An Early Observation Text for Mars: HSM 1899.2.112 (=HSM 1490)

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This tablet, acquired by Harvard in 1899 and probably from Babylon, is a fragment of a text which recorded observations and calculated phenomena of Mars, year by year, from around the beginning of the reign of Esarhaddon (−679) through the end of the reign of Nebuchadnezzar (−561). The astronomical nature of the text was recognized by Claudine Vincente in 1994. It is published with the kind permission of Prof. Piotr Steinkeller, Curator of the Collection of Cuneiform Tablets at the Harvard Semitic Museum. I am indebted to Prof. Paul-Alain Beaulieu of Harvard for his generous assistance and suggestions with difficult readings, and for the copy of the text presented here as Figure 1. I also wish to thank Prof. Hermann Hunger for his helpful comments on the challenging reverse of the tablet. Remaining errors of reading, interpretation, or over-ambitious reconstruction are, of course, my own.

Physical Description

The surviving fragment, 8cm (h) × 4.5cm (w), appears to comprise between 1/2 and 1/3 of the original tablet in height. Left and bottom edges are preserved on the obverse (left and top on the reverse). The tablet turns over the bottom edge (O/R). Columns, separated by vertical rulings, run left to right on obverse; right to left on reverse, so that the last column on obverse continues over onto reverse. The fragment thus preserves the bottom of column (i) with traces of column (ii) on the obverse and part of the top of the last column on the reverse. The tablet is well written in a Neo-Babylonian scholarly hand,[1] and uses the

[1] Description courtesy of Paul-Alain Beaulieu.

 | DOI:10.1163/9789047412441_004

cursive form of '9', but possibly the older form, *mul*, instead of *múl*.

Column (i) preserves statements of the dates of appearances and disappearances of Mars together with one positional statement for years 0–10 of Šamaš-šuma-ukin (−667 to −656). Horizontal rulings separate successive years, and the ten preserved years take up 13 lines. By the end of the text more information is recorded for each year, and in the last column data for years 35 to 38 Nebuchadnezzar (−569 to −566) requires 15 lines. Thus by the end of the text there is nearly three times as much information per year as at the beginning.

If the unbroken tablet was 20cm in height, it would have had room for ca. 33 lines on the obverse and a few more on the more tightly written reverse, allowing room for up to 16 years at the beginning of column 1 and up to 6 years at the end of the reverse. Thus the text almost certainly included information from the beginning of Esarhaddon's reign (ca. −680), and perhaps a few years earlier, and it probably continued through the last (43rd) year of Nebuchadnezzar's reign (−561/0) or perhaps one year later.[2]

Column (i) appears to have covered roughly 25 years, whereas the last column covered only 9 or 10. In between there are 86 years of information distributed over an even number of columns. Two columns of 25 years (implying no change in information density) on the obverse and two averaging 18 years (e.g. 24 and 12 as in Figure 2) on the reverse would accommodate the missing years, and imply a marked increase in information density between ca. −605 and −569. The alternative, three missing columns per side, would imply a steady increase in information density until roughly −600, followed by a level density at 9 to 10 years per column on the reverse. On balance it seems more likely that the text contained three columns to a side, with a substantial increase in informational density occurring in the first half of the 6th century. However, in the absence of additional evidence this remains a tentative assumption.

[2] It is perhaps coincidental, but noteworthy, that BM 36731, a compilation of computed dates of solstices, equinoxes and Sirius visibility phenomena from 0 or 1 Nabopolassar, also appears to conclude with the last year of Nebuchadnezzar's reign.

Text

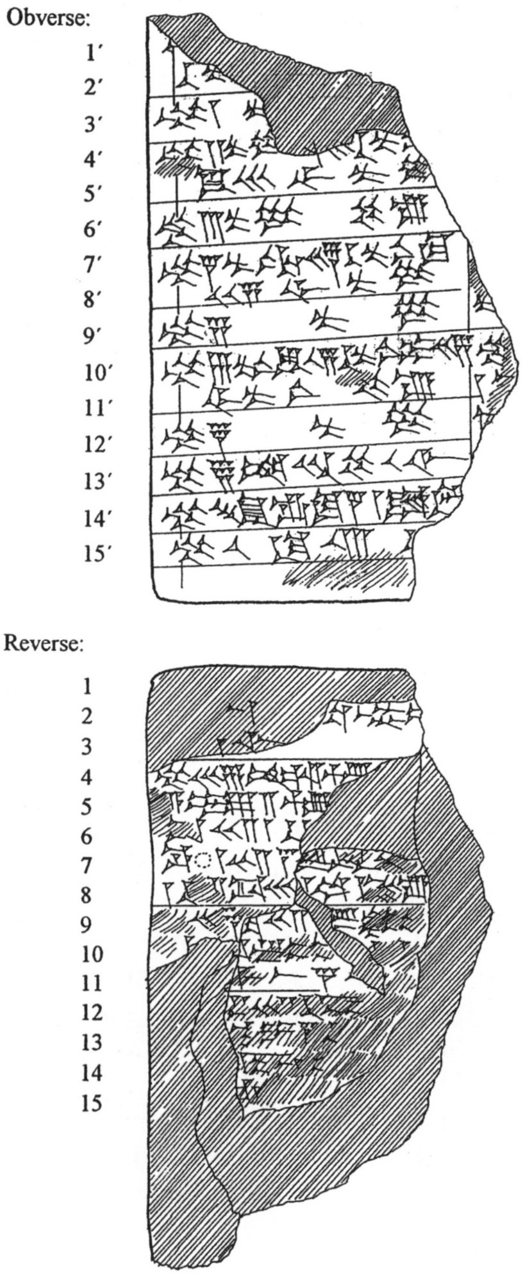

Figure 1 (courtesy of Paul-Alain Beaulieu)

