]
	[du$_6$]	2̣	gụ$_4$
3)	apin	1	maš-maš
	gan	30	mạš-mạš
5)	⌞ab⌟[		]
	zíz[		]
7)	še	<[	]
	bar	<[	]
9)	[g]u$_4$[		]
	[sig		]
11)	[šu		]
	[izi		]⌜gu⌝
13)	k]in		]zib
	⌜du$_6$⌝	11,15	⌜ḫun⌝
15)	apin	10,30	gu$_4$
	[gan	9],45	maš-maš
17)	[ab]	9	alla$_x$

II

destroyed

⌜ki̤n⌝	11,15	[ḫun]	(9
[d]u$_6$	10,30	[gu$_4$]	
apin	9,45	[maš-maš]	(11
[ga]n	9	alla$_x$	
ab	8,15	A	(13
zíz	7,30	absin	
še	6,30	⌞rín⌟	(15

Rev.

I sic

1)	ba[r	5],30	gír-tab
	[g]u$_4$	4,30	pa
3)	[sig]	3,30	máš
	[šu]	2,30	gu
5)	izi	1,30	zib
	kin	45	ḫun
7)	du$_6$	30	[ḫu]n
	apin	29,15	gu$_4$
9)	gan	28,30	maš-maš
	ab	27,45	alla$_x$
11)	zíz	27	A
	še	26	absin
13)	bar	25	⌞rín⌟
	gu$_4$	24	[gír-]tab
15)	[sig]	23	pa
	[šu	2]2	máš

II

izi	21	[g]u	(1
kin	20,15	zib	
du$_6$	19,30	ḫun	(3
apin	18,45	gu$_4$	
gan	18	maš-maš	(5
ab	17,15	alla$_x$	
zíz	16,30	A	(7
še	15,30	absin	
diri-še	14,30	rín	(9
bar	13,30	g[ír-tab]	
gu$_4$	12,30	p[a]	(11
sig	11,30	m[áš]	
šu	10,30	g[u]	(13
izi	9,45	[zib]	
k[in]	[sign] sic	[ḫun]	(15

of 29;15° per month, without regard to the region of the ecliptic. These two parameters imply an increase in lunar longitude for twelve months of

$$6 \cdot 29^\circ + 6 \cdot 29;15^\circ = 174^\circ + 175;30^\circ = 5,49;30^\circ \text{ or}$$
$$d_{12}\lambda = 6,0^\circ - 10;30^\circ .$$

We have encountered this same relationship in Text S and Text L, and there can be no doubt that the present scheme is simply an extension to monthly motion of the scheme found in those texts for depicting uniform motion between eclipse possibilities. In so doing the scheme in Text F takes no account of the effective correction in velocity introduced every time there is an eleven-month interval. Instead, it simply reflects an average monthly progress in lunar (and solar) longitude of 29;7,30°, so that the year is

$$\frac{6,0^\circ}{29;7,30^\circ/\text{m}} = 12;21,37,51, \ldots \text{ synodic months},$$

which compares poorly with 12;22,7,51, . . .—the value implicit in texts S and L. Nevertheless, it is noteworthy that the extreme six-month velocities under this crude scheme, 175;30° and 174°, are precisely those found in Column II of Text L for the motion from ascending to descending node and conversely.

Our text begins with month VI of 46 S.E., which is also a lunar eclipse possibility (Table 6). No longitude is preserved, but the next three lines imply a progress of 29° per month, which leads to *Aries* 3° as the first entry. As noted above, there are difficulties with all the data preserved in Column I of the obverse. If we extend the scheme preserved in obverse II and the reverse back to obverse I, we also arrive at *Aries* 3° for the first line, but find the progress in lines 2–4 to be 29;15° per month rather than 29° as in the text. In lines 14–17, on the other hand, the progresses are consistent with the rest of the text, but the longitudes are 10;30° less than expected, suggesting that they may have been originally computed for months one Saros earlier.[33] Thus the errors in obverse I arise from (at least) two different and independent sources.

