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Studies in Babylonian lunar theory: part III. The introduction of the uniform zodiac

John P. Britton

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Abstract This paper is the third of a multi-part examination of the Babylonian mathematical lunar theories known as Systems A and B. Part I (Britton, AHES 61:83–145, 2007) addressed the development of the empirical elements needed to separate the effects of lunar and solar anomaly on the intervals between syzygies, accomplished in the construction of the System A lunar theory early in the fourth century B.C. Part II (Britton, AHES 63:357–431, 2009) examines the accomplishment of this separation by the construction of a successful theory depicting the variations due to lunar anomaly in System A and its subsequent adaptation in System B. The present paper examines the introduction of the uniform zodiac, necessary for any theory depicting variations depending on the position of syzygy. It addresses three questions: (1) In light of all available evidence, what is the magnitude of the constant term in the expression $\Delta\lambda^* = C - 1.3828°Y$, describing the difference between the Babylonian sidereal longitudes and modern tropical longitudes? (2) What considerations governed the placement of the Babylonian sidereal zodiac relative to the fixed stars? (3) When

Communicated by Alexander Jones.

John P. Britton—deceased.

This paper with Parts I, II and their sequels are dedicated to the memory of Asger Aaboe, who securely laid the foundations of a deeper understanding of Babylonian lunar theory and introduced me to these studies. Much of the relevant research was conducted while I was a Senior Fellow at the Dibner Institute, and I am indebted to both the Dibner Institute and Dibner Fund for their generous support. I should also like to thank Alexander Jones and John Steele for their careful reading and helpful comments and suggestions. Naturally, all remaining errors are my own.

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was the uniform zodiac introduced? To the first question it finds $C = 3.20° \pm 0.1°$, scarcely different from Huber's (Centaurus 5:192–208, 1958) estimate of 3.08°, essentially confirming Huber's result obtained from much less data. For the second it shows that accommodating the three asterisms comprising Taurus limited the placement of the zodiac to within 3°, while the prominence of half sign multiples among the measured intervals between prominent Normal Stars led irresistibly to the choice adopted. Finally, it finds that the zodiac was introduced between −408 and −397 and probably within a very few years of −400.

Abbreviations

ADART I–III	A.J. Sachs and H. Hunger, *Astronomical Diaries* and *Related Texts from Babylonia*, Vol. I (–651 to –261), 1988; Vol. II (–260 to –164), 1989: Vol. III (–163 to end), 1995 (Vienna, Verlag d. Österreich. Akad. d. Wiss.)
V	H. Hunger, *Astronomical Diaries and Related Texts from Babylonia:Lunar and Planetary Texts,* including materials by A.J.Sachs with an Appendix by J.M. Steele, Vol V, 2001 (Vienna, Verlag d. Österreich. Akad. d. Wiss.)
AfO	*Archiv für Orientforschung*, Verlag Ferdinand Berger & Sönne G.M.B.H.
AHES	*Archive for History of the Exact Sciences*, Springer-Verlag.
Alm.	*Ptolemy's ALMAGEST,* translated and annotated by G.J. Toomer, (New York, Berlin, Heidelberg, Tokyo, 1984), Springer-Verlag.
AOAT	*Alter Orient und Altes Testament*, (Neukirchen-Vluyn), Verlag Butzon & Bercker Kevelaer
D-*nnn*	Diary for Julian year -*nnn* in ADART I–III
H5, *nn*	Text No. *nn* in ADART V
HAMA	O. Neugebauer, *A History of Ancient Mathematical Astronomy*, (New York, Heidelberg, Berlin, 1975), Springer-Verlag.
HdM:	P.J. Huber and S. de Meis, *Babylonian Eclipse Observations from 750 BC to 1 BC,* (2004), IsIAO–Mimesis
JCS	*Journal of Cuneiform Studies* (New Haven, Cambridge MA, Philadelphia, Ann Arbor)
JHA	*Journal for the History of Astronomy*, Science History Publications, UK
RSW	Roughton, Steele and Walker (2004)
SH1	ADART I
UOS	*Under One Sky: Astronomy and Mathematics in the Ancient Near East*, J.M. Steele–A. Imhausen, eds., Papers delivered at a Symposium held at the British Museum 25–27 June, 2001, *AOAT* 297 (Münster, 2002) Ugarit-Verlag

1 Introduction

The introduction of a uniform scale for measuring the positions of the moon and planets in their journeys around the sky was indispensable for depicting variations of phenomena due to their positions and consequently for the development of mathematical astronomy. This scale was, of course, the uniform "zodiac" comprised of 12 LU.MAŠ, abstract "constellations" of conceptually equal length, subdivided into 30 UŠ and their sexagesimal fractions, and named for the principal constellations through which they ran. Centered on the middle of the path in which eclipses occurred, hence "ecliptic", the zodiac was modeled on the schematic calendar of 12 ideal 30-"day" "months", which dominated astronomical practice from Old Babylonian times to the eighth century.

It also paralleled a time-keeping convention of equal antiquity, in which a day comprised 12 DANNA, a unit of time written as KASKAL.GID$_2$ which literally meant "long journey", thence "stage" in a day's march, a large unit of distance, comprised of 30 UŠ[1] and equal to about 10 km. 1 DANNA—equivalent to 2 of our hours—was therefore a unit of time corresponding to[2] a distance of 30 UŠ $\cong$ 10 km, whereby a day came also to comprise 360 UŠ. The new scale thus had dual antecedents, deeply rooted in ancient traditions, which assumed that a circuit—whatever its nature—contained 360 units.

The fixed sidereal nature of the Babylonian zodiac was demonstrated half a century ago by Peter Huber in an elegant paper entitled "On the zero-point of the Babylonian Ecliptic" (Huber 1958). In it, Huber deduced the Babylonian longitudes of eight Normal Stars (NSs) from sign entries and NS passages reported in pairs of Almanacs and NS Almanacs for the same years[3] around -100. Three of these overlapped and agreed with six longitudes preserved in a fragment of a pre-Seleucid star catalog (BM 46083) previously published by Sachs (1952), thereby demonstrating that the Babylonian zodiac had remained unchanged over the intervening centuries. Combining the two sets of data, Huber concluded that for -100, the mean difference between Babylonian sidereal and modern tropical longitudes was

$$\Delta\lambda^*_{\mathrm{H}}(-100) = 4;28^\circ \pm 0;20^\circ,$$

equivalent to

$$\Delta\lambda^*_{\mathrm{H}}(\mathrm{Y}) = 3.08^\circ - 1.3828^\circ\mathrm{Y} \pm 0.33^\circ, \tag{1}$$

where Y measures Julian centuries from year 0. For -500 expression (1) results in the conveniently nice number,

$$\Delta\lambda^*_{\mathrm{H}}(-500) = 10.00^\circ,$$

which I shall use as Huber's result in the discussion to follow.

Recent papers by Kollerstrom (2001), Jones (2004), and Steele and Gray (2007) have confirmed the fixed sidereal nature of the Babylonian zodiac, and Huber's estimate of $\Delta\lambda^*$ has been widely accepted, although both Kollerstrom (2001) and

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1 The sign should probably to be read GEŠ$_\mathrm{x}$ meaning simply "sixty" since 1 UŠ=60 NINDA $\cong$ 360 m.

2 i.e., the amount of time necessary to cover the distance (at a brisk pace). Interestingly, 5 km/h is described in some French military manuals as a standard marching pace.

3 S.E. 189 and 201 ($-122/1$ and $-110/9$).

Steele and Gray (2007) present evidence of at least modestly different values.[4] Furthermore, Roughton et al. (2004) have recently published BM 36609, containing a new pre-Seleucid NS catalogue with additional attested longitudes, accompanied by a new edition of BM 46083 which changes two of the longitudes used by Huber. Since expression (1), or its equivalent, is needed to compare meaningfully Babylonian longitudes with modern tropical longitudes, an appraisal of the expanded evidence bearing on the likely magnitude of $\Delta\lambda^*$'s constant term seems desirable.

This paper addresses three questions. First, what correction, if any, should be applied to Huber's estimate of $\Delta\lambda^*_{\mathrm{H}}$ in light of all available evidence? Next, what considerations are likely to have governed how the uniform zodiac was placed relative to the stars? Finally, when was the uniform zodiac introduced?

2 Magnitude of $\Delta\lambda^*$

Evidence of the magnitude of $\Delta\lambda^*$ comes from two types of sources with different issues and degrees of reliability:

A. Normal Star (NS) longitudes attested or inferred from various sources
B. Planetary sign-entry dates reported in Almanacs and Diaries

In examining each, I have assumed that the Babylonian zodiac was sidereally fixed, as demonstrated initially by Huber and placed beyond doubt by the above-mentioned authors. Consequently, $\Delta\lambda^*$ varies with precession over time, reducing the investigation to determining the magnitude of the potential correction to the constant term ($\delta\Delta\lambda^*$) in expression (1). For convenience and to reflect circumstances predating the zodiac's introduction I have precessed all computed longitudes to their equivalents at -500.0, at which date $\Delta\lambda^*_{\mathrm{H}} = 10.00°$.

2.1 NS longitudes

The standard list of Normal Stars described in Sachs–Hunger (ADART 1, pp. 17–19) numbers 32, in addition to which Jones (2004) discusses another 9 occasional reference stars for a total of 41. However, Jones also demonstrates a marked difference between the frequencies with which 28 "core" stars appear in reports of planetary passages and those of the infrequently referenced 13 "additional stars". The latter group includes five dispersed asterisms comprising multiple stars for which longitudes are cited in BM 36609, but whose locations are diffuse and identifications uncertain. These are excluded from the following analysis, which consequently addresses only the 28 "core" stars identified by Jones (2004) described in Table 1.

[4] Kollerstrom (2001) finds the equivalent of $\Delta\lambda^*_{\mathrm{K}} = 3.93° - 1.35°Y \cong \Delta\lambda^*_{\mathrm{H}}(0) + 0.85°$ from an analysis of 5 Babylonian and 21 Hellenistic horoscopes ranging in date from -234 to $+497$. Huber's result is included with the Babylonian data, but only as a single data point, equally weighted with others having up to 10 times the probable error. There are also unexamined issues with the Hellenistic data, so this result must be regarded as tenuous. Steele and Gray (2007) analyze 338 sign entry dates recorded in Almanacs and Diaries with results that suggest a composite $\Delta\lambda^*_{\mathrm{SG}} = 3.22° - 1.23°Y \cong \Delta\lambda^*_{\mathrm{H}}(0) + 0.14°$. Having established that $\Delta\lambda^*$ varies approximately with precession, however, they do not reanalyze their data with a correct value for precession, and recommend adopting Huber's result for $\Delta\lambda^*$.