Transliteration

Obverse:

Column (i) Column (ii)

1′ || M[U SAG ^{md}GIŠ.NU$_{11}$-MU-GI.NA (mn)(d)
2′ || ŠÚ NU [ŠEŠ (mn) (d) IGI NU ŠEŠ
3′ || MU 1 NU [ŠEŠ KIN DIRI
4′ || MU 2 NU ⌜ŠEŠ GU$_4$ 20⌝ ŠÚ NU ⌜x⌝ [o
5′ || KIN 30 IGI NU ŠE[Š o
6′ || MU 3 NU ŠEŠ ŠE DIRI [
7′ || MU 4 NU PAP SIG 27 ŠÚ NU PAP DU$_6$ [
8′ || 25 IGI NU ŠEŠ | [
9′ || MU 5 NU ŠEŠ | M$^?$[U$_x$ 1′
10′ || MU 6 NU PAP KIN 15 ŠÚ NU PAP GAN 25 | MU[2′
11′ || IGI NU PAP ŠE DIRI | *ana* ⌜x⌝ 3′
12′ || MU 7 NU ŠEŠ | ⌜x⌝ [4′
13′ || MU 8 NE 20 ŠÚ ŠE 10 IGI [
14′ || MU 9 KIN DIRI DU$_6$ 4 *ana* MURUB$_4$ ⌜ALLA⌝ [
15′ || MU 10 DU$_6$ 13 Š[Ú

{lower edge}

Reverse:

{upper edge}

1 || { blank }
2 || M[U 35]⌜SAG SIG⌝ [Í]M *ina* GÌR G[U$_4$ o]
3 || Š[Ú KIN] ⌜1 IGI⌝ { blank$^?$ }
4 || MU 36 NE 12 $\frac{1}{2}$ KÙ[Š *ina* IGI MUL IGI]
5 || šá GÌR$^!$ LU 2$\frac{1}{2}$ KÙŠ [*ana* ULU SIG UŠ]
6 || ⌜KIN⌝ 23 ⌜SIG$^?$⌝ [MUL KUR šá DUR *nu-nu*]
7 || E ⌜DU$_6$⌝ 22 4 KÙŠ ⌜*meš-ḫat*⌝ [*ana* ULU]
8 || *ana* ⌜ŠÚ DIB⌝ UŠ 30 *ana* NIM LAL ŠE DIR
9 || MU 37 SIG 22⌜$\frac{1}{2}$⌝ KÙŠ ⌜ár MUL⌝
10 || ⌜TUR⌝ [šá] ⌜4⌝ KÙŠ ár [o A] ⌜ŠÚ⌝
11 || [DU$_6$ o o *n*]*a*-⌜*su*⌝ *ina* 4 IG[I x o o]
12 || [MU 38] ⌜KIN⌝ 22 ⌜E$^?$ MUL⌝ [ŠUR GIGIR]
13 || [šá ULU U]Š ⌜APIN⌝ 4 ⌜ár⌝ [IS DA E]
14 || [GAN o x+]1 *ina* IGI [IS DA UŠ]
15 || [MU 39]⌜NE$^?$⌝ [o o o o SÚ]
16 || [o o o] x [o o o o o IGI]

Translation

Obverse:

	Column (i)	Column (ii)	
1′	Accession year of Šamaš-šuma-ukin, (month) (day)		
2′	Ω, not [observed, (month) (day) Γ, not observed		
3′	Year 1, not(hing) [observed, VI_2		
4′	Year 2, not(hing) observed, II 20 Ω, not [observed		
5′	VI 30 Γ, not obser[ved		
6′	Year 3, not(hing) observed, XII_2		
7′	Year 4, no watch, III 27 Ω, not watched for, VII		
8′	25 Γ, not observed		
9′	Year 5, not(hing) observed	Y[ear? x	1′
10′	Year 6, no watch, VI 15 Ω, not watched for, IX	Year [	2′
11′	Γ, not watched for, XII2	towards [x	3′
12′	Year 7, not(hing) observed	⌜x⌝	4′
13′	Year 8, V 20 Ω, XII 10 Γ		
14′	Year 9, VI_2, VII 4 towards the middle of the Crab		
15′	Year 10, VII 13 Ω		

Reverse:

Column (vi)

1 || { blank }

2 || Ye[ar 35]⌜beginning of III o⌝r end of I[I,]

3 || ⌜Ω⌝. [VI] ⌜1, Γ⌝. { blank? }

4 || Year 36 V 12, $\frac{1}{2}$ cub[it in front of]

5 || β-ari, $2\frac{1}{2}$ cubits [below to the south, Φ;]

6 || ⌜VI⌝ 23, ⌜below?⌝ [η-psc]

7 || Θ; VII 22, 4 cubits ⌜measured⌝ [to the south (having)]

8 || ⌜passed⌝ to ⌜the west⌝, Ψ; the 30th back towards the east; XII_2.

9 || Year 37 III 22, ⌜$\frac{1}{2}$⌝ cubit ⌜behind⌝

10 || ⌜ρ-leo, Ω;⌝

11 || [VII x y° (h]igh); around the 4th Γ, [...].

12 || [Year 38] VI 22 ⌜above? MUL⌝

13 || [ζ-tau,] Φ; ⌜VIII⌝ 4 ⌜behind⌝ [α-tau, Θ;]

14 || [IX x+]1, in front of [α-tau, Ψ.]