All the errors (or inconsistencies) occur prior to the five-month interval between eclipse possibilities in S.E. 47*, XII and S.E. 48, IV, while all preserved data after that interval are consistent. Also, the reconstructed longitudes for the four eclipse possibilities prior to that interval (46:VI, 46:XII, 47*:VI, and 47*:XII) are all con-

[33] These four longitudes are also identical with those in obverse II, 9–12.

TABLE 24

	Text	B_2 (Syst. A)	$\lambda_☾$ (mod.)	Text $- B_2$	Text $- \lambda_☾$	$B_2 - \lambda_☾$
Obv. I, 1. 46 VI		29;48 ♓	25;6 ♓			4;42
VII	2 ♉	29;48 ♈	24;53 ♈	2;12	7;7	4;55
VIII	1 ♊	29;48 ♉	24;58 ♉	1;12	6;2	4;50
IX	30 ♊	29;48 ♊	25;2 ♊	0;12	4;58	4;46
X		29;48 ♋	24;53 ♋			4;55
XI		29;48 ♌	24;18 ♌			5;30
XII		29;37,30 ♍	23;13 ♍			6;24
47 I		27;45 ♎	21;38 ♎			6;7
II		25;52,30 ♏	19;46 ♏			6;6
III		24 ♐	17;50 ♐			6;10
IV		22;7,30 ♑	16;7 ♑			6;0
V		20;15 ♒	14;47 ♒			5;28
VI		18;44 ♓	14;1 ♓			4;43
VII	11;15 ♈	18;44 ♈	13;46 ♈	−7;29	−2;31	4;58
VIII	10;30 ♉	18;44 ♉	13;53 ♉	−8;14	−3;23	4;51
IX	9;45 ♊	18;44 ♊	14;7 ♊	−8;59	−4;22	4;37
X	9 ♋	18;44 ♋	14;10 ♋	−9;44	−5;10	4;34
Obv. II, 1. XI		18;44 ♌	13;47 ♌			4;57
XII		18;44 ♍	12;52 ♍			5;52
XII_2		17;22,30 ♎	11;25 ♎			5;58
48 I		15;30 ♏	9;32 ♏			5;58
II		13;37,30 ♐	7;30 ♐			6;8
III		11;45 ♑	5;32 ♑			6;13
IV		9;52,30 ♒	3;57 ♒			5;56
V		8 ♓	2;55 ♓			5;5
VI	11;15 ♈	7;40 ♈	2;28 ♈	3;35	8;47	5;12
VII	10;30 ♉	7;40 ♉	2;33 ♉	2;50	7;57	5;7
VIII	9;45 ♊	7;40 ♊	2;54 ♊	2;5	6;51	4;46
IX	9 ♋	7;40 ♋	3;11 ♋	1;20	5;49	4;29
X	8;15 ♌	7;40 ♌	3;6 ♌	0;35	5;9	4;34
XI	7;30 ♍	7;40 ♍	2;28 ♍	−0;10	5;2	5;12
XII	6;30 ♎	7 ♎	1;13 ♎	−0;30	5;17	5;47