Table 1 "Core" Normal Stars following Jones (2004)

Core #	"Core" 28 Normal Stars (Jones 2004)		Modern (−500): $\Delta\lambda^*_H$=10.00			
	Standard description	Translation	Star	Mag	λ^*	β
1	múl kur *šá* dur *nu-nu*	Bright star of the Ribbon of the Fish	η-Psc	3.6	2.10	5.24
2	múl igi *šá* sag hun	Front star of the head of the Hired Man	β-Ari	2.6	9.28	8.31
3	múl *ár šá* sag hun	Rear star of the head of the Hired Man	α-Ari	2.0	12.98	9.77
4	múl múl	Stars	η Tau	2.8	35.29	3.77
5	*is le*$_{(9)10}$	Jaw of the Bull	α-Tau	1.0	45.03	−5.64
6	šur gigir *šá* si	Northern rein of the Chariot	β-Tau	1.7	57.85	5.18
7	šur gigir *šá* ulù	Southern rein of the Chariot	ζ-Tau	3.0	60.06	−2.52
8	múl igi *šá še-pit* maš-maš	Front star of the Twins' feet	η-Gem	3.4	68.71	−1.22
9	múl ár *šá še-pit* maš-maš	Rear star of the Twins' feet	μ-Gem	2.9	70.58	−1.15
10	maš-maš *šá* sipa	Twins of the Shepherd	γ-Gem	2.0	74.39	−7.02
11	maš-maš igi	Front Twin	α-Gem	1.9	85.63	9.91
12	maš-maš *ár*	Rear Twin	β-Gem	1.2	88.90	6.49
13	múl *ár šá* alla *šá* ulù	Southern rear star of the Crab	δ-Cnc	3.9	103.97	−0.03
14	sag a	Head of the Lion	ε-Leo	3.0	115.97	9.52
15	lugal	King	α-Leo	1.4	125.27	0.36
16	múl tur *šá* 4 kùš *ár* lugal	Small star 4 cubits behind the King	ρ-Leo	3.8	131.67	0.02
17	giš-kun a	Rump of the Lion	θ-Leo	3.3	138.66	9.64
18	gìr *ár šá* a	Rear foot of the Lion	β-Vir	3.6	151.89	0.64
19	dele *šá* igi absin	Single (star) in front of the Furrow	γ-Vir	2.9	165.76	2.96
20	sa$_4$ *šá* absin	Bright (star) of the Furrow	α-Vir	1.0	179.15	−1.89
21	rin *šá* ulù	Southern part of the Scales	α-Lib	2.7	200.41	0.63
22	rin *šá* si	Northern part of the Scales	β-Lib	2.6	204.61	8.74
23	múl e *šá* sag gír-tab	Upper star in the head of the Scorpion	β-Sco	2.6	218.46	1.30
24	si$_4$	Lisi	α-Sco	1.1	225.05	−4.25
25	múl kur *šá* kir$_4$ *šil* pa	Bright star on the tip of PA's arrow	θ-Oph	3.2	236.67	−1.52
26	si máš	Horn of the Goat-fish	β-Cap	3.1	279.30	4.87
27	múl igi *šá* suhur-máš	Front star of the Goat-fish	γ-Cap	3.7	297.05	−2.35
28	múl ár *šá* suhur-máš	Rear star of the Goat-fish	δ-Cap	2.9	298.80	−2.40

Modern coordinates and magnitudes are from SkyMapPro v.8 except for γ-Vir (19),[5] which are from Moesgaard (1976). $\lambda^* = \lambda_{\mathrm{trop}}(-500.0) + 10.00°$

With one exception, each of the core Normal Stars is a distinct star with a more or less precisely known modern longitude. The exception is (4), the Stars (Pleiades to us), which famously comprise seven sisters plus Atlas and Pleione, spread over nearly a degree of longitude. Conventionally, and in Table 1, the asterism is identified with η-Tau (Alcyone), the brightest and centermost of its members. However, this identification is quite arbitrary and introduces a longitudinal uncertainty of more than half a degree[6] into any analysis which includes it.

Table 2 shows the longitudes for which there is some Babylonian evidence, accompanied by indications of source (7) and individual corrections ($\delta\Delta\lambda^*$) to Huber's $\Delta\lambda^*_H = 10.00°$, both simply as $\delta\Delta\lambda^* = \lambda^*_{\mathrm{bab}} - \lambda^*_{\mathrm{mod}}$ (8) and as adjusted (10) for major alignment errors (9) as estimated by Jones (2004, p. 501) at mean latitude of

5 For reasons which remain obscure SMP coordinates for γ-Vir are sensibly different from those from other sources.

6 Arguably as plausible would be associating the Pleiades with its leading member, 17-Tau, 0.58° to the west of η-Tau.

Table 2 Attested Babylonian longitudes (6) for core Normal Stars from various sources (7)

1	2	3	4	5	6	7	8	9	10
2 #	Modern (−500): $\Delta\lambda^*_{\mathrm{H}} = 10.00$				Babylonian			Align error	Adj $\delta\Delta\lambda^*$
	Star	Mag	λ^*mod	β	λ^*bab	Source	$\delta\Delta\lambda^*$		
1	η-Psc	3.6	2.10	5.24	3.33	rsw	1.23		1.23
2	β-Ari	2.6	9.28	8.31					
3	α-Ari	2.0	12.98	9.77	13	ph+	0.02		0.02
4	**η-Tau**	**2.8**	**35.29**	**3.77**	**33**	**pjh**	**−2.29**	**−1.53**	**−0.76**
5	α-Tau	1.0	45.03	−5.64					
6	β-Tau	1.7	57.85	5.18	57	ph+	−0.85		−0.85
7	ζ-Tau	3.0	60.06	−2.52	60	pjh	−0.06		−0.06
8	η-Gem	3.4	68.71	−1.22					
9	μ-Gem	2.9	70.58	−1.15					
10	γ-Gem	2.0	74.39	−7.02					
11	α-Gem	1.9	85.63	9.91	85	ph+	−0.63	−1.49	0.86
12	β-Gem	1.2	88.90	6.49	90	pjh	1.10		1.10
13	δ-Cnc	3.9	103.97	−0.03					
14	ε-Leo	3.0	115.97	9.52	115	ph+	−0.97		−0.97
15	α-Leo	1.4	125.27	0.36	125	ph+	−0.27		−0.27
16	ρ-Leo	3.8	131.67	0.02					
17	**θ-Leo**	**3.3**	**138.66**	**9.64**	**142**	**ajs***	**3.34**	**3.89**	**−0.55**
18	β-Vir	3.6	151.89	0.64	151	pjh,ajs	−0.89		−0.89
19	γ-Vir	2.9	165.76	2.96	165	ajs*	−0.76		−0.76
20	α-Vir	1.0	179.15	−1.89	178	pjh,ajs	−1.15		−1.15
21	α-Lib	2.7	200.41	0.63	200	ajs	−0.41		−0.41
22	β-Lib	2.6	204.61	8.74	205	pjh,ajs	0.39		0.39
23	β-Sco	2.6	218.46	1.30					
24	α-Sco	1.1	225.05	−4.25					
25	θ-Oph	3.2	236.67	−1.52	237	pjh	0.33		0.33
26	β-Cap	3.1	279.30	4.87	281.5	rsw	2.20	1.03	1.17
27	γ-Cap	3.7	297.05	−2.35	298.5	rsw	1.45		1.45
28	δ-Cap	2.9	298.80	−2.40	300	pjh,rsw	1.20		1.20
	Avg	2.6		2.05			0.16		0.06

Shown in bold are details of extreme $\delta\Delta\lambda^*$ values, which also reflect extreme alignment errors

planetary passages. Consideration of the mean corrections to $\delta\Delta\lambda^*$ and a$\delta\Delta\lambda^*$ for attested longitudes is postponed until after first considering the results for individual sources.

2.1.1 Sources

Normal Star longitudes are attested or inferred from the following sources, some of them overlapping:

(a) "pjh" longitudes, inferred by Huber from Almanac and NS Almanac data and included in his determination of $\Delta\lambda^*_{\mathrm{H}}$;
(b) "ajs" longitudes, attested in BM 46083, originally published by Sachs (1952) as emended ("ajs") in Roughton et al. (2004);
(c) "ph+" longitudes, derived by Huber from Almanac and NS Almanac data, but excluded from his determination of $\Delta\lambda^*_{\mathrm{H}}$ as insufficiently certain;
(d) "rsw" longitudes, attested in BM 36609 published in Roughton et al. (2004);

Each has its own issues and characteristics.

(a) *PJH longitudes.* Huber (1958) used 8 longitudes inferred from Almanac and NS Almanac data in his determination of $\Delta\lambda^*_{\mathrm{H}}$. Notably, they included all three stars, ζ-Tau (7), β-Gem (12), and δ-Cap (28), whose longitudes define sign boundaries. In addition to its positional uncertainty, noted above, the Pleiades (4) appear affected by an error resulting from alignment with ζ-Per ($\lambda^* = 38.4°$, $\beta = 11.0°$), estimated (Jones 2004, p. 501) to equal $-1.53°$ at the mean latitude of planetary passages.

2a	Modern (−500): $\Delta\lambda^*_{\mathrm{H}} = 10.00$				Babylonian			Align error	Adj $\delta\Delta\lambda^*$
#	Star	Mag	λ^* mod	β	λ^*bab	Source	$\delta\Delta\lambda^*$		
4	η-Tau	3.7	35.29	3.91	33	pjh	**−2.29**	**−1.53**	**−0.76**
7	ζ-Tau	3.0	60.06	−2.52	60	pjh	−0.06		−0.06
12	β-Gem	1.2	88.90	6.49	90	pjh	1.10		1.10
18	β-Vir	3.6	151.89	0.64	151	pjh,ajs	−0.89		−0.89
20	α-Vir	1.0	179.15	−1.89	178	pjh,ajs	−1.15		−1.15
22	β-Lib	2.6	204.61	8.74	205	pjh,ajs	0.39		0.39
25	θ-Oph	3.2	236.67	−1.52	237	pjh	0.33		0.33
28	δ-Cap	2.9	298.80	−2.40	300	pjh,rsw	1.20		1.20
	8 avg	2.6	156.92	1.43	157		−0.17		0.02

(b) *AJS longitudes.* BM 46083, initially identified and published by Sachs (1952) and recently republished with corrections in (Roughton et al. 2004, Appendix A), contains longitudes of 6 successive "core" Normal Stars, three of which are also among the PHJ stars. Sachs had only a photograph and a partial copy by Strassmaier to work from, and collation resulted in two emended longitudes: θ-Leo (17) from "20 A" (=140°) to "22" [no sign] (=142°); and γ-Vir (19) from "16" to "15" [ABSIN][7]. Neither was among the longitudes deduced independently by Huber, so his conclusion that longitudes remained unchanged over the intervening centuries is unaffected. With these changes Huber's analysis would have yielded $\Delta\lambda^*(-500) = 10.07°$. The longitude of θ-Leo is affected by a large error arising from alignments with o-Psc ($\lambda^* = 136.5$, $\beta = 14.2$) estimated (Jones 2004, p. 501) to equal $+3.89°$ at mean planetary passage latitude.

2b	Modern (−500): $\Delta\lambda^*_{\mathrm{H}} = 10.00$				Babylonian			Align error	Adj $\delta\Delta\lambda^*$
#	Star	Mag	λ^*mod	β	λ^*bab	Source	$\delta\Delta\lambda^*$		
17	θ-Leo	3.3	138.66	9.64	**<u>142</u>**	ajs*	**3.34**	**3.89**	**−0.55**
18	β-Vir	3.6	151.89	0.64	151	pjh,ajs	−0.89		−0.89
19	γ-Vir	2.9	165.76	2.96	**<u>165</u>**	ajs*	−0.76		−0.76
20	α-Vir	1.0	179.15	−1.89	178	pjh,ajs	−1.15		−1.15
21	α-Lib	2.7	200.41	0.63	200	ajs	−0.41		−0.41
22	β-Lib	2.6	204.61	8.74	205	pjh,ajs	0.39		0.39
	6 avg	2.7	173.41	3.45	174		0.09		−0.56

[7] Both emendations, underlined in the accompanying table, are highly plausible. Mostly (β-Lib in line 5′ may be an exception) the text cites the sign only for the first longitude in that sign, making 20 A unlikely for θ-Leo. Placing γ-Vir at the mid-point of its sign seems consistent with an apparent preference for multiples of 5°.

(c) *PH+ longitudes*. Huber (1958) also computed longitudes for five additional stars but omitted them from his determination of $\Delta\lambda^*_H$, mostly for reasons of too large uncertainties.[8] The group reflects a distinctively large negative correction to $\Delta\lambda^*$, but otherwise is hard to distinguish from those he accepts. I see no good reason to exclude any of its members.