15 || [Year 39]⌜V⌝ [...Ω;]

16 || [......x ...Γ]

Critical Apparatus

Obverse:

col. (i)

1′	The location of ŠÚ on the following line argues against MU 13 (Esarhaddon).
2′	There is enough space in the missing column for a second NU ŠEŠ.
4′	Possibly 30 in place of 20.
7′ff.	NU PAP/NU ŠEŠ (∼*naṣaru*, 'to watch for'), here translated 'not watched for' (PAP) and 'not(hing) observed' (ŠEŠ), but no distinction may be warranted.
14′	Cursive (3-wedge) 9.

col. (ii)

1′	N[U possible for M[U.
1′/2′	Rows not aligned precisely with col. (i); traces of possible NU between 1′ and 2′.

Reverse (generally, very poorly preserved):

2	GÌR, or possibly GAN (HÉ), appears in BM 37361 in the context SAG, $MURUB_4$, GÌR, which evidently denote 'beginning, middle and end'. It seems to be an archaic form which was replaced in later Diaries and observation texts by the more widely used TIL.
5	GÌR, scribal error for SAG or different description of β-ari? Note LU(DIB), not LÚ, for Aries. $2\frac{1}{2}$, possible scribal error for $5\frac{1}{2}$.
13	Scoring should be under the following line.

Commentary[3]

Dates

Four intercalary months are mentioned: in column (i) a XII_2 in years 3 and 6 and a VI_2 in year 9; in column (vi) a XII_2 in year 36*. From the 8th century onwards, the last could only refer to

[3] Notation here follows the conventions in ACT. Years with intercalary months XII_2 and VI_2 are designated Y* and Y** respectively. Synodic phenomena are designated by Greek letters as follows: Ω (ŠÚ∼disappearance); Γ (IGI∼first appearance); Φ (UŠ∼first station); Θ (E∼opposition); Ψ (2-UŠ∼second station).

36 Nebuchadnezzar (−568/7), which thus establishes the dates in that column. In theory (although improbably from the contents) this might be the obverse of the tablet, but no subsequent reign of at least 10 years reflects the intercalations in column (i).[4] Before Nebuchadnezzar, attested intercalations and reign lengths rule out all but Šamaš-šuma-ukin (SSU), confirmation of which is provided by the positional remark in year 9. The text thus provides evidence of 3 hitherto unconfirmed intercalary years, namely SSU 3*, 6*, and 9**.

Contents

The planet's name is not mentioned, but the synodic intervals of roughly 26 months for šú(Ω) and igi(Γ) in column (i) and the close agreement between reported and calculated data for all five synodic phenomena recorded in column (vi) show that the text concerns Mars exclusively.

Data is recorded for every year, whether or not there is anything to report. In column (i), except in year 9 (line 13′) which contains a unique statement of position, only dates of appearances, igi(Γ), and disappearances, šú(Ω), are reported together with intercalary months. Until year 8 these are invariably preceded and followed by either 'nu šeš' or 'nu pap', both essentially meaning 'not observed', (∼*naṣaru*) and thus by implication computed in some fashion, but with what difference of nuance and whether predicted or computed back is not at all clear. Nor is any consistent pattern of usage evident: in year 2 we find three instances of 'nu šeš'; in year 6 three of 'nu pap', and in year 4 two 'nu pap's followed by a 'nu šeš'. In contrast, years 3, 5, and 7 in which neither phenomenon occurred are marked by a single 'nu šeš'. In years 8–10 (−659/8) these remarks no longer appear, suggesting that for these years the text records actual observations.

[4] These intercalations are attested for the reign of Cyrus which, however, lasted only 9 years with a (late) intercalary VI_2 in year 2, which is not mentioned in the text.

line	(i) −680	(ii) −656	(iii) −631
1	Heading	SSU 11 II 26 igi	KAN 16 IV 22 šú
2	SA2 8 III 25 šú	SSU 12 X 19 šú	KAN 16 VII 29 igi
3	SA2 8 VI 28 igi	SSU 13 III 22 igi	17
4	1	14	KAN 18 V 12 šú
5	ASR 2 IV 17 šú	SSU 15 XII 20 šú	KAN 18 IX 9 igi
7	3	16	KAN 20 VI 6 šú
8	ASR 4 V 8 šú	SSU 17 II 29 šú	KAN 20 XII 26 igi
9	ASR 4 IX 9 igi	SSU 17 VI 3 igi	21
10	5	18	KAN 22 VII 25 šú
11	ASR 6 VI 4 šú	SSU 19 III 26 šú	NBL 1 II 29 igi
12	ASR 7 I 9 igi	SSU 19 VI 28 igi	NBL 2 XII 2 šú
13	ASR 8 IX 2 šú	20	NBL 3 III 23 igi
14	ASR 9 II 25 igi	KAN 1 IV 17 šú	4
15	ASR 10 XII 6 šú	KAN 1 VIII 1 igi	NBL 5 I 26 šú
16	ASR 11 IV 17 igi	2	NBL 5 V 13 igi
17	12	KAN 3 V 8 šú	6
18	ASR 13 I 25 šú	KAN 3 IX 19 igi	NBL 7 III 2 šú
19	ASR 13 V 7 igi	4	NBL 7 VI 5 igi
20	1	KAN 5 VI_2 6 šú	8
21	SSU 2 II 28 šú	KAN 6 I 21 igi	NBL 9 III 27 šú
22	SSU 2 V 30 igi	KAN 7 IX 22 šú	NBL 9 VII 1 igi
23	3	KAN 8 III 26 igi	10
24	SSU 4 III 22 šú	KAN 9 XII 13 šú	NBL 11 IV 17 šú
25	SSU 4 vi 28 igi	KAN 10 iv 18 igi	NBL 11 VIII 4 igi
26	5	11	12
27	SSU 6 V 12 šú	KAN 12 I 28 šú	NBL 13 V 9 šú
28	SSU 6 IX 3 igi	KAN 12 V 7 igi	NBL 13 X 3 igi
29	7	13	14
30	SSU 8 VI 4 šú	KAN 14 II 30 šú	NBL 15 VI_2 13 šú
30	SSU 8 XI 18 igi	KAN 14 VI 1 igi	NBL 16 I 27 igi
31	9	15	NBL 17 X 14 šú
32	SSU 10 VII 12 šú		