	Text	B_2 (Syst. A)	$\lambda_☾$ (mod.)	Text $- B_2$	Text $- \lambda_☾$	$B_2 - \lambda_☾$
Rev. I, 1. 49 I	5;30 ♏	5;7,30 ♏	29;28 ♎	0;22	6;2	5;40
II	4;30 ♐	3;15 ♐	27;24 ♏	1;15	7;6	5;51
III	3;30 ♑	1;22,30 ♑	25;18 ♐	2;8	8;12	6;4
IV	2;30 ♒	29;30 ♑	23;26 ♑	3	9;4	6;4
V	1;30 ♓	27;37,30 ♒	22;4 ♒	3;52	9;26	5;34
VI	0;45 ♈	26;36 ♓	21;17 ♓	3;9	9;28	5;19
VII	30 ♈	26;36 ♈	21;7 ♈	3;24	8;53	5;29
VIII	29;15 ♉	26;36 ♉	21;25 ♉	2;39	7;50	5;11
IX	28;30 ♊	26;36 ♊	21;51 ♊	1;54	6;39	4;45
X	27;45 ♋	26;36 ♋	22;4 ♋	1;9	5;41	4;32
XI	27 ♌	26;36 ♌	21;43 ♌	0;24	5;17	4;53
XII	26 ♍	26;36 ♍	20;52 ♍	−0;36	5;8	5;44
50 I	25 ♎	24;45 ♎	19;20 ♎	0;15	5;40	5;25
II	24 ♏	22;52,30 ♏	17;23 ♏	1;8	6;37	5;30
III	23 ♐	21 ♐	15;16 ♐	2	7;44	5;44
IV	22 ♑	19;7,30 ♑	13;14 ♑	2;52	8;46	5;54
Rev. II, 1. V	21 ♒	17;15 ♒	11;35 ♒	3;45	9;25	5;40
VI	20;15 ♓	15;32 ♓	10;27 ♓	4;43	9;48	5;5
VII	19;30 ♈	15;32 ♈	9;56 ♈	3;58	9;34	5;36
VIII	18;45 ♉	15;32 ♉	9;58 ♉	3;13	8;47	5;34
IX	18 ♊	15;32 ♊	10;20 ♊	2;28	7;40	5;12
X	17;15 ♋	15;32 ♋	10;43 ♋	1;43	6;32	4;49
XI	16;30 ♌	15;32 ♌	10;44 ♌	0;58	5;46	4;48
XII	15;30 ♍	15;32 ♍	10;10 ♍	−0;2	5;20	5;22
XII_2	14;30 ♎	14;22,30 ♎	8;58 ♎	0;8	5;32	5;24
51 I	13;30 ♏	12;30 ♏	7;14 ♏	1	6;16	5;16
II	12;30 ♐	10;37,30 ♐	5;13 ♐	1;52	7;17	5;24
III	11;30 ♑	8;45 ♑	3;10 ♑	2;45	8;20	5;35
IV	10;30 ♒	6;52,30 ♒	1;20 ♒	3;38	9;10	5;32
V	9;45 ♓	5 ♓	29;56 ♒	4;45	9;49	5;4
VI	9 ♈	4;28 ♈	29;7 ♓	4;32	9;53	5;21

nectible with Column II of Text L, whereas those after the interval are not.[34]

In Table 24 are listed, for reasons of comparison, first, the preserved longitudes from the text; next, the longitudes B_2 conforming to the consistent corpus of System A texts; and last, the longitudes of the full moon computed by modern methods, with modern parameters, and obeying the modern convention of measuring longitudes from the vernal equinox.

There is excellent agreement between B_2 and the text near the years' ends, and the maximal deviation of nearly 5°—the text's longitudes are almost everywhere larger than B_2—is then a measure of the quality of the primitive scheme.

Though it has nothing to do with our text we have included in the last column the differences between B_2 and the modern longitudes; they all lie in the interval 5;30° ± 1°. This is remarkable, for B_2 takes into account only solar anomaly, while the modern values depend on lunar anomaly as well.[35]

---

[34] This follows from the fact that in the underlying scheme the omitted month in a five-month interval has an implicit lunar velocity of 30°, whereas in Text F the omitted month has a velocity of 29° or 29;15° (here 29°). Thus every five-month interval the scheme reflected in Text F advances 1° or 0;45° relative to the underlying sheme.

[35] See Aaboe and Henderson [1975], 194f.