2c	Modern (−500): $\Delta\lambda^*_H = 10.00$				Babylonian			Align error	Adj $\delta\Delta\lambda^*$
#	Star	Mag	λ^*mod	β	λ^*bab	Source	$\delta\Delta\lambda^*$		
3	α-Ari	2.0	12.98	9.77	13	ph+	0.02		0.02
6	β-Tau	1.7	57.85	5.18	57	ph+	−0.85		−0.85
11	α-Gem	1.9	85.63	9.91	85	ph+	**−0.63**	**−1.49**	**0.86**
14	ϵ-Leo	3.0	115.97	9.52	115	ph+	−0.97		−0.97
15	α-Leo	1.4	125.27	0.36	125	ph+	−0.27		−0.27
	5 avg	2.0	79.54	6.95	79		−0.54		−0.20

(d) *RSW longitudes*. BM 36609, identified by Roughton, and recently published in RSW (2004) confirms the longitude of δ-Cap (28) in "pjh" (a) and adds longitudes of 8 asterisms. None of these overlap longitudes preserved in BM 46083 and 5 describe diffuse asterisms comprised of multiple stars of uncertain identity. Nevertheless, BM 46083 preserves enough traces of additional star names, to show that the two "catalogues" addressed the same set of stars.

However, differences in the two texts suggest that they were compiled when the conventional characterization of the zodiac was still unsettled. Most prominently, BM 36609 describes the zodiacal signs as month-names prefaced with a sign that RSW reads as an otherwise unattested MULU4. However, according to Hunger[9] this should be read as E2 ~ *bitu* and translated as "place" or "area" as in BM 53282 (Hunger 1999), referencing the theoretical location of the Sun in the schematic calendar. BM 46083, in contrast, uses the familiar standard names of zodiacal signs. Another difference is reflected in the precision of the longitudes cited in the two texts. In BM 46083 all 6 preserved longitudes are whole numbers, whereas in BM 36609, 5 of the 9 preserved longitudes reflect fractional degrees of which 1/4, 1/3, and 1/2 are attested.

2d	Modern (−500): $\Delta\lambda^*_H = 10.00$				Babylonian			Align error	Adj $\delta\Delta\lambda^*$
#	Star	Mag	λ^*mod	β	λ^*bab	Source	$\delta\Delta\lambda^*$		
1	η-Psc	3.6	2.10	5.24	3.33	rsw	1.23		1.23
26	β-Cap	3.1	279.30	4.87	281.50	rsw	**2.20**	**1.03**	**1.17**
27	γ-Cap	3.7	297.05	−2.35	298.50	rsw	1.45		1.45
28	δ-Cap	2.9	298.80	−2.40	300	pjh,rsw	1.20		1.20
	4 avg	3.3	309.31	1.34	311		1.52		0.52

8 Huber's analysis suggested that $\lambda^*(\alpha\text{-Gem}) = 84;53^\circ \cong 85^\circ = \lambda^*(\beta\text{-Gem}) - 5^\circ$, which seemed implausibly inconsistent with the actual longitude difference with β-Gem of 3.27°. This discrepancy, however, appears explicable as a result of some "stretching" the longitude of β-Gem to place it on the sign boundary combined with a relatively large passage point correction (−1.36°) arising from alignment with δ-Gem (Jones 2004, p. 507). *Ziqpu* lists also separate α- and β-Gem by ΔR.A. $\cong \Delta\lambda = 5^\circ$ (Roughton et al. 2004, 540 and John Steele, private communication).

9 Hermann Hunger, private communication, 2009.

Although BM 36609 preserves nine NS longitudes, only four are for core Normal Stars, which exhibit a distinctively large positive correction, $\delta\Delta\lambda^* = 1.52°$. The rest refer to groups of 3 or 4 stars, whose components are for the most part uncertain. Assuming Jones's (2004, p. 483) identifications,[10] the average longitudes of the component stars of each member yield a nearly identical average correction, $\delta\Delta\lambda^* = 1.55°$, although with considerably more variation.

2dx #	Stars(?) (Jones)	Mag range	Avg λ^* mod	Avg β	λ^*bab	Source	Avg $\delta\Delta\lambda^*$	Range λ^*mod	Range β
a8	$\gamma, \delta, \varepsilon, \eta$ Sgr	1.8–3.1	248.95	−9.1	249	rsw x	0.05	246.58–250.39	−6.13 to 12.94
a9	$\sigma, \tau, \zeta, \varphi$ Sgr	2.1–3.1	258.04	−4.5	260	rsw x	1.96	257.66–260.17	−3.09 to −6.86
a11	$\varphi, \chi, \psi 3$ Aqr	4.2–5.0	322.26	−2.9	324	rsw x	1.74	322.03–322.44	−0.84 to 4.68
a12	29, ..33 Psc	4.4–5.1	334.32	−4.4	337.5	rsw x	3.18	334.18–334.47	−2.94 to −5.82
a13	ε, ζ, μ Psc	4.3–5.2	355.45	−0.1	356.25	rsw x	0.80	352.86–358.40	2.15 to 3.08
	5 avg	3.8	317.52		319		1.55		

The consistently large positive corrections resulting from all RSW longitudes, combined with the differences noted above, raise the question of whether these longitudes belong with the others, or whether in the early days following the introduction of the zodiac there may have been two distinct versions of Normal Star longitudes. Arguing against this is the common longitude for δ-Cap (28) in addition to the evidence that both BM 46083 and BM 36609 cover exactly the same stars. Also, as we shall see in the next section, the sign-entry data reflects a roughly sinusoidal variation of $\delta\Delta\lambda^*$, which peaks in the vicinity of δ-Cap at roughly the same size. As noted in Roughton et al. (2004) (554) a relatively large position error in a star such as δ-Cap would probably have affected the position errors of neighboring stars. On balance I conclude that the RSW longitudes are part of a common tradition with the rest, although with less confidence than I would prefer.

2.1.2 Results

The mean corrections and related statistics from the longitudes for which there is some Babylonian evidence are shown in Table 3 for: all 19 longitudes; 17 longitudes excluding the extreme results for the Pleiades (4) and θ-Leo (17); and 14 longitudes excluding the Pleiades and θ-Leo plus the 3 RSW longitudes unattested in other sources. Average deviations have been used as a measure of variation in place of standard deviations, since they are less affected by large deviations.

The average deviations and extremes of the unadjusted results are sensibly influenced by alignment errors, but once the outliers are removed, there is little difference between unadjusted and adjusted results. In contrast, omitting the unsupported RSW longitudes turns a positive correction into a sensible negative one. However, as noted, the systematically high values of $\delta\Delta\lambda^*$ obtained from RSW stars seem more likely to reflect a general error affecting stars in this region of the zodiac, possibly influenced

[10] But identifying Dur Simmah (a13) with μ-Psc instead of δ-Psc.

Table 3 Average $\delta\Delta\lambda^*$ and adj $\delta\Delta\lambda^*$ with related data for progressively more restrictive sets of core Normal Stars

Data set	$\delta\Delta\lambda^*$					
	#	Avg	+/−	Avedev	Min	Max
All	19	0.16	0.24	1.05	−2.29	3.34
excl 4,17	**17**	**0.11**	**0.20**	**0.84**	**−1.15**	**2.20**
+excl rsw	14	−0.21	0.16	0.61	−1.15	1.20
	Adj $\delta\Delta\lambda^*$					
All	19	0.06	0.18	0.77	−1.15	1.45
excl 4,17	17	0.14	0.19	0.78	−1.15	1.45
+ excl rsw	14	−0.10	0.17	0.65	−1.15	1.20

by the sizable error in δ-Cap's longitude than an alternative formulation of the zodiac. Consequently, I see no compelling reason to exclude them.

Less certain is whether the effects of any alignment errors should be included in the correction to $\Delta\lambda^*_{\mathrm{H}}$ from Normal Star longitudes. My inclination is that they should be, but there are arguments on both sides of the question. Consequently, I propose to accept the unadjusted results from the 17 longitudes excluding the outliers, bolded in Table 3, as best reflective of NS longitudes, thereby finding

$$\delta\Delta\lambda^*_{\mathrm{H}}\ (\text{Normal Stars}) = +0.11^\circ \pm 0.2^\circ, \tag{2}$$

a result insensibly different from averaging the unadjusted and adjusted $\delta\Delta\lambda^*$ for all 19 longitudes.

2.2 Sign-entry data

Independent evidence of the magnitude of $\Delta\lambda^*$ is provided by the dates on which planets entered various signs reported in Almanacs and Diaries. The evidence from each source was analyzed separately by Steele and Gray (2007) in two-factor regression analyses, which showed fairly similar results from the two sets of data and reflected temporal variations roughly equal to the rate of precession. In effect the authors used some of the information available in the data to demonstrate an approximate correlation with precession. The following analysis extends this investigation to obtain a more secure estimate of the constant term in expression (1), using the known rate of precession to precess the computed longitudes for all reported events to the common date of −500.0. The procedure also facilitates comparing the sign-entries reported in Almanacs and Diaries, which turn out to have few distinguishing characteristics.

Babylonian dates of 245 planetary sign-entries reported in Almanacs were kindly furnished by Hermann Hunger and converted to Julian dates using P.V. Neugebauer's visibility criteria incorporated in Peter Huber's CRESDAT[11] program. Planetary

[11] Huber (1982, pp. 91–102).

longitudes were calculated in accordance with Bretagnon's theories for evening phenomena at 7 p.m. in Babylon (16 h UT) and for morning phenomena at 5 a.m. (2 h UT). These were precessed to −500.0 and compared with the beginning longitude of the designated sign, or ending longitude if the planet was moving retrograde, to find $\Delta\lambda^*(-500)_i$ for that record, from which $\delta\Delta\lambda_i^* = \Delta\lambda_i^* - 10.00°$.

The reported data and computed longitudes for −500.0 are shown in Appendix B. Three records [marked "x"] exhibit gross errors and have been excluded from the analysis. Ten other day-dates [marked "d"] are questionable readings, the appropriateness of whose inclusion is debatable. Records marked "r" involve retrograde motion, where the planet enters the sign at its upper boundary. Planets are designated by their initials, except for Mercury which is designated as "E" to distinguish it from Mars ["M"]. Finally, "e" and "m" indicate whether the associated longitude is computed for evening or the following morning. The record dates range from −164 to +74, with an average date of −55.

Similar data are presented in Appendix C for 104 sign-entries reported in Diaries, collected by Steele and Gray (2007) and kindly furnished by John Steele. Two gross errors ["x"] have been excluded from the analysis, and "r", "e", and "m" connote retrograde, evening and morning as above. Record dates are somewhat earlier than for Almanac records, ranging from −212 to −72 with an average date of −127.

Table 4 presents the results of the analysis. Records with gross errors have been excluded, and Almanac records have been analyzed with and without questionable day-dates. Results from Diary records reflect slightly larger average deviations than Almanac records but not sensibly greater extreme deviations. On balance, there seems no significant difference between the two sets of records and thus no reason not to combine them as in the last two columns. I consider the results excluding questionable dates more reliable, but recognize the subjective nature of this judgment. On balance I find from sign-entry records.

$$\delta\Delta\lambda_H^* \text{ (sign entries)} = +0.13° \pm 0.07°. \tag{3}$$

Table 5 shows that retrograde sign-entries were recorded or estimated slightly earlier on average than the far more prevalent direct motion records, but with smaller variability (avedev) and much smaller extreme deviations. On balance, however, retrograde sign-entries are largely indistinguishable from the rest.

The combined records of direct motion sign-entries, excluding questionable day-dates, have an median date of –81. The reduction in average deviation from earlier to later records suggests slight improvement in consistency of estimation, which, however, is not supported by a corresponding decrease in extreme deviations or a sensible difference in $\Delta\lambda^*$. All in all no sensible change in methodology with time is evident from these records.