Figure 2: Schematic potential arrangement of HSM 1490 showing calculated dates of igi(Γ) and šú(Ω). In practice the empty space in each column would have been filled with additional data.

line	(iv) −606	(v) −582	(vi) −569
1	NBL 18 III 27 igi	NBK 22 IV 17 šú	NBK 35 III 2 šú
2	NBL 19 XII 21 šú	NBK 22 VIII 10 igi	NBK 35 VI 4 igi
3	NBL 20 IV 17 igi	23	36
4	NBK 1 II 3 šú	NBK 24 V 10 šú	NBK 37 III 22 šú
5	NBK 1 V 9 igi	NBK 24 XI 2 igi	NBK 37 VII 7 igi
6	2	25	38
7	NBK 3 III 1 šú	NBK 26 VII 19 šú	NBK 39 IX 27 šú
8	NBK 3 VI 4 igi	NBK 27 II 3 igi	NBK 39 V 13 igi
9	4	NBK 28 X 28 šú	40
10	NBK 5 IV 22 šú	NBK 29 II 28 igi	NBK 41 VI$_2$ 13 šú
11	NBK 5 VII 3 igi	NBK 30 XII 27 šú	NBK 42 I 29 igi
12	6	NBK 31 IV 17 igi	NBK 43 IX 4 šú
13	NBK 7 V 12 šú	32	
14	NBK 7 VIII 15 igi	NBK 33 II 6 šú	
15	8	NBK 33 V 9 igi	
16	NBK 9 VI 9 šú	34	
17	NBK 9 XII 17 igi		
18	10		
19	NBK 11 VIII 12 šú		
20	NBK 12 II 1 igi		
21	NBK 13 XI 12 šú		
22	NBK 14 III 21 igi		
23	15		
24	NBK 16 I 1 šú		
25	NBK 16 IV 12 igi		
26	17		
27	NBK 18 II 4 šú		
28	NBK 18 V 6 igi		
29	19		
30	NBK 20 III 27 šú		
30	NBK 20 VII 4 igi		
31	21		
32			

Figure 2 (cont'd.): For columns (i)–(iii) and possibly column (iv) this could have been remarks on the location of visibility phenomena. By column (v) at the latest, however, data for stations and oppositions would have been included.

The preserved traces of column (ii) concern 2 or 3 years, perhaps years 11–13 Kandalanu, and contain at least one positional report implied by the *ana* in line 3′. This would be consistent with the practice of recording the approximate location of visibility phenomena with less frequent 'nu šeš/pap' remarks, reflected in the compilation of appearances and disappearances of Saturn recorded in BM 76738[5] for the reign of Kandalanu. Most of this information could be incorporated in place of the frequent 'nu šeš/pap's in column (i) without materially increasing the number of lines per year as long as mainly visibility phenomena are reported.

By the end of the text, however, the information recorded has changed dramatically in substance, precision, and—as we shall see—accuracy. Here we find both dates and positions recorded for each of the five characteristic synodic phenomena: disappearance,[6] šú(Ω); first appearance, igi(Γ); first station, uš(Φ); opposition, e(Θ); and second station, 2-uš(Ψ). The dates often omit the months—evidently the intervals between successive synodic phenomena were well enough known by this time that the omission was not thought important—while positions, often in two coordinates, are recorded in cubits relative to stars which appear consistent with Normal Stars preserved in later texts. These are accompanied by occasional comments suggesting greater or less reliability and precision, as well as an observation of when the planet resumed perceptible direct motion after its second station (Ψ). Thus by its end, the text reflects systematic and precise observations of virtually all planetary phenomena recorded in the later Diaries,[7] including detail—e.g., the precise locations of šú and igi and the dates of perceptible resumption of direct motion—which at some later date ceased to be part of the regular observational regimen.[8]

Figure 2 shows the possible approximate beginning of each

[5] [Walker 1999, 61ff.]

[6] 'Last visibility' in ACT, but shown for Venus by [Huber 1982] to be the day following last visibility.

[7] The most conspicuous omission is the absence of data for the time interval between planet-rise and sunrise (*nasu*) at first appearance found in later Diaries and observation texts.

[8] It is also not impossible that the apparent reference to 'me' (day) between šú and igi in year 37 is part of some comment about conjunction.

column together with the dates of šú and igi, arranged to show how the text might have appeared if one line were accorded each of these phenomena as at the beginning of column (i). The blank space at the bottom of each column suggests the expansion of information recorded, although probably understating this process in column (ii), where additional information would have replaced the 'nu šeš's and 'nu pap's in column (i). As shown here the pattern is consistent with a sharp increase in informational density around −580, although the increase could have occurred more gradually. Obviously this is only a schematic rendering of a process whose precise details remain obscure, but which appears to have taken place early in the sixth century.