Text G: B.M. 36580 (=80-6-17,590)

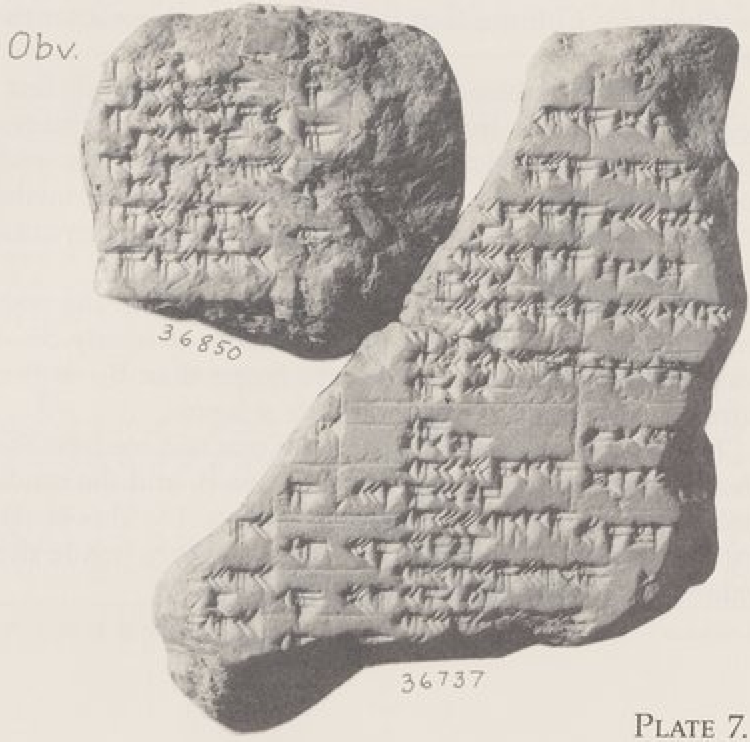
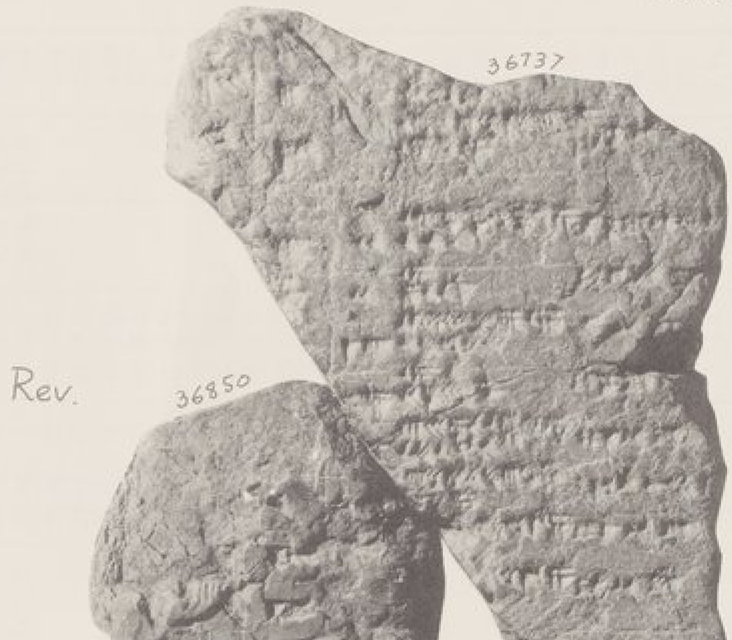


Plate 7.



TEXT G

Contents: Parts of Columns II and III of Text S[36] concerning solar eclipse possibilities from 11 Xerxes, VIII to 8 Artaxerxes I, IV (−474 to −456)

Transcription: Table 25; *Photograph*: Plate 7

Description of Text:

Text G comprises part of the upper left corner (obverse) of the tablet called Text C [B.M. 36737 (80-6-17,470)] in Aaboe and Sachs [1969], to which it is now physically joined. All edges are badly rubbed, as are the edges of Text C, so the surfaces do not join closely. However, there is no doubt at all about the join as may be seen in Plate 7.