Table 6 presents the results for individual planets, which though not directly relevant to the present inquiry are nonetheless of interest. Venus accounts for nearly half the records with Mars and Mercury accounting for the lion's share of the rest. Especially notable is the apparent correlation of variability, as reflected in average, standard, and extreme deviations, with planetary speed. This suggests that errors derive

Table 4 Summary results for $\Delta\lambda^*(-500)$

	Almanacs		Diaries	Combined	
	All	Excl "d"	All	All	Excl "d"
Number	242	232	102	344	**334**
Avg $\Delta\lambda^*$	10.11	10.15	10.07	10.10	**10.13**
Avedev	1.27	1.27	1.44	1.32	1.32
Stdev	1.68	1.66	1.88	1.74	1.73
Max-dev	5.49	5.44	5.73	5.71	**5.68**
Min-dev	−5.36	−5.40	−5.60	−5.62	**−5.65**
Avd-avg	0.08	0.08	**0.14**	0.07	**0.07**
Std-avg	0.11	0.11	0.19	0.09	0.09

Table 5 Miscellaneous statistics (334 records)

	Number	Avg$\Delta\lambda^*$	Avedev	Max-dev	Min-dev
Retro	13	10.81	1.20	**2.43**	**−1.80**
< -81 dir	160	10.16	1.48	5.65	−5.68
> -81 dir	161	10.10	1.17	5.49	−4.23

Table 6 Planetary statistics (334 records)

	Mercury	Venus	Mars	Jupiter	Saturn
Number	62	157	82	23	10
Avg $\Delta\lambda^*$	9.73	10.36	9.77	10.78	10.34
Avedev	**1.98**	**1.16**	**1.22**	**0.64**	**0.44**
Stdev	**2.45**	**1.47**	**1.69**	**0.90**	**0.59**
Max-dev	6.08	4.10	4.57	1.77	1.09
Min-dev	−5.25	−4.49	−5.02	−2.44	−1.06

in sensible part from errors in dates rather than errors in positions or in the location of sign boundaries.

Table 7 shows the variation of $\Delta\lambda^*$ with sign boundaries, accompanied by the effective modern sign boundaries and the resulting sign-lengths assuming $\Delta\lambda^*(-500) = 10.13°$ found for the sample analyzed. The composite results are similar to those found by Steele and Gray (2007) for the separate data sets, and confirm their finding that the effective sign-lengths appear to have been very nearly equal, the present sample reflecting a standard deviation of only $\pm 0.6°$.

Figure 1 shows the variation of $\Delta\lambda^*$ with longitude for sign boundaries and for individual Normal Stars. A noticeable periodicity is apparent in the sign boundary data, which roughly parallels the results from individual Normal Stars with three exceptions. The exceptions are the Pleiades, θ-Leo, and β-Cap, the three stars with the most disparate longitudes, which seem not to have had any sensible effect on their

Table 7 Sign boundary statistics (334 sample)

λ^*-bab	Number	Avg $\Delta\lambda^*$	Avedev	λ^*-mod	Dev	Preceding S-length
30	22	10.00	1.35	30.13	−0.11	**30.92**
60	27	9.70	0.92	60.43	−0.41	30.30
90	35	10.32	0.86	89.81	0.20	29.39
120	28	9.91	1.23	120.22	−0.20	30.40
150	28	9.53	1.07	150.60	−0.59	30.39
180	26	9.30	0.98	180.83	−0.81	30.23
210	25	**9.12**	1.09	211.01	−0.99	30.18
240	30	9.49	1.18	240.64	−0.63	29.63
270	30	10.18	1.55	269.95	0.07	29.31
300	27	11.31	1.24	298.82	1.20	**28.87**
330	28	**11.57**	1.37	328.56	1.46	29.74
360	28	10.92	1.21	359.21	0.81	30.64
Avg	28	10.11	1.17		0.00	30.00
Avedev		0.62	0.16			0.51
Min-dev		−0.99	−0.31			−1.13
Max-dev		1.46	0.38			0.92

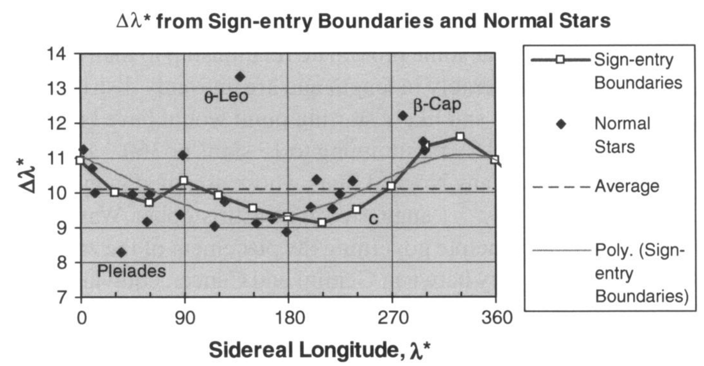

Fig. 1 $\Delta\lambda^*$ from sign boundaries and Normal Stars

nearby sign-boundaries, in contrast to β-Gem and δ-Cap whose influence is evident. Perhaps by the time of the sign-entry reports, the disparity of their longitudes had been recognized or even corrected.

2.3 Conclusion

Normal Star longitudes and sign-entry data give essentially identical values of $\delta\Delta\lambda^*$, with each exhibiting a small range of variation depending on whether all data are included, or the most problematical are excluded. Together, and regardless of which set

Data set	All			Most reliable	
	Wt.	#	$\delta\Delta\lambda^*$	#	$\delta\Delta\lambda^*$
Normal Stars	1	19	$+0.16° \pm 0.24°$	17	$+0.11° \pm 0.20°$
Sign-entries	4	344	$+0.10° \pm 0.07°$	334	$+0.13° \pm 0.07$
Combined			$+0.11° \pm 0.12°$		$+0.13° \pm 0.11°$

is assumed to be more relevant, these support the conclusion that

$$\delta\Delta\lambda^* = +0.12° \pm 0.11°, \tag{4}$$

from which expression (1) becomes

$$\Delta\lambda^* = 3.20° - 1.3828°Y \pm 0.09°, \tag{5}$$

where Y, as before, is measured in Julian centuries from 0.0. The modest magnitude of this correction to Huber's original result based on only 11 data points, is a tribute to the artfulness of Huber's analysis.

3 Placement of the zodiac

How were the longitudes to the Normal Stars established[12], and what considerations are likely to have governed this process? A general consideration was obviously that the individual signs should bear some proximate relationship to their eponymous constellations, which vary considerably in length and are unevenly distributed around the ecliptic. Another requirement and likely starting point would have been a set of measured intervals among Normal Stars, summing to 12 signs or 360°, and thus reducible to a set of intervals relative to any Normal Stars whose assigned longitude would then determine the rest. Previously[13] I suggested with Christopher Walker (Britton and Walker, 1996, 49) that the principle governing the placement of the zodiac was simply placing β-Gem at the boundary between Gemini and Cancer, equivalent to 90° by our counting, from which the rest would have followed from observed intervals. However, while this was clearly a result and may have influenced the process, β-Gem turns out not to have been a key reference star and principal determinant of the placement.

3.1 Conjectured longitudes

Before examining the intervals between Normal Stars, it will be helpful/useful to consider the longitudes of the 9 stars for which there is no direct Babylonian evidence.

[12] This question is sometimes framed as an attempt to explain the "zero-point" of the zodiac, an effort frustrated by the absence of a prominent star near the beginning of Aries. In fact the "zero-point" of the Babylonian zodiac is a modern artifact, the Babylonian zodiac being simply a serial set of 30° signs, which began with Aries (Hun, Lu) because the civil year began after the spring equinox, thought at the time to occur when the sun reached Aries 10°.

[13] As noted by Kollerstrom (2001, 145 n2).

Table 8 Conjectured Babylonian longitudes based on their modern sidereal counterparts and rounded to whole degrees based on various considerations

c #	Modern (−500): $\Delta\lambda^* = 10.12$				Babylonian		
	Name	Mag	λ^*(m)	β	λ^*(b)	Notes	$\delta\Delta\lambda^*$
2	β-Ari	2.6	9.4	8.31	10	a,c	0.60
5	α-Tau	1.0	45.1	−5.64	45	a,b,c	−0.15
8	η-Gem	3.4	68.8	−1.22	69	b	0.17
9	μ-Gem	2.9	70.7	−1.15	70	a	−0.70
10	γ-Gem	2.0	74.5	−7.02	75	a,b	0.49
13	δ-Cnc	3.9	104.1	−0.03	104	b	−0.09
16	ρ-Leo	3.8	131.8	0.02	132	b	0.21
23	β-Sco	2.6	218.6	1.30	218	b,c	−0.58
24	α-Sco	1.1	225.2	−4.25	225	a,b,c	−0.17

a rounded to nearest 5°, *b* rounded to nearest 1°, *c* some Greek evidence

The most likely possibilities are shown in Table 8, based on their respective sidereal longitudes reflecting $\delta\Delta\lambda^*_{\mathrm{H}} = +0.12°$ as found above, and rounded to whole degrees influenced by one or more considerations listed under "Notes". Two considerations are simply rounding to either or both of the nearest whole degree or the nearest multiple of 5°. The other, described as "some Greek evidence", requires additional comment.

As Kollerstrom (2001, p. 147) notes, Cleomedes remarks (De Motu I,11 p106:25–108:5, HAMA 960) that α-Tau and α-Sco are located at the mid-points of their respective signs, an assertion repeated by "Anonymous of the Year 379" (CCAG 5, 1 p198:4f and p203:4,16).[14] Neugebauer asserts (HAMA, 960) that these must be tropical longitudes, effectively dating Cleomedes to around 370 A.D. Kollerstrom rejects this assumption, and his skepticism is almost certainly correct, for everything else known of Cleomedes suggests a very elementary knowledge of pre-Ptolemaic astronomy and possibly a much earlier date. Instead it seems likely that both statements refer to the sidereal zodiac, especially since $\Delta\lambda^*_{\mathrm{H}}$ places both stars almost precisely at the mid-points of their signs.

Un-remarked by Kollerstrom or others to my knowledge, is supporting evidence from none other than Ptolemy, whose star catalogue in *Alm.* 7 lists the tropical longitudes of both stars as 12;40° of their signs. At 137.5 (CE), the epoch of Ptolemy's catalogue, Ptolemy's longitudes reflect a systematic error of −1;7°, due to the error in his mean solar longitude, traceable to the dates he assumes for contemporary equinoxes and solstices (or alternatively, his assumed tropical year length). For the same

[14] Kollerstrom ascribes a supporting statement to Rhetorius (ca. 500 A.D.) but then notes correctly that Rhetorius actually places the two stars at 16;20° of their respective signs, which are obviously tropical longitudes.

epoch $\delta\Delta\lambda^* = 1;18°$, so the difference between Babylonian sidereal and Ptolemy's tropical longitudes is[15]

$$\Delta\lambda^*_{\mathrm{Ptol}}\,(+137.5) = \lambda^*_{\mathrm{Bab}} - \lambda_{\mathrm{Ptol}} = 1;18° + 1;7° = 2;25° \cong 2;20°.$$

Thus, taking account of the error in Ptolemy's solar model, the difference between Babylonian sidereal and Ptolemy's tropical longitudes rounded to the nearest 0;10°, places α-Tau and α-Sco exactly in the mid-points of their signs as stated by Cleomedes.

This unexpected evidence of a correspondence between two of Ptolemy's longitudes and those from the sidereal zodiac suggests looking at Ptolemy's longitudes for all 28 core Normal Stars. These are shown in Appendix A, where longitudes from Ptolemy's star catalogue have been increased by 2;20° with the resulting differences from computed sidereal longitudes shown in the final column. Clearly Ptolemy's longitudes are *not* simply derived from Babylonian sidereal ones. Of the 19 known or inferred Babylonian longitudes discussed above, three are the same as Ptolemy's, while for all of the rest except Regulus[16] Ptolemy's longitudes are improvements, often substantial, over their Babylonian counterparts.