Accuracy

Occurrences: Figure 3a compares the dates and negative solar altitudes at planet-rise/set ($h*$) for šú(Ω) and igi(Γ) recorded in column (i) with those calculated from modern theory[9] using Schoch's *arcus visionis* values[10] as visibility criteria. Dates in the text accompanied by 'nu šeš/nu pap' are underlined. These are significantly less accurate than the last three dates, lending support to the assumption that they were calculated in some fashion. On balance they are systematically late, especially the igi(Γ)'s, and reflect a collective scatter (standard deviation) in $h*$ of $\pm 6°$. In contrast, the last three dates, unqualified by 'nu šeš/nu pap' and presumably observed, reflect an average $h*$ that is slightly higher (by 1.3°) than assumed in the calculations, but with a much lower scatter of only $\pm 1.3°$.

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9 The calculations employ the program PLANETS.EXE by Peter Huber to calculate the daily positions of the planet and sun and the altitude of the sun at planet-rise and set for the years in question, whence calculated dates for visibility phenomena are derived from assumed visibility criteria. Sidereal longitudes, denoted by $\lambda*$, are calculated from tropical longitudes to be consistent with the mean Babylonian sidereal zodiac (of later date) by the formula $\lambda* = \lambda_{trop} + 9.91° - (Y + 500) \times 1.3825°/100$, where Y is the Julian year in astronomical notation.

10 [Schoch 1928, 103]. For Mars these are 13.2° at šú(Ω) and 14.5° at igi(Γ).

Mars

				Calculated				
	King(JYr)	Yr	Phen	JD	M	D	$h*$	$\lambda*$
1	SSU	0	šú(Ω)	1477538	I	25	13.0	40.6
2	(−667)	0	igi(Γ)	1477639	V	7	14.7	107.0
3	(−665)	2	šú(Ω)	1478309	II	28	13.1	80.1
4	(−665)	2	igi(Γ)	1478399	V	30	14.5	137.8
5	(−663)	4	šú(Ω)	1479071	III	22	13.0	112.2
6	(−663)	4	igi(Γ)	1479165	VI	28	14.7	173.4
7	(−661)	6	šú(Ω)	1479829	V	12	13.0	141.7
8	(−661)	6	igi(Γ)	1479938	IX	3	14.6	216.3
9	(−659)	8	šú(Ω)	1480589	VI	4	13.1	173.8
10	(−658)	8	igi(Γ)	1480750	XI	18	14.6	293.6
11	(−657)	10	šú(Ω)	1481365	VII	13	13.2	219.8
12	SSU	11	igi(Γ)	1481585	II	26	14.5	28.3
13					η-cnc			100.6
14					θ-cnc			100.9
15	SSU	9	(−658)	1481002	VII	4		101.5
16					γ-cnc			102.8
17					δ-cnc			103.9

Figure 3a: HSM 1490: Comparisons of calculated and recorded data for Mars from column (i), obverse. Underlinings indicate record accompanied by 'not observed' ('nu šeš/nu pap'). According to Huber's Cresdat algorithm, month VI in SSU 10 should have been 31 days long, here treated as 30 days long.

				Calculated				
	King(JYr)	Yr	Phen	JD	M	D	$h*$	$\lambda*$
1	NBK	35	šú(Ω)	1513395	III	2	13.0	101.7
2	(−569)	35	igi(Γ)	1513486	VI	4	14.5	160.4
3	(−568)	36	uš(Φ)	1513821	V	15		8.1
4	(−568)	36	e(Θ)	1513856	VI	20		0.2
5	(−568)	36	uš(Ψ)	1513889	VII	24		353.8
6	(−567)	37	šú(Ω)	1514153	III	22	13.2	131.1
7	(−567)	37	igi(Γ)	1514256	VII	7	14.6	200.0
8	(−566)	38	uš(Φ)	1514597	VI	23		59.9
9	(−566)	38	e(Θ)	1514636	VIII	3		50.2
10	(−566)	38	uš(Ψ)	1514673	IX	10		41.8
11	NBK	39	šú(Ω)	1514912	V	13	13.1	161.9

Figure 3b: HSM 1490: Comparisons of calculated and recorded dates for synodic phenomena of Mars from column (vi), reverse.

Mars

Text				Differences (Text−Calc)		
JD	M	D	$h*$	δD	$\delta h*$	
	[I ff]	na				1
	na	na				2
1478301	II	20	15.5	−8	2.4	3
1478429	VI	30	24.9	30	10.4	4
1479076	III	27	11.6	5	−1.4	5
1479192	VII	25	23.5	27	8.8	6
1479861	VI	15	6.1	32	−7.0	7
1479960	IX	25	20.4	22	5.8	8
1480575	V	20	15.9	−14	2.7	9
1480772	XII	10	15.8	22	1.3	10
1481365	VII	13	13.2	0	0.0	11
1481585	column	(ii)				12
	igi šá alla šá si					13
	igi šá alla šá ulú					14
1481002	VII	4	'middle of the Crab'			15
	ár šá alla šá si					16
	ár šá alla šá ulú					17

Figure 3a (cont'd.): Visibility criteria used in calculations are from [Schoch 1928]: 14.5 for igi(Γ); 13.2 for šú(Ω). $\lambda*$ = sidereal longitude calculated from $\lambda_{trop} + \delta\lambda$, where $\delta\lambda = 9.91 - 1.3825 \times (Y + 500)/100$, where Y is the Julian year in astronomical notation. $h*$ = negative altitude of sun at moment when planet sets.