Part of the upper edge is preserved.[37] The obverse contains Columns II and III of Text S for the first five eclipse possibilities of (solar) Saros Cycle 16. Column II contains values of Φ_1 which are consistent with the reconstruction in Aaboe and Sachs [1969], 17. Beneath the first four Φ values are numbers which we still do not understand. These are followed alternately by the terms "me" and "zalág" which are otherwise unattested in Text S,[38] but which suggest intervals, probably measured in time degrees.

Just enough of Column III is preserved in the obverse to confirm the structure of the function Ψ(S) for the first group of eclipse possibilities and to show that the values agree with the traces preserved in Text B (Aaboe and Sachs [1969], 12).

The reverse is very poorly preserved. Only three values of Column III can be clearly read along with the ending of one Φ value in Column II and the term "šá zalág" under what would be Column IV, which agrees with the (partially preserved) heading for the same column in Text B. Of greatest importance, however, are the preserved values of Column III, which permit the secure reconstruction of the function Ψ(S) for the sole group of eclipse possibilities where its structure was uncertain.

The edge of the text contains traces of the following four numbers written across the edge from obverse to reverse.

---

36 See note 24 above.

37 We are indebted to Christopher Walker of the British Museum for his careful collation of this fragment, in which he furnished several of the readings presented here.

38 Elsewhere in Texts S the terms šú and gin alternately follow similar numbers.

TABLE 25

Text G [I]	II	III
Xerx. 11 VIII	2,13,20 34 me	⌜5⌝
12* II	2, . ,33,31, 6,40 1,33 zalág	6
VIII	2,11,[37,57],46,40 1,2⌜4⌝ me	17
13 I	2,5,56,6,40 21 zalág	18
VII	2,6,15,22,13,20 (blank)	7⌝
Art. II 6 X	[2,3,55,44,26,40]	[10]
7 IV	[2,8,15,44,26,40]	10
X	[2,9,18,20]	2⤙
8* IV	[2,2,53,8,5]3,20	2⤙
		šá zalág

(Edge)

Column II obv (III rev):	2,1]3,20
" :	]5,40
Column III obv (IV rev):	3,22
" :	30

The first of these is probably 2,13,20 used simply as the name of Column Φ or as a truncated value of Φ.[39] The rest is obscure.

Commentary:

For a detailed discussion of Text S, including a description of the consolidated text which incorporates the evidence of Text G here, see Britton [1989].

[39] Cf. Aaboe [1968], 8 and ACT I, 212 for this use of 2,13,20.

BIBLIOGRAPHY

Aaboe [1964]: A. Aaboe, "On Period Relations in Babylonian Astronomy." *Centaurus* 10 (1964): 213–231.

—— [1968]: A. Aaboe, "Some Lunar Auxiliary Tables and Related Texts from the Late Babylonian Period." *Danske Vidensk. Selskab, Mat.-fys. Medd.*: 36, 12.

—— [1969]: A. Aaboe, "A Computed List of New Moons for 319 B.C. to 316 B.C. from Babylon: B.M. 40094." *Danske Vidensk. Selskab, Mat.-fys. Medd.*: 37, 3.

—— [1971]: A. Aaboe, "Lunar and Solar Velocities and the Length of Lunation Intervals in Babylonian Astronomy." *Danske Vidensk. Selskab, Mat.-fys. Medd.*: 38, 6.

—— [1972]: A. Aaboe, "Remarks on the Theoretical Treatment of Eclipses in Antiquity." *Journal for the History of Astronomy* 3 (1972): 105–118.

—— [1984]: "Mesopotamian Mathematics, Astrology, and Astronomy," to appear in *Cambridge Ancient History,* Volume III 2: 276–292.

—— [1987]: A. Aaboe, "A Late-Babylonian Procedure Text for Mars, and Some Remarks on Retrograde Arcs," *From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E.S. Kennedy*, ed. by D.A. King and G. Saliba (*Annals of the New York Academy of Sciences*, vol. 500, New York, 1987), 1–13.

Aaboe and Hamilton [1979]: A. Aaboe and N.T. Hamilton, "Contributions to the Study of Babylonian Lunar Theory." *Danske Vidensk. Selskab, Mat.-fys. Medd.*: 40, 6.