Furthermore, nearly two-thirds of Ptolemy's sidereal longitudes have fractional parts, whereas 16 of the 19 Babylonian longitudes so far known are integers, evidently reflecting a largely independent procedure of derivation. Nevertheless, Ptolemy's sidereal longitudes for α-Ari (3), β-Tau (6), and ζ-Tau (7) each agree with their Babylonian counterparts, suggesting that some of his other integer longitudes may have had similar correspondences. Of Ptolemy's seven other integer longitudes three, η-Psc (1), β-Gem (12), and α-Vir (20), improve upon their Babylonian counterparts. Of the rest the longitudes of α-Tau (5) and α-Sco (24) are affirmed by Cleomedes; β-Ari (2) at 10° is a natural multiple of 5°, echoing the placement of the spring equinox in lunar System A; and β-Sco (23) at 218° is just what one should expect from typical interval errors and its proximity to α-Sco. On balance, there seems no reason to doubt that α-Tau and α-Sco were located at the mid-points of their signs, while the other two of Ptolemy's integer longitudes seem entirely plausible.

The conjectured longitudes in Table 8 have an average $\delta\Delta\lambda^*$ of $-0.02°$, insensibly different from the result derived above. Moreover, each of the longitudes for which there appears to be Greek evidence is supported by one or both natural rounding considerations. On balance, it seems all but certain that the Babylonian longitudes of α-Tau and α-Sco were at the mid-points of their signs, while the other conjectured longitudes seem likely, if less than certain.

[15] An alternative derivation, anticipating the result $\Delta\lambda^*(-500) = 10.12°$, implying $\Delta\lambda^*(-128) = 4;58°$, is to assume that Hipparchus determined $\Delta\lambda^*$ (-128) as $\cong 5°$, whence $\Delta\lambda^*_{\mathrm{Ptol}}(+138) = 5;0° - 2;40° = 2;20°$.

[16] Regulus's Babylonian longitude is decreased by a minimal 0;10° in Alm. 7, where an increase would have been more accurate.

3.2 Intervals

Table 9 combines attested and conjectured longitudes, omitting the Pleiades and θ-Leo as before, and separates them into multiples of 5° and the rest. The former account for half (14) of core NS longitudes and half of these (7) are either mid-points or trailing boundaries of their respective signs. The last three columns of Table 9 shows the intervals and their absolute errors between each star and ζ-Tau, an attested longitude on the trailing boundary of Taurus. These reflect the same precision as their associated longitudes.

The unnatural preponderance of 5° multiples prompts a suspicion that this may have been an arbitrary preference, in which case one would expect such intervals to exhibit larger errors on balance than their more precise counterparts. This proves *not* to be the case, however, and in fact the 5° longitudes reflect significantly lower average deviations in both $\delta\Delta\lambda^*$ and interval errors than the rest. Measured relative to ζ-Tau the average interval error of the 5° longitudes is roughly $^1/_4$ cubit with an average deviation of half as large. This is consistent with accurate measurements with a precision of half a cubit, which seems likely to be close to, if not at, the limit of realistically achievable accuracy. In contrast, the 1° and fractional degree longitudes exhibit average deviations of $\delta\Delta\lambda^*$ and interval errors 35% and 70% higher, respectively. Thus, the 5° and 15° intervals appear to have been a natural occurrence, measured with somewhat greater accuracy than the rest.

Table 10 illustrates the relative accuracy of intervals measured with respect to different prominent stars for each of the main precision groupings. In both groups the relative accuracy and dispersion of intervals relative to α-Tau, ζ-Tau, and α-Sco are conspicuously similar, with 1° longitudes being consistently less accurate than 5° longitudes as previously noted. Thereafter, average interval errors increase, being slightly larger in both groups relative to α-Leo, similar to 1° errors relative to γ-Gem and larger still relative to β-Gem, which clearly played no prominent role in the establishment of the interval grid. Conversely, intervals relative to α-Tau, ζ-Tau, and α-Sco are both the most accurate and essentially indistinguishable, suggesting that these three stars, or one of them, served as the foundation of the interval grid.

Interestingly, the interval errors appear to have been independent of the size of the interval measured. This may be seen in Fig. 2, which plots the difference between Babylonian and modern intervals as a function of interval size, assuming measurements from the nearest of either α-Tau or α-Sco. While the Babylonian intervals are too short on average by roughly $^1/_4$°, the negligible slope of the linear trend line (−0.0007) and equally negligible R^2 value (0.0006), are a striking attestation of non-correlation.

3.3 Constellation boundaries

The constellations for which the zodiacal signs were named vary considerably in size and distribution along the ecliptic, creating a challenge for the author of the zodiac to fit the signs to their eponymous constellations. Taurus (comprised of

Table 9 Attested and conjectured longitudes of core Normal Stars and their intervals and interval errors measured from ζ-Tau

NS c#	Modern (−500): DI* = 10.12 Babylonian						$\|\lambda(*) - \lambda(\zeta - T\alpha\nu)$		Error $\|B - M\|$
	Name	$\lambda^*(\beta)$	$\lambda^*(\mu)$	β	Source	$\delta\Delta\lambda^*$	Bab	Mod	
2	β-Ari	10	9.40	8.3	grk	0.60	50	50.8	0.8
5	**α-Tau**	**45**	**45.15**	**−5.6**	**grk**	**−0.15**	**15**	**15.0**	**0.0**
7	**ζ-Tau**	**60**	**60.18**	**−2.5**	**pjh,grk**	**−0.18**			
9	μ-Gem	70	70.70	−1.1		−0.70	10	10.5	0.5
10	**γ-Gem**	**75**	**74.51**	**−7.0**		**0.49**	**15**	**14.3**	**0.7**
11	α-Gem	85	85.75	9.9	ph+	−0.75	25	25.6	0.6
12	**β-Gem**	**90**	**89.02**	**6.5**	**pjh**	**0.98**	**30**	**28.8**	**1.2**
14	ε-Leo	115	116.09	9.5	ph+	−1.09	55	55.9	0.9
15	α-Leo	125	125.39	0.4	ph+	−0.39	65	65.2	0.2
19	**γ-Vir**	**165**	**165.88**	**3.0**	**ajs***	**−0.88**	**105**	**105.7**	**0.7**
21	α-Lib	200	200.53	0.6	ajs	−0.53	140	140.3	0.3
22	β-Lib	205	204.73	8.7	pjh.ajs	0.27	145	144.6	0.4
24	**α-Sco**	**225**	**225.17**	**−4.2**	**grk**	**−0.17**	**165**	**165.0**	**0.0**
28	**δ-Cap**	**300**	**298.92**	**−2.4**	**pjh,rsw**	**1.08**	**240**	**238.7**	**1.3**
					Avg	−0.10			0.59
					Avedev	0.56			0.30
					Min	−1.09			0.01
					Max	1.08			1.26
1	η-Psc	3.3	2.2	5.2	rsw	1.08	41.7	42.9	1.2
3	α-Ari	13	13.1	9.8	ph+,grk	−0.10	32	32.0	0.0
6	β-Tau	57	58.0	5.2	ph+,grk	−0.97	12	12.8	0.8
8	η-Gem	69	68.8	−1.2		0.17	24	23.7	0.3
13	δ-Cnc	104	104.1	0.0		−0.09	59	58.9	0.1
16	ρ Leo	132	131.8	0.0		0.21	87	86.6	0.4
18	β-Vir	151	152.0	0.6	pjh.ajs	−1.01	106	106.9	0.9
20	α-Vir	178	179.3	−1.9	pjh.ajs	−1.27	133	134.1	1.1
23	β-Sco	218	218.6	1.3	grk	−0.58	173	173.4	0.4
25	θ-Oph	237	236.8	−1.5	pjh	0.21	192	191.6	0.4
26	β-Cap	281.5	279.4	4.9	rsw	2.08	236.5	234.3	2.2
27	γ-Cap	298.5	297.2	−2.4	rsw	1.33	253.5	252.0	1.5
					Avg	0.09			0.78
					Avedev	0.76			0.51
					Min	−1.27			0.05
					Max	2.08			2.23

Shown in bold are details for stars located at the mid-points and trailing boundaries of their signs

Table 10 Average errors of intervals relative to prominent Normal Stars for each of the two principal precision groups

Ref *>	α-Tau	ζ-Tau	α-Sco	α-Leo	γ-Gem	β-Gem
5° longitudes						
#	13	13	13	13	13	13
Avg	0.59	0.59	0.59	0.62	0.82	1.18
Avedev	0.29	0.30	0.30	0.36	0.36	0.48
Max	1.23	1.26	1.25	1.47	1.58	2.06
1° and fractional longitudes						
#	12	12	12	12	12	12
Avg	0.78	0.79	0.78	0.86	0.91	1.15
Avedev	0.51	0.50	0.51	0.52	0.47	0.52
Max	2.23	2.26	2.25	2.47	1.76	2.24
1° as a % of 5°						
Avg	132%	134%	133%	138%	110%	98%
Avedev	176%	166%	170%	143%	130%	108%
Max	181%	179%	180%	168%	111%	109%

Data in degrees except for # and %

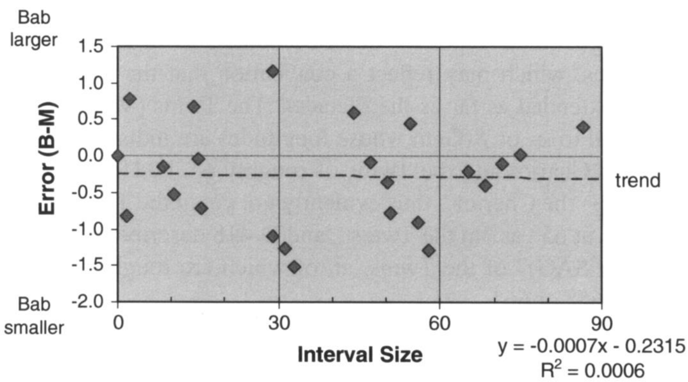

Fig. 2 Interval error vs interval size

MUL$_2$-MUL$_2$, GU$_4$-AN plus GIGIR), Leo (UR-A), Aquarius (GU-LA), are long constellations extending for more than a sign and thus necessarily into adjacent signs. Cancer (ALLA) and Virgo (ABSIN) on the other hand are short, leaving gaps between constellations within their signs. Overlaps also occur, most notably by Sagittarius (PA), whose bow and arrow overlap the tail of the Scorpion (GIR$_2$ TAB).