Text				Differences (Text−Calc)		
JD	M	D	$h*$	δD	$\delta h*$	
1513393	II/III	0±	13.6	∼ −2	∼ 0.6	1
1513483	VI	1	13.4	−3	−1.1	2
1513818	V	12		−3		3
1513859	VI	23		3		4
1513887	VII	22		−2		5
1514153	III	22	13.2	0	0.0	6
1514253	[VII]	4	13.5	−3	−1.1	7
1514596	VI	22		−1		8
1514637	VIII	4		1		9
1514680	[IX]	x+1				10
	[V]					11

Figure 3b (cont'd.): $h*$ and $\lambda*$ are calculated as in Figure 3a.

Saturn

	King(JYr)	Yr	Phen	Calculated $h* \geq 12.0$ JD	M	D	$h*$	$\lambda*$
1	KAN	1	igi(Γ)*	1485303	IV	23	11.9	102.92
2	(−645)	2	igi(Γ)*	1485681	V	17	12.0	116.43
3	(−644)	3	igi(Γ)*	1486059	V	11	12.1	129.63
4	(−643)	4	igi(Γ)*	1486437	VI	5	12.2	142.52
5	(−642)	5	igi(Γ)*	1486815	VI	29	12.4	155.07
6	(−641)	6	igi(Γ)*	1487192	VI	22	12.1	167.21
7	(−640)	7	igi(Γ)*	1487569	VII	15	12.0	179.10
8	(−639)	8	igi(Γ)*	1487946	VII	8	12.2	190.75
9	(−638)	9	igi(Γ)*	1488322	VII	30	11.7	202.10
10	(−637)	10	igi(Γ)*	1488699	VIII	23	12.3	213.43
11	(−636)	11	igi(Γ)*	1489075	VIII	15	12.0	224.57
12	(−635)	12	igi(Γ)*	1489451	IX	7	11.8	235.67
13	(−634)	13	igi(Γ)	1489828	IX	30	12.2	246.89
14	KAN	14	igi(Γ)	1490205	IX	23	12.4	258.16

	King(JYr)	Yr	Phen	Calculated $h* \geq 12.0$ JD	M	D	$h*$	$\lambda*$
15	KAN	1	šú(Ω)	1485269	III	19	11.0	98.52
16	(−645)	2	šú(Ω)	1485648	IV	14	10.9	112.20
17	(−644)	3	šú(Ω)	1486026	IV	8	11.1	125.46
18	(−643)	4	šú(Ω)	1486404	V	2	11.1	138.40
19	(−642)	5	šú(Ω)	1486782	V	25	11.0	151.01
20	(−641)	6	šú(Ω)	1487159	V	19	11.2	163.20
21	(−640)	7	šú(Ω)*	1487536	VI	12	11.3	175.13
22	(−639)	8	šú(Ω)	1487913	VI_2	5	11.3	186.81
23	(−638)	9	šú(Ω)*	1488290	VI	28	11.3	198.31
24	(−637)	10	šú(Ω)	1488667	VII	21	11.1	209.65
25	(−636)	11	šú(Ω)	1489043	VII	13	11.5	220.80
26	(−635)	12	šú(Ω)	1489420	VIII	6	11.3	232.02
27	(−634)	13	šú(Ω)	1489797	VIII	28	11.1	243.22
28	KAN	14	šú(Ω)	1490174	VIII	21	10.9	254.49

Figure 4: Comparison of reported and calculated dates for first appearance, igi(Γ), and disappearance, šú(Ω), of Saturn from BM 76738+. Calculated dates use *arcus visionis* values of 12.0 degrees (igi) and 11.5 degrees (šú); corresponding values from [Schoch 1928] are 13.0 and 10.0 respectively.

Saturn

Text				Differences (Text−Calc)		
JD	M	D	$h*$	δD	$\delta h*$	
1485304	IV	24	12.6	1	0.7	1
	V					2
1486059	V	16				3
	VI					4
	VI	end		~0	0.0	5
1487192	VI	22	12.1	0	0.0	6
1487569	VII	15	12.0	0	0.0	7
1487943	VII	5	9.5	−3	−2.6	8
1488323	VIII	x1	12.6	1	0.9	9
1488699	VIII	23	12.3	0	0.0	10
1489075	VIII	15	12.0	0	0.0	11
1489449	IX	5	10.0	−2	−1.7	12
1489829	X	1	13.1	1	0.8	13
	IX	2x				14
	avg		11.8	−0.2	−0.2	
	std		1.2	1.4	1.1	

Text				Differences (Text−Calc)		
JD	M	D	$h*$	δD	$\delta h*$	
	III					15
	IV					16
1486024	IV	7	11.7	−1	0.6	17
	IV	end		~ −3		18
1486780	V	23	12.0	−2	1.0	19
1487160	V	20	10.7	1	−0.5	20
	VI	1x				21
1487913	VI_2	5	11.3	0	0.0	22
1488290	VI	28?	11.3	0	0.0	23
1488666	VII	20	11.6	−1	0.5	24
1489043	VII	13	11.5	0	0.0	25
1489419	VIII	5	11.8	−1	0.5	26
1489795	VIII	26	12.2	−2	1.1	27
1490173	VIII	20	11.5	−1	0.6	28
	avg		11.6	−0.7	0.4	
	std		0.4	0.9	0.5	

Figure 4 (cont'd.): Phenomena designated with * include reported positions; those underlined are described as not observed. $h*$ = negative altitude of sun at planetset; $\lambda*$ = sidereal longitude, calculated as described in Figure 3a.