Aaboe and Henderson [1975]: A. Aaboe and J.A. Henderson, "The Babylonian Theory of Lunar Latitude and Eclipses According to System A." *Archives Internationales d'Histoire des Sciences* 25 (1975): 181–222.

Aaboe and Sachs [1966]: A. Aaboe and A.J. Sachs, "Some Dateless Computed Lists of Longitudes of Characteristic Planetary Phenomena from the Late-Babylonian Period." *Journal of Cuneiform Studies* 20 (1966): 1–33.

—— [1969]: A. Aaboe and A.J. Sachs, "Two Lunar Texts of the Achaemenid Period from Babylon." *Centaurus* 14 (1969): 1–22.

ACT: O. Neugebauer, *Astronomical Cuneiform Texts,* 3 vols., (London, 1955), Lund Humphries. Reprinted (1983), Springer-Verlag.

Alm.: *Ptolemy's Almagest,* trans. and annot. by G.J. Toomer, (New York, Berlin, Heidelberg, Tokyo, 1984), Springer-Verlag.

Bernsen [1980]: L. Bernsen, "Some Investigations on the Ephemerides of the Babylonian Moon Texts, System A." *Centaurus* 24 (1980): 36–50.

Bowen and Goldstein [1989]: A.C. Bowen and B.R. Goldstein, "Meton of Athens and Astronomy in the Late Fifth Century B.C.," *A Scientific*

Humanist: Studies in Honor of Abraham Sachs, ed. by E. Leichty, M.deJ. Ellis, P. Gerardi (Philadelphia, 1989), Univ. Museum, 39–81.

Britton [1987]: J.P. Britton, "The Structure and Parameters of Column Φ," *From Ancient Omens to Statistical Mechanics: Essays on the Exact Sciences presented to Asger Aaboe*, ed. by J.L. Berggren and B.R. Goldstein, (Copenhagen, 1987), Univ. Library.

—— [1989]: "An Early Function for Eclipse Magnitudes in Babylonian Astronomy." *Centaurus* 32 (1989): 1–52.

Epping and Strassmaier [1893]: J. Epping and J.N. Strassmaier, "Der Saros-Canon der Babylonier." *ZA* 8 (1893): 149–178.

Goldstine [1973]: H.H. Goldstine. "New and Full Moons from 1001 B.C. to A.D. 1651." *Memoirs of the American Philosophical Society* 94 (1973; reprinted, 1991).

Grayson [1975]: K. Grayson, *Assyrian and Babylonian Chronicles* (Locust Valley, NY, 1975), J.J. Augustin.

HAMA: O. Neugebauer, *A History of Ancient Mathematical Astronomy* (New York–Heidelberg–Berlin, 1975), Springer-Verlag.

Huber [1973]: P.J. Huber, "Babylonian Eclipse Observations: 750 B.C. to 0," unpublished paper.

Kugler [SSB]: F.X. Kugler, *Sternkunde und Sterndienst in Babel*, I (1907); II (1909–24), Münster, Aschendorff.

JCS: *Journal of Cuneiform Studies.*

Langdon, Fotheringham, and Schoch [1928]: S. Langdon, J.K. Fotheringham, and C. Schoch, *The Venus Tablets of Ammizaduga* (London, 1928), Oxford Univ. Press.

LBAT: T.G. Pinches, J.N. Strassmaier, A.J. Sachs, *Late Babylonian Astronomical and Related Texts* (Providence, 1955), Brown Univ. Press.

Moesgaard [1980]: K.P. Moesgaard, "The Full Moon Serpent. A Foundation Stone of Ancient Astronomy." *Centaurus* 24 (1980): 51–96.

Neugebauer [1938]: O. Neugebauer, "Untersuchungen zur antiken Astronomie III." *QS* B 4 (1938): 248–252; and (V): 407–411.