The most likely longitudinal boundaries of the zodiacal constellations are shown in Table 11, which ignores the overlapping parts of intruding constellations. We have no good idea how the constellation comprising Aries was visualized, either as Hired Man ($^{\text{lú}}$HUN-GA) or Ram (LU), both of which are attested, but γ-Ari and ζ-Ari seem likely to define its extent. Taurus encompasses three asterisms—the Pleiades (MUL$_2$-

Table 11 Babylonian zodiacal constellations' likely boundaries

Name	Star	Mag	beg-λ^*	β	Star	Mag	end-λ^*	β
HUN, LU	γ-Ari	4.5	8.6	7.0	ζ-Ari	4.9	27.4	2.7
GU_4-AN, GIGIR	?ζ-Ari	4.9	27.4	2.7	ζ-Tau	3.0	60.2	−2.5
MAŠ-MAŠ	1-Gem	4.2	66.3	−0.5	κ, β-Gem	3.6	89.1	2.8
ALLA	?χ-Cnc	4.2	96.3	7.4	?κ-Leo	4.5	110.7	10.2
UR-A	ϵ-Leo	4.2	116.1	9.5	β-Vir	3.6	151.9	0.6
ABSIN, AB-SIN_2	θ-Vir	4.4	163.5	1.8	?82-Vir	5.1	182.2	1.9
RIN_2	?κ-Vir	4.2	189.9	3.0	48-Lib	4.9	215.8	6.4
GIR_2-TAB	ξ-Sco	4.3	216.7	9.6	ι-Sco	3.0	242.9	−16.4
PA	3-Sgr	4.6	242.6	−4.1	62-Sgr	4.5	272.4	−6.8
$MAŠ_2$	α, β-Cap	3.6	279.3	7.2	δ-Cap	2.9	298.9	−2.4
GU-LA, GU	β-Aqr	2.9	298.8	8.8	29-Psc	5.1	334.6	−2.9
KUN^{me}, KUN	29-Psc	5.1	334.6	7.5	α-Psc	4.1	4.7	−9.2

MUL_2), Bull of Heaven (GU_4-AN) extending beyond the Pleiades to the west, and Chariot (GIGIR), which together appear to extend from o-Tau ($\lambda^* = 26.6°$) to ζ-Tau. Since o-Tau overlaps ζ-Ari, the latter is considered the effective boundary in Table 11. However, several positional reports[17] describe planets as in Aries, which were up to 5° within Taurus, which may reflect a convention that the asterism comprising HUN and/or LU extended as far as the Pleiades. The Twins (MAŠ-MAŠ) appear to extend from 1 Gem to κ- or β-Gem whose longitudes are indistinguishable, leaving a gap between the Chariot and the Twins of roughly 6°. D-418 describes Venus at 64° as "behind (*ar*$_2$) the Chariot", thus evidently not yet in the Twins, Hunger 5, 56A describes Γ-Venus at 65° as "in the Twins", and D-418 describes Venus at 69° as "in the beginning (*ina* SAG)" of the Twins, all of which are roughly consistent with a beginning around 65° or 66°.

Following the end of the Twins at κ, β-Gem is another gap of 6° until the Crab (Alla) begins, probably with χ-Cnc. D-418 describes Jupiter at 94° as "in front of (IGI)" the Crab, but "in the beginning (SAG) of the Crab" at 99°. H5, 56B describes Venus at 111° as "in" the Crab, but "behind (*ár*) it at 112°, suggesting that the asterism extended to κ-Leo. Another 5° gap follows before the Lion (Ur-A) intrudes, apparently beginning with ε-Leo (SAG A) and continuing through Leo to end with β-Vir.

Virgo is problematic. ABSIN is conventionally translated as "furrow", although Sachs (1952, 146 n3) cites instances where "barley stalk" is meant. In BM 36609 and conventionally, γ-Vir is described as DELE *ina* IGI ABSIN, "the single star in front of the Furrow or Barley Stalk", implying that the asterism ABSIN begins behind it. Sachs (1952) interpreted the entry in BM 46083 as the "root (*šur-ši*) of ABSIN", a transcription retained in RSW's new edition of the text. However, Hunger avers[18]

17 H5, 56A(2) and D-418 (Appendix D).

18 Private communication.

that this is simply a misreading of the standard description DELE *ina* IGI, which seems likely. Since β-Vir is part of Leo and η-Vir seems part of the (date-palm) Frond (Gössmann 1950, 3), it is hard to visualize ABSIN as a linear furrow wobbling from θ through α to κ, especially since γ is considered distinct and "in front" of it. Consequently, Sachs's interpretation of ABSIN as "Barley Stalk" extending from Spica to ζ-Vir, with roots extending west to θ-Vir ($\lambda^* = 163.5°$) and (perhaps) east to 82 Vir ($\lambda^* = 182.2°$) seems likely to be more appropriate than "Furrow". Observational evidence is unhelpful; H5, 56B places Venus "in the end (TIL)" of ABSIN at 182°, while D-463 places it "behind (*ár*) AB-SÍN" at the same longitude.

The Scale (RIN_2) is readily recognizable as a scale comprised of a triangular beam with α at its apex and β and σ at each end from which hang balance pans, θ-48 and υ–τ, which intrude nearly 5° into Scorpius. The Scale appears to be suspended at α from κ-Vir, leaving a gap of roughly 7° between it and the Barley Stalk. Nearly touching the pans of the Scale are the pincers of the Scorpion (GIR_2-TAB), another easily visualized asterism, which extends through α-Sco to its curved stinger whose furthest extent is marked by ι-Sco. The latter intrudes slightly into Sagittarius and is at essentially the same longitude as 3 Sgr, which—ignoring the overlap—can be considered the effective beginning of PA who extends to 62 Sgr and intrudes slightly into Capricorn.

There follows another gap of 7° to the beginning of the Goat-fish, which I find hard to visualize but appears clearly delineated, evidently beginning with α,β-Cap (insensibly different in longitude) and ending with δ-Cap. The Giant (GU-LA) is another sprawling, problematic asterism, which effectively begins with β-Agr at the same longitude as δ-Cap, and apparently intrudes into Pisces with a trailing "Rear Basket" placed at 337.5° in BM 36609 and identified by Jones with a quadrangle of faint stars around 334°. D-453 puts Mercury *ina* TIL GU-LA at 334° and Venus *ina* KUN^{me} at 335°, so I've assumed the Giant extends to at least 29 Psc in Tables 10 and 11. This still leaves a 3° error in BM 36609's longitude of the "Rear Basket", the largest of any of the attested Normal Stars, raising a question of whether this might not be a scribal error for 334.5. However, D-382 places Mercury *ina* GU at 337°, which cannot plausibly refer to the sign, suggesting that the Giant may have extended as far as ω-Psc ($\lambda^* = 337.9°$), in which case the "Rear Basket" may have instead comprised the pentagon defined by $\gamma, \theta, \iota, \lambda$, and κ Psc.

The constellation boundaries and extents described above are summarized in Table 12, together with their intrusions into neighboring signs. The latter reflect a net aggregate positive intrusion (i.e., into the following sign) of +16°. Optimal balance would thus entail a shift of 1° or 2° in the direction of lower Babylonian and sidereal longitudes and thus $\Delta\lambda^*$. Its absence suggests that optimizing the balance of constellational placement in a quantitative sense was *not* a consideration in the placement of the zodiac.

3.4 Placement

Three NSs—ζ-Tau, β-Gem, and δ-Cap—define the trailing boundaries of their constellations, which sets an upper limit of 30° to their longitudes, if they are to remain

Table 12 Constellation boundaries and intrusions into neighboring signs

Sign	λ*-beg	Constellation boundaries				Intrusion	
		Asterism	λ*-beg	λ*-end	Extent	Beg	End
Aries	0	HUN, LU	9	27	19		
Taurus	30	GU_4-AN, GIGIR	27	60	**33**	−3	
Gemini	60	MAŠ-MAŠ	66	89	23		
Cancer	90	ALLA	96	111	14		
Leo	120	UR-A	116	152	**36**	−4	2
Virgo	150	ABSIN, AB-SIN_2	164	182	19		2
Libra	180	RIN_2	190	216	26		6
Scorpius	210	GIR_2-TAB	217	243	26		3
Sagittarius	240	PA	243	272	30		2
Capricorn	270	$MAŠ_2$	279	299	20		
Aquarius	300	GU-LA, GU	299	335	**36**	−1	5
Pisces	330	KUN^{me}, KUN	335	5	30		5

within the signs named for their constellations. In the other direction, lowering longitudes by 3° would place the Pleiades—conventionally part of Taurus—at Aries 30°. Thus assuming whole degree shifts, only two alternatives to the placement adopted would avoid violating one convention or another. Finally, and probably decisively, all three of the trailing boundary stars are among those separated from α-Tau and α-Sco by multiples of 15° and from a majority of the remaining stars by multiples of 5°. Given these measured intervals, and in the absence of any compelling reason to prefer longitudes 1° or 2° smaller, placing α-Tau and α-Sco at the midpoints of their signs and ζ-Tau, β-Gem, and δ-Cap at the ends of theirs would have been the natural and aesthetically compelling choice.

In summary, the placement of the zodiac appears to have been a consequence of keeping both the Pleiades and ζ-Tau within Taurus combined with the accurate estimates that α-Tau was separated from ζ-Tau by half a sign and in opposition to α-Sco. This made placing α-Tau and α-Sco at the mid-points of their signs a logical choice, which also put ζ-Tau, β-Gem, and δ-Cap at the ends of their respective signs thereby marking those sign boundaries directly. The rest of the Normal Star longitudes would have followed from their measured intervals, which happened to contain an unusual number of 5° multiples.

4 When was the zodiac introduced?

Diaries and observational reports from the seventh to the early fifth centuries[19] typically describe planetary positions as either distances from Normal Stars or as being *ina*

[19] SH1, D-651 and D-567; H5, 52, 54 and 55. H5, 53 is now dated (Jones, 204, 529) to SE 24-27 (–287ff).

IGI or ar_2 ZN, meaning "in front of" or "behind"[20] the named zodiacal entity, which is unambiguously an asterism, whether a constellation or individual star. Positions within constellations are occasionally reported simply as "*ina* ZN (zodiacal name), but not until after −460 do we encounter the more precise internal descriptions *ina* SAG ZN[21] or *ina* TIL/*qit* ZN[22]", indicating a position within the zodiacal entity but towards its beginning or end. Thereafter, such more precise descriptions become increasingly frequent.

In his classic paper on the "History of the Zodiac" van der Waerden (1953, p. 220) cites reports in the Diary for −418[23] of planetary positions in the beginnings and ends of zodiacal entities as evidence for the introduction of the zodiac before that date, citing the opinions of Schnabel, Weidner and Rehm[24] that such descriptions referred to zodiacal signs and not constellations. Neugebauer endorsed Rhem in the first edition of *Exact Sciences in Antiquity* (1952, pp. 97, 133), but by the second edition Weidner had published the text, and Sachs added a note (Neugebauer 1952, 2nd ed., 1957, p. 140) challenging that conclusion on the grounds that "in front of" and "behind" must refer to constellations. In *Anfänge der Astronomie* (1965, p. 124) van der Waerden conceded that distinguishing signs from constellations is a "difficult question" but insisted that references to "beginning" and "end" must imply signs, and citing evidence from reports of Venus observations in BM 45674 (H5-56) placed the introduction of the zodiac back to at least −445. Toomer (1968, p. 193) reviewing *AA*, dismisses this conclusion as "based on interpretations of two fifth century cuneiform texts which competent Assyriologists (presumably referring to Sachs) reject". Nevertheless, van der Waerden's opinion gained currency, and new Diary evidence led to a general opinion[25] that the zodiac was introduced around the middle of the fifth century, and probably between −463 and −453. As further, albeit indirect, evidence supporting this dating Rochberg (1998) mentions two texts containing calculated longitudes of syzygies and planets for dates ranging from −474 to −430, which evidently refer to zodiacal signs and seem to lend at least vague support to the argument from terminology implying a mid-century introduction of the zodiac. As we shall see, neither the assumption—that *ina* SAG or *ina* TIL reliably refer to signs rather than constellations, or that calculated longitudes referring to signs are roughly contemporaneous with their contents—withstands close examination. Anticipating the discussion which follows, the zodiac appears to have been introduced around −400 rather than −450. (Sachs was right.)

[20] i.e., in the direction of daily rotation, hence *ina* IGI = "west"; ar_2 = "east".

[21] The earliest attestation of *ina* SAG appears in H5, 56B where the first appearance of Venus as morning star (Γ) is described as occurring *ina* SAG RIN_2 (in the beginning of the Scales).

[22] First attested in D-453, iv $2'$ describing Mercury's disappearance as morning star ($\sum$) as occurring *ina* TIL GU-LA ("in the end of the Giant").

[23] ADART I, D-418 (VAT 4924).