It is tempting to assume that the month name 'kin' for šú(Ω) in year 6 is a gross error, but the deviation in $h*$ of (−)7.1° is less than those for igi(Γ) in years 2 and 4. Conversely, the deviation of 22 days in date for igi(Γ) in year 8, seemingly simply in keeping with the error evidenced by the three preceding igi(Γ)'s, reflects only a modest deviation in $h*$ (1.3°), which is not inconsistent with an actual observation.

In short, the apparently computed dates of visibility phenomena comprising the first 6 preserved entries in column (i) reflect distinctively large deviations from assumed visibility criteria leading to errors of a month or more in the dates of visibilities. In contrast, the last three entries, beginning in −659, reflect smaller deviations in $h*$ consistent with fairly careful actual observations. Similar care is reflected in the one positional remark in column (i), which placed Mars 'in the middle of the Crab' on VII 4 of SSU 9. On the evening of that date Mars was indeed located midway between η-cnc/θ-cnc and γ-cnc/δ-cnc, the reference stars (later) associated with Cancer, with a tropical longitude of 89.4°, curiously close to the solstitial point.

By the end of the text, a century later, the accuracy of observation has clearly improved as may be seen from Figure 3b which shows the same data, but for column (vi). Here the text's dates are a day early on average, with a scatter or (2 days and maximal differences from calculation which do not exceed 3 days, including the hard-to-observe dates of stations and oppositions. For the small number of visibility phenomena deviations of $h*$ average −0.4° with a scatter of ±0.8°, again reflecting improvement over the earlier period.

It is instructive to compare the accuracy of these records with that of the dates of visibility phenomena for Saturn preserved for years 1–14 of Kandalanu in BM 76738+. These are shown in Figure 4, separated by phenomenon. Here neither phenomenon exhibits a sensible systematic error,[11] while the scatter in $h*$ is ±1.1° for igi and half as much for šú. Evidently, for visibility phenomena at least, a level of observational accuracy consistent with that reflected in the records at the end of our text (ca −570)

[11] The calculation utilizes *arcus visionis* values, which best fit these observations ($h*$[igi] = 12.0°, $h*$[šú] = 11.5°) and differ slightly from those of [Schoch 1928] ($h*$[igi] = 13.0°, $h*$[šú] = 10.0°).

was achieved by the reign of Kandalanu (−646 ff).

Measurements: Column (i) contains only one statement of position which locates Mars, accurately but imprecisely 'in the middle of the Crab'. A century later, column (vi) preserves four measurements of position—two of longitude and two of latitude, supplemented by an imprecise (before/behind:above/below) directional remark. All measurements are in cubits, relative to reference stars which seem to be identical with those found in the Diaries and later observation texts.[12] Longitudinal measurements are preserved for first station and disappearance—uš(Φ) and šú(Ω)—but omitted for opposition, e(Θ), whose position is only described by 'under' in line 6 and 'behind' in line 13. No positional data is preserved for first appearance, igi(Γ), but in light of the greater attention paid in earlier Saturn observations to the location of igi(Γ) compared to šú(Ω), it seems likely that longitudinal measurements were often included for it as well. Latitude measurements are preserved for both stations—uš(Φ) and uš(Ψ)—together with a longitude interval in the case of uš(Φ). Thus it seems that measurements of both coordinates were frequently, but not systematically, recorded for the four unambiguous synodic phenomena [igi(Γ), uš(Φ), uš(Ψ), and šú(Ω)], while for opposition, e(Θ), only the date and approximate position were recorded.[13]

Figure 5 compares computed and reported positions for synodic phenomena recorded in column (vi) of HSM 1490. With one exception the interval measurements appear to be accurate within approximately a cubit with no sensible average error. The exception could easily be a scribal error in recording the latitude for uš(Φ) in year 36, as '$2\frac{1}{2}$ cubits [below] β-ari' instead of $5\frac{1}{2}$ cubits.

Finally, the text remarks on the date, following second station, when the planet [was perceived to have] resumed direct motion, approximately a week after the planet became stationary. The date is consistent with a direct motion from Mars's stationary position of a quarter of a degree, which is a reasonable magnitude for the smallest positional difference which could be distinguished.

[12] No star names are preserved, but the agreement with modern calculation is too good to be otherwise.

[13] Cf. Diary −567 [Sachs & Hunger 1988–96], which records an opposition of Jupiter on I 11 or 12 with no positional remark.

				Text			Mars (calc)	
	King	Yr	Phen	JD	M	D	λ*	β
1	NBK	35	šú(Ω)	1513390	II/III	0±	100.47	1.12
2	NBK	35	igi(Γ)	1513483	VI	1	158.16	1.12
3	NBK	36	uš(Φ)	1513818	V	12	8.08	−4.61
4	NBK	36	e(Θ)	1513859	[VI]	23	359.51	−3.73
5	NBK	36	uš(Ψ)	1513887	[VII]	22	353.81	−1.90
6	NBK	37	šú(Ω)	1514153	III	22	131.15	1.18
7	NBK	37	igi(Γ)	1514253	VII	4	197.67	0.60
8	NBK	38	uš(Φ)	1514596	VI	22	59.92	−0.80
9	NBK	38	e(Θ)	1514637	[VIII]	4	50.13	0.90
10	NBK	38	uš(Ψ)	1514680	[IX]	~12	41.84	1.94
11	NBK	39	šú(Ω)		na			
12	NBK	36	2uš(Ψ)	1513887	[VII]	22	353.80	Text
13				1513889	[VII]	24	353.76	Calc
14				1513895	[VII]	30	353.99	Direct
15							0.23	Direct− Calc

Figure 5: Comparison of calculated and reported positions for Mars from HSM 1490, column (vi). λ* = sidereal longitudes calculated as described in Figure 3a.