—— [1957]: O. Neugebauer, *The Exact Sciences in Antiquity*, 2nd ed. (Providence, 1957), Brown Univ. Press, Reprinted (New York, 1969), Dover.

—— [1989]: O. Neugebauer, "A Babylonian Lunar Ephemeris from Roman Egypt." *A Scientific Humanist: Studies in Honor of Abraham Sachs*, ed. by E. Leichty, M.deJ. Ellis, P. Gerardi (Philadelphia, 1989), Univ. Museum , 301–304.

Neugebauer and Sachs [1967]: O. Neugebauer and A.J. Sachs, "Some Atypical Astronomical Cuneiform Texts I." *JCS* 21 (1967): 183–218.

—— [1969]: O. Neugebauer and A.J. Sachs, "Some Atypical Astronomical Cuneiform Texts II." *JCS* 22 (1969): 92–113.

Oppolzer [1887/1962]: T. v. Oppolzer, *Canon of Eclipses*, trans. by O. Gingerich (New York, 1962), Dover.

Pannekoek [1917]: A. Pannekoek, "The Origin of the Saros." Koninkligke Akad. van Wetenschappen te Amsterdam. *Proceedings* 20 (1917): 943 ff.

PD^3: R.A. Parker and W.H. Dubberstein, *Babylonian Chronology* (Providence, 1956), Brown Univ. Press.

PV Neugebauer [1929]: P.V. Neugebauer, *Astronomische Chronologie*, 2 vols., (Berlin–Leipzig, 1929), De Gruyter.

—— [1934]: P.V. Neugebauer, "Spezieller Kanon der Mondfinsternisse für Vorderasien und Aegypten von 3450 bis 1 v. Chr." *Astronomische Abhandlungen* (1934): 9–2.

QS: *Quellen u. Studien z. Geschichte d. Mathematik, Astronomie, u. Physik.*

Reade [1986]: J.E. Reade, "Rassam's Babylonian Collection: the Excavations and the Archives." Introduction to E. Leichty, *Catalogue of the Babylonian Tablets in the British Museum, Volume VI: Tablets from Sippar I* (London, 1986), British Museum Publications.

Sachs [1974]: A.J. Sachs, "Babylonian Observational Astronomy." *Phil. Trans. Roy. Soc. London* A. 276 (1974): 43–50.

—— [1977]: A.J. Sachs, "Achaemenid Royal Names in Babylonian Astronomical Texts." *American Journal of Ancient History* 2 (1977): 129–147.

Sachs and Hunger [1988]: A.J. Sachs and H. Hunger, *Astronomical Diaries and Related Texts from Babylon* (Vienna, 1988), Österreich. Akad. d. Wiss.

Sachs and Wiseman [1954]: A.J. Sachs and D.J. Wiseman, "A Babylonian King List of the Hellenistic Period." *Iraq* 16 (1954): 202–212.

Stephenson and Clark [1978]: F.R. Stephenson and D.H. Clark, *Applications of Early Astronomical Records*, Monographs on Astronomical Subjects: 4 (New York, 1978), Oxford Univ. Press.

Strassmaier [1895]: J.N. Strassmaier, "Der Saros-Canon Sp II, 71." *ZA* 10 (1895): 64–69.

van der Waerden [1942]: B.L. van der Waerden, "Die Berechnung der ersten and letzen Sichtbarkeit von Mond und Planeten und die Venustafeln des Ammisaduga." *Sächsische Acad. d. Wiss. zu Leipzig, Berichte d. Math.-phys. Ke.* 94 (1942): 23–56.

—— [1966]: B.L. van der Waerden, *Die Anfänge der Astronomie: Erwachende Wissenschaft II*, (Groningen, 1966), Noordhoff.

—— [1968]: B.L. van der Waerden, "The Date of Invention of Babylonian Planetary Theory." *Archive for History of the Exact Sciences* 5 (1968): 70–78.

ZA: *Zeitschrift für Assyriologie und verwandte Gebiete.*

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