[24] As reported by Rehm (1941, p. 22), Schnabel apparently told Meissner that zodiacal signs first appear in VAT 4924, then unpublished, which Weidner subsequently confirmed in a letter to Rehm. I am indebted to Alexander Jones for accounts of these earlier discussions.

[25] Advanced, for example, by the author in Britton and Walker (1996, p. 49), and in more detail in Rochberg (1998, p. 30 and 2004, p. 130).

Table 13 Types of planetary position reports: −463 to −381

Description	5th c. <−408	4th c. >−397	Total	Referent		
				Ambig	xSign	**Sign**
ina IGI/ar_2	10	4	14	0	14	**0**
ina SAG/TIL	13	10	23	11	9	**3**
ina	40	43	83	73	9	**1**
Total	63	57	120	84	32	**4**

4.1 Reports of planetary positions

120 reports of planetary positions on specific dates are preserved which range in date from −463 to −381. Slightly more than half (63) are earlier than −408, and the balance are later than −397. Most concern details of appearances and disappearances, but reports of month-end planetary positions from Diaries and of otherwise dated positions from one horoscope are also included. Details of each report are presented in Appendix D, whose contents are summarized in Table 13. Roughly two-thirds (84) of the reports are ambiguous with respect to whether their referents are signs or asterisms and thus unhelpful for present purposes. The rest include 14 external references—*ina* IGI, *ár*, SIG, *šaplat* ("in front of, behind, below")—whose referents cannot be signs, and 22 statements of internal position (*ina* SAG, *ina*, *ina* TIL/*qit*) of which 18 appear to refer to asterisms, but 4 most probably refer to signs.

The 36 reports which bear on the introduction of signs are collected in Table 14, together with two whose terminology is further evidence of this. Here dates in brackets [ ] have been emended to agree broadly with the positions described, whose sidereal longitudes (λ^*p) are calculated for the dates in question (rather than for the calculated dates of visibility phenomena). The last column characterizes the reports as either referring to signs ("S") or *not* referring to signs ("xS"), accompanied by a very abbreviated designation of the principal reason for the characterization. As explained at the bottom of the table these fall chiefly into one of three groups. The most certain are the external references, "in front of/behind ZN", marked "*" which make no sense in the context of a continuum of signs. A second group, marked "C", are those descriptions for which the computed positions agree significantly better with constellation boundaries than with sign boundaries. Finally, a third group, labeled "c?" pertains only to the constellation HUN/LU, which 3 fifth century reports seem to imply extends 3° to 5° into Taurus, in conflict, as noted above, with other reports placing its boundary around Aries 27°.

Among the fifth century reports the last three are from two horoscopes published by Rochberg (1998, Nos. 1 and 2), whose positional statements have generally been considered to refer to signs. However, in AB251 *šaplat* SI GÍR-TAB evidently refers to a star (σ-Lib), while the preceding external reference, *ina* IGI GU, from AO 17649 must refer to the constellation, even if the computed position of Venus at the time places it within rather than in front of the Giant. Requiring more detailed comment, is the reading "ar_2 SI_4" as the position of Mercury in obv. 3 of AO 17649. Following a clear ar_2 is a damaged sign, initially read as ⌜MAŠ⌝-MAŠ (Gemini). However, as Rochberg notes, Mercury's first appearance as morning star that year occurred at $\lambda^* = 242°$ across the zodiac from Gemini, and in front of, not behind, MÁS which seemed the closest alternative reading. Since the calculated date is within a day of the text's, a gross error in position seems unlikely. Reading the sign as a slightly smudged SI_4, however, for ^{d}Lisi $\sim$ α-Sco, makes sense of the text, since Mercury's position at first appearance would have been on the boundary between the figures of Scorpion and Pabilsag, 17° behind α-Sco and not yet clearly within the constellation PA[26]. Coupled with the description of Venus's disappearance *ina* IGI GU, there appears scant room for doubt that the positions given in the text refer to stars or constellations and not signs.

Working backwards within the fifth century reports, a series of referential reports from D-418 appear to exclude references to signs. The latest, a position of Venus at the end of Darius 2, month XII_2 describes Venus, then at 35° or 5° Tau as *ina* HUN-GÁ. The discrepancy is too large to be a plausible reference to the sign Aries, and reflects an anomaly encountered elsewhere (e.g., ARTX1 15 I and 23 I) in which the figure comprising Aries (alternatively described here and elsewhere in Appendix D as Ram (LU) or Hired Man (HUN(-GA_2)) appears to extend as far as the Pleiades between 3° and 5° into Taurus. Since there are almost no visible stars in the area between 30° Aries and the Pleiades, it is hard to understand what is envisaged. However, the repetition suggests that it was not accidental.

Immediately before, are several reports from D-418 which place Saturn or Mercury "in the end of Pisces" (ina TIL/*qit* KUN^{me}) when their calculated positions were up to 5° into Aries, but still within the boundaries of the constellation KUN^{me}. Reports from the same text of positions of Jupiter and Venus relative to constellations, lend further support to the conclusion that as late as −418 positions were reported relative to asterisms and not signs. Reports with similar descriptions of positions at 3° or 4° of Aries as *ina* KUN^{me} appear in −445 and −453 by which time relative position (*) reports predominate.

In summary, despite some minor interpretive issues, positional reports prior to −408 consistently refer to stars or constellations and reflect no evidence of references to zodiacal signs.

Fourth century reports, in contrast, exhibit a different mix of referents, among other differences. First, the frequency of significant reports is sharply lower: 13 of 57 fourth century reports compared with 25 out of 63 from the fifth century. More significantly, four reports exclude references to stars or constellations, and thus inferentially refer to zodiacal signs. The earliest of these describes the disappearance of Mars (Ω) in −394 as *ina* TIL ALLA on ARTX2 IV 8. Calculation places Mars at 123° (i.e., Leo 3°) on that date, and disappearance a day earlier and a degree less. Although the report inaccurately places Mars in the end of Cancer rather than at the beginning of Leo, it cannot have referred to the constellation Crab, whose furthest extent at 111° it had passed 12° earlier before entering the Lion on passing by SAG A (ε-Leo) at longitude

26 In an e-mail, Rochberg affirmed this reading and interpretation.

Table 14 Positional reports implying signs or constellations

AppD	Source	Jy	Reign	Yr	Mo	Day	λ*p	phen	P	rel place	Name	xS,	S
1	D-463	–463	ARTX1	1	VI	23	182	Γ	Sat	*ar*$_2$	ABSIN	*	xS
3	H5,56B	–459	ARTX1	5 A	IV	22	112	Σ	Ven	*ar*$_2$	ALLA	*	xS
4	H5,56B	–459	ARTX1	5 A	VI	26	190	Ξ	Ven	*ina* SAG	RÍN	C	xS
6	H5,56A	–457	ARTX1	7	I	16	43	Ξ	Ven	*ina* IGI	LU (!)	*	xS
7	H5,56A	–454	ARTX1	10 A	III	26	104	Ξ	Ven	*ar*$_2$	ALLA	*	xS
8	H5,56A	–453	ARTX1	10 A	XII	27	364	Ω	Ven	*ina*	KUN^{me}	C	xS
9	H5,56A	–453	ARTX1	10 A	XII	28	363	Γ	Ven	*ina*	KUN^{me}	C	xS
11.1	D-453	–452	ARTX1	11	[XI]?	29	114		Jup	*ar*$_2$ ALLA *ina*	IGI SAG UR-A	*	xS
10.1	D-453	–452	ARTX1	11	[XI]	28	334	Σ	Mer	*ina* TIL	GU-LA	C	xS
16	H5,56B	–452	ARTX1	12	VII	22	212	Γ	Ven	*ina*	RÍN	C	xS
21	H5,56A	–449	ARTX1	15	I	6	34	Ξ	Ven	*ina*	HUN	c?	xS
23	H5,56A	–445	ARTX1	18	XII	21	363	Ω	Ven	*ina* TIL	KUN^{me}	C	xS
26	H5,56A	–441	ARTX1	23	I	4	33	Ξ	Ven	*ina*	LU	c?	xS
34	D-418	–418	DARI2	5 A	I	30	74		Jup	*ina* SAG	MAŠ-MAŠ	C	xS
35	D-418	–418	DARI2	5 A	I	30	70		Ven	*ina* SAG	MAŠ-MAŠ	C	xS
39	D-418	–418	DARI2	5 A	II	22	64		Ven	*ar*$_2$	GIGIR	*	xS
42	D-418	–418	DARI2	5 A	II	29	362		Sat	*ina* TIL	KUN^{me}	C	xS
45	D-418	–417	DARI2	5 A	XII	[24]	365	Ξ	Mer	..*q*]*it*	KUN^{me}	C	xS
46	D-418	–417	DARI2	5 A	XII	29	96		Jup	*ina* IGI	ALLA	*	xS
48	D-418	–417	DARI2	5 A	XII	29	364		Sat	*ina qit*	KUN^{me}	C	xS
49	D-418	–417	DARI2	5 A	XII2	1	364	Ω	Sat	*ina qit*	KUN^{me}	C	xS
53	D-418	–417	DARI2	5 A	XII2	29	35		Ven	*ina*	HUN-GÁ	c?	xS
57	AO 17649	–410	DARI2	13	IX	15	242	Γ	Mer	*ar*$_2$	SI$_4$	*	xS

Table 14 Continued

AppD	Source	Jy	Reign	Yr	Mo	Day	λ * p	phen	P	rel place	Name	xS,	S
59	AO 17649	−409	DARI2	13	XI	14	307	Σ	Ven	*ina* IGI	GU	*	xS
61	AB251	−409	DARI2	14	I	14	214		Moon	*šaplat*	SI GIR TAB	*	xS
64	H5,59	−396	ARTX2	8	V	?	150	Γ	Mars	*ina*	A	Name	
65	H5,59	−395	ARTX2	9	VI	?	336	Ψ	Mars	*ina*	*zib*	Name	
69	H5,59	−394	ARTX2	10 A	IV	8	123	Ω	Mars	*Ina* TIL	ALLA	xC	~S
78	H5,59	−388	ARTX2	16 U	IV	27	100	Γ	Mer	*ina* SAG	ALLA	C	xS
79	H5,59	−388	ARTX2	16 U	V	16	128	Σ	Mer	*ina* SAG	A	xC	S
80	H5,59	−388	ARTX2	16 U	VII	13	205	Γ	Mer	2 2/3k ar_2	RÍN *šá* ULÙ	*	XS
81	H5,59	−387	ARTX2	17	II	15	43	Γ	Mars	*ina*	MÚL.MÚL	xC	S
84	H5,60	−385	ARTX2	19	IV	19	18	Φ	Jup	SIG SAG	HUN (13)	*	xS
90	H5,60	−384	ARTX2	20	II	6	37	Γ	Jup	*ina* SAG	MÚL.MÚL	xC	S
101	D-384	−384	ARTX2	20 A*	IX	30	60		Sat	*ina*	GIGIR	C	xS
107	H5,60	−383	ARTX2	21*	I	16	63	Ω	Jup	ar_2	GIGIR	*	xS
108	H5,59	−383	ARTX2	21*	II	8	86	Ξ	Mer	SIG	MAŠ-MAŠ	*	xS
120	D-382	−381	ARTX2	22	X	29	337		Mer	*ina*	GU	?C	xS

S referent is sign, *xS* referent is not sign, * External position relative to star or constellation, *C* position more consistent with constellation boundary than with sign boundary, *c*? uncertain extent of constellation HUN/LU, longitude beyond Aries, *name* new form without 5th c. precedent

116°. Thus, however inaccurately, the report can only refer to the sign Cancer, and is the earliest direct evidence we possess for the introduction of the uniform zodiac.

The next report from −388 (16 ARTX2 IV 27) places the first appearance of Mercury (Γ) as morning star *ina* SAG ALLA, compared with a computed longitude for that date of 100° (10° Cnc) and computed first appearance a day earlier at 99°. This fits the constellation, which began around 96°, far better than the sign, although the latter cannot be confidently ruled out. In the following month of the same year (−388) Mercury's disappearance as morning star (Σ) is reported a occurring *ina* SAG A on a date (16 ARTX2 V 16) when Mercury was at longitude 128° (8° Leo), a day after its computed disappearance at 126°. Although further into Leo than the roughly 5° which Steele and Gray (2007, pp. 453, 454) found typical of later "ina SAG/TIL" reports, this cannot plausibly be interpreted as referring to the constellation Lion which begins at least 12° earlier with SAG A. This then is a second report, which must refer to a zodiacal sign rather than constellation.

Two subsequent reports of first appearances in Taurus, by Mars in −387 and Jupiter in −384, must also refer to zodiacal signs. In the earlier (−387) of the two reports the first appearance of Mars (Γ) is described as *ina* $\mathrm{MUL_2}$-$\mathrm{MUL_2}$ on 17 ARTX2 II 15 when Mars on that date was at 43° (13° Leo) only 2° short of α-Leo (Is-$\mathrm{le_{10}}$, the Jaw of the Bull) and more than 7° beyond the closest of the Pleiades. In the later (−384) report the first appearance (Γ) of Jupiter on 20 ARTX2 II 6 is described as *ina* SAG $\mathrm{MUL_2}$-$\mathrm{MUL_2}$, when Jupiter at longitude 37° (7° Leo) on that date had already passed the last of the Pleiades. Even had it not, the description *ina* SAG would hardly have been applied to an asterism less than 1°in extent and included among the NSs. These reports also depart from the expected practice of naming signs for their principal constellations by naming Taurus for the Stars ($\mathrm{MUL_2}$-$\mathrm{MUL_2}$) instead of either of its more extensive and traditional referents, Bull of Heaven ($\mathrm{GU_4}$-AN) or Chariot (GIGIR). Whether in response to the ambiguous boundary between HUN/LU and $\mathrm{GU_4}$-AN noted above, or to avoid confusion with the name of month II, $\mathrm{GU_4}$-UD, or some other consideration, it was a distinctive change in practice, unprecedented in earlier reports, which was evidently associated with the introduction of signs in place of constellations.

We thus have four reports beginning in −394, which refer to signs rather than constellations with negligible uncertainty. Among the rest, four marked "*" continue to utilize external referents to stars or constellations, one (−384) places Saturn *ina* GIGIR which can only mean the asterism Chariot, and two (−388 and −381) involve positions of Mercury which better fit the boundaries of constellations than of signs. Clearly, references to constellations or stars did not disappear from positional reports with the introduction of zodiacal signs, although they did become noticeably less frequent.

In summary, positional references to zodiacal signs do not appear in reports before −408 but do appear in a report for −394 and continue intermixed with references to stars and constellations for the next decade. Between these dates we have only two reports, the first being of a first appearance of Mars in −396 "*ina* A" when Mars was at 150° (30° Leo) and thus located in both the sign and the constellation, and the second in −395 when Mars's second station (Ψ) at 336° (6°Psc) is described as "*ina zib*". The significance of these reports, whose referents are otherwise ambiguous, is that

Table 15 Summary of evidence from reports of planetary positions implying references to signs or constellations

Description	<−408	>−397	Total
xS	25	7	32
S	**0**	**4**	4
Total	25	11	36
GU_4-AN	3	**1**	4
MUL_2	**0**	2	2
UR-A	3	**0**	3
A	**0**	9	9
KUN^{me}	15	**0**	15
zib	**0**	7	7

each is the earliest instance of a change in terminology describing the zodiacal entity from the convention used consistently in reference to constellations in reports before −408. Thus "A" for Leo, which first appears in the report for −396 and thereafter is consistently used in at least six subsequent reports, replaces "UR-A" which is used consistently to designate the Lion in pre-408 reports. Similarly, "*zib*" and later zib^{me}, Akkadian abbreviations for KUN^{me} (Tails) consistently replace KUN^{me} after −396, which otherwise appears exclusively in over a dozen fifth century reports.

Thus, the introduction of the zodiac appears to have been accompanied by a shift in nomenclature distinguishing the signs we know as Pisces, Taurus, and Leo from their component constellations. It is probably not accidental that the signs so affected encompass constellations that either intrude significantly into adjacent signs (Pisces and Leo) or include several asterisms as in Taurus with uncertain boundary issues. Whatever the reason, the change in terminology reflected in the first two fourth century reports in Table 14, nudges the earliest evidence for the introduction of the zodiac back a couple of years to −396, leaving an evidential gap from −408 to −397.

Table 15 summarizes the evidence from reports of planetary positions, indicating that the uniform zodiac was introduced between −408 and −397. No evidence of signs is present in fifth century reports, while both direct evidence of signs and indirect evidence from terminology appear in the earliest fourth century reports.

4.2 Other evidence

As Rochberg notes, several texts from mathematical astronomy contain computed longitudes of fifth century phenomena, which evidently refer to zodiacal signs and could be potential evidence of an earlier introduction of the zodiac. The earliest of these, sometimes known as Text S[27], contains calculated longitudes of conjunctions and associated Φ-values (among other computed quantities) for 38 solar eclipse pos-

[27] BM 36599 and its duplicate BM 36737+36850+47912 published in Aaboe and Sachs (1969, Texts B and C+D), and Aaboe et al. (1991, Text G), discussed as "Text S" in Britton (1989) and Aaboe et al. (1991, 43 n 24, pp. 69–71.)

sibilities from −474 to −456. Column Φ, however, was constructed certainly after −403 and probably after −401[28], so the text must have been written after one or both of these dates. Another text[29] contains a primitive scheme describing longitudes of Venus over a synodic cycle, probably beginning 8 Darius II (−415/4)[30], but also Φ-data and descriptions of Greek Letter phenomena for Mars from the mid-fourth century. Thus the text itself clearly dates from the fourth century and while the Venus section is probably a copy of earlier work, nothing suggests that it is contemporary with its contents[31] and consequently evidence of the introduction of the zodiac. A third text with computed longitudes from the fifth century is BM 36651 (Aaboe et al. 1991, Text E). The obverse (Text "M") contains three columns of year-numbers and longitudes of disappearances of Mercury as evening star (Ω) from 41 Artaxerxes I (-415) to 2 Artaxerxes II (−401) computed according to system A_3 (BM 36321,ACT, 816[32]). The reverse (Text "L") contains longitudes and nodal elongations of full moons for 2 saroi of lunar eclipse possibilities from 7 Darius II (-416/7) to 24 Artaxerxes II (−380). Thus with the possible, but unlikely, exception of the crude Venus scheme for −415, all of the mathematical astronomical texts containing fifth century longitudes reflecting a uniform zodiac were composed after −401 and offer no evidence of its earlier introduction.

28 Column Φ was anchored to the full moon syzygy on −403 Aug 18 (GN 7391), which ended the shortest 6-month interval between lunar eclipses since the reign of Nabonassar. Its construction also assumes a mean value for the synodic month (Britton ,1987, 1990, 1999 and 2009, 386, 397ff.) seemingly derived from an estimate that 4267m = 126007d (Britton 2002, pp. 37–39 and 2007, pp. 116–120) based on lunar eclipses separated by this interval. If systematic records of lunar eclipses (Steele 2000) began with the eclipse in 0 Nabonassar XII 14 (−746 Feb 6), the first eclipse which would have permitted an estimate of this interval occurred on 2 Artaxerxes II XI 14 (−401 Feb 2).

29 BM 36301 published in Neugebauer and Sachs (1967) as Text C with further commentary in Britton and Walker (1991, pp. 112–113).

30 Neugebauer and Sachs suggest −431 and −423 as most probable dates for the text's Venus scheme, and Britton and Walker (1991, pp. 112–113) propose −423. The text's data for Φ and Ξ, however, agree best with −415.

31 More likely it was a (not very competent) theoretical exercise anchored to a rare observation of a second station of Venus from an earlier period.

32 ACT pp. 425–428. *Excursus*. According to its colophon (ACT p. 24, Zu) the text was written by Bel-apla-iddina, son of Mušallim-Bel and descendent of Mu-še-zib, who authored a Diary for −321 and BM 33552, a fourth century scheme for Venus (Britton and Walker, 1991, pp. 110–112). Presumably this is the same Bel-apla-iddina described as the father of Marduk-šapik-zeri and grandfather of Iddin-Bel, scribe of BM 37266 (Atyp F), BM 36722 (Atyp K), BM 41004 (Atyp E), BM 33801 (ACT 811), and MNB 1856 (Atyp H). The last text describes entries of Mars into zodiacal signs explicitly as "for 5 Philip (−317)" in agreement with calculation. A Bel-apla-[...] was the father of Uballissu-Bel, author of a Diary for −361. If these were all members of of Mušezib's patriarchal line, the most compact genealogy would encompass 6 generations from Mušezib (420–380) to Iddin-Bel (320–280), place Mušallim-Bel and Uballissu-Bel in the same generation (380–340), have MNB 1856 written not long after its contents near the start of Iddin-Bel's career and place Bel-apla-iddina (II) towards the end of his career when he wrote D-361 "for his good health". A large number of these texts, including BM 36651 are from the unique archive accessioned by the BM on June 17, 1880, which was excavated by Rassam in the fall of 1879 from a house on the inner city wall close by the southwest corner of the Esagila complex (Reade 1986, xix). Many of them, including BM 36651, are also copies combining unrelated elements of older texts, reflecting an archival activity on the part of family members.

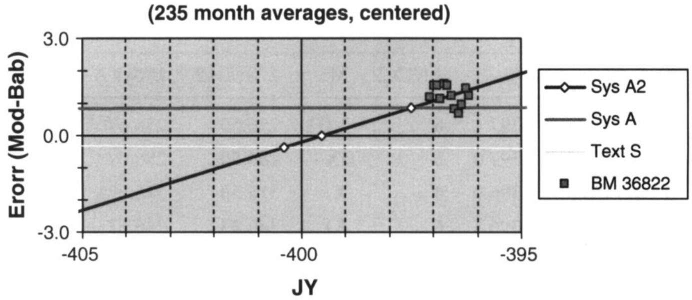

Fig. 3 Solar model errors

4.3 BM 36822

A text that does shed light on the issue is BM 36822 (Aaboe and Sachs 1969, Text A), which presents a variety of data for successive new moons during years 6 and 7 of Artaxerxes II (−397). The text has many unusual elements, which I shall discuss more fully in a subsequent paper. For now what is of interest is its unique scheme for the longitude of conjunction, which reflects the methodology of System A, but with different parameters, to wit:

$$\begin{aligned} \Pi &= 12{,}23\ (743)\ \text{months} = 1{,}0\,(60)\ \text{years};\\ \text{thus 1 year} &= 12;23\ \text{months}\\ w_1 &= 30^\circ/\text{m};\ w_2 = 28;30^\circ/\text{m};\\ w_2/w_1 &= 17/18;\ \text{Solar apogee (A)} = 81;15^\circ \end{aligned}$$

The scheme is the earliest example we have of a system A scheme in lunar theory, by nearly a century. It differs from the standard scheme chiefly in its period, which is convenient, but remarkably inaccurate, and the ratio 17:18 of its velocities and underlying intervals. Otherwise it parallels the standard scheme precisely in methodology and interestingly closely in the longitude of its effective apogee (A).

The text's longitudes, shown in Table 16, confirm its dating, established tentatively by Aaboe and Sachs (1969) from accompanying Φ-values, but with the caveat that these were inconsistent with the normal correspondence between Φ-values and dates by 2 and 3 months on obverse and reverse respectively. However, as may be seen in Figure 3, the scheme's ("Sys A2") average error grows at the rapid rate of 4° per decade, ruling out any realistic possibility of an alternative date. Furthermore, the scheme's