Reference Star			Planet–Star (cubits)				Error (cubits)		
			Calc		Text		(Text–Calc)		
Star	$\lambda*$	β	$\delta\lambda*$	$\delta\beta$	$\delta\lambda*$	$\delta\beta$	$\delta\lambda*$	$\delta\beta$	
[θ-cnc]	100.94	−1.00	−0.2	0.9					1
[γ-vir]	165.67	3.00	−3.1	−0.8					2
β-ari	9.16	8.40	−0.4	−5.4	−0.5	−2.5	−0.1	**2.9**	3
η-psc	2.01	5.24	−1.0	−3.7		under		under	4
η-psc	2.01	5.24	−3.4	−3.0		−4.0		−1.0	5
ρ-leo	131.58	0.01	−0.2	0.5	0.5		0.7		6
[α-lib]	200.29	0.66	−1.1	0.0					7
ζ-tau	59.97	−2.52	0.0	0.7		above		above	8
[α-tau]	44.94	−5.65	2.2	2.7		behind		behind	9
[α-tau]	44.94	−5.65	−1.3	3.2		before		before	10
									11
			1 c. = 2.4 degrees						
									12
									13
									14
									15

Transformations to cubits assume 1 cubit = 2.40 degrees [Grasshoff 1999, 138]. Apparent scribal error is highlighted in bold.

Conclusion

Apart from the Venus Tablet of Amizaduga, the text contains the earliest observations of planetary phenomena, systematically compiled, that we possess. It is a pity that more of it is not preserved, for the complete text would provide an invaluable overview of the emergence and development of observational practice in the seventh and sixth centuries (B.C.). Nevertheless, several features bear comment. First, it is clear that the text represents a systematic compilation of observations of Mars's synodic phenomena, with only occasional interjections of other positional reports. At the outset and still by the end of the first column (−656) only appearances (igi) and disappearances (šú) are recorded, and before −658 even these are reported to have been 'not observed', It seems likely, however, that at least some actual observations were recorded in the missing beginning of column (i), and that these would have comprised the earliest ones available to the text's author. Thus it would seem that at least occasional observations of Mars's appearances and disappearance began to be recorded around the beginning of Esarhaddon's reign in −679.

Only 10 years after the end of column (i) observations of appearances and (some) disappearances of Saturn record the approximate location of the planet at the time of the event, information which is missing in column (i) of this text, but which could have been included in column (ii) without much disturbance, replacing the ubiquitous 'nu šeš/pap's of column (i). Thus it would appear that regular observations of the dates of appearances and disappearances began during the reign of Šamaš-suma-ukin, a practice expanded by the reign of Kandalanu to include the approximate location of the planet at the time of first appearance and, occasionally, disappearance.

During the subsequent lacuna of roughly 60 years (−633 to −569) systematic observations of the stations and oppositions were introduced,[14] and positions of the distinctive synodic phenomena (i.e. excepting oppositions) began to be recorded as measured intervals from Normal (reference) Stars in two coordinates. These innovations were accompanied by an increase in the accu-

[14] But note that the Diary for −651 records a station of Mars.

racy of the dates of recorded phenomena, which by the end of the text reflected average errors of roughly 1 day and maximal errors of less than 3 days. Positional measurements, recorded with a precision of half a cubit, seem to have had a generally accuracy (scribal errors excepted) consistent with that precision, suggesting an ongoing program of careful, systematic observations.

In short, by the end of the reign of Nebuchadnezzar, regular planetary observations included nearly all of the elements reflected in the later Diaries and observation texts, including a record of the interval between planet-rise/set and sunrise/set near first appearance (line 11). In addition, the text records the date after second station when the planet is seen to resume direct motion, which drops out of later observational practice and which demonstrates that motion of $\frac{1}{4}^{\circ}$ was perceptible to sixth-century observers.

Abbreviations

ACT	[Neugebauer 1955]
ASR	Esarhaddon
KAN	Kandalanu
NBK	Nebuchadnezzar
NBL	Nabopolassar
SA2	Sennacherib
SSU	Šamaš-šuma-ukin

Bibliography

G. Grasshoff, 'Normal Star Observations in Late Babylonian Astronomical Diaries', in *Ancient Astronomy and Celestial Divination*, ed. N. M. Swerdlow, Cambridge MA, 1999, pp. 97–147.

P. J. Huber, *Astronomical Dating of Babylon I and Ur III* (*Occasional Papers on the Near East*, vol. 1, no. 4), Malibu CA, 1982.

O. Neugebauer, *Astronomical Cuneiform Texts*, 3 vols, London, 1955.

A. J. Sachs & H. Hunger, *Astronomical Diaries and Related Texts from Babylon*, 3 vols, Vienna, 1988–96.

C. Schoch, 'Astronomical and Calendarical Tables', in S. Langdon, J. Fotheringham, and C. Schoch, *The Venus Tablets of Ammizaduga*, London, 1928, pp. 94–109.

C. B. F. Walker, 'Babylonian Observations of Saturn during the Reign of Kandalanu', in *Ancient Astronomy and Celestial Divination*, ed. N. M. Swerdlow, Cambridge MA, 1999, pp. 61–76.

Plate 1: HSM 1899.2.112 (+HSM 1490) Obverse (courtesy Harvard University)

Plate 2: HSM 1899.2.112 (+HSM 1490) Reverse (courtesy Harvard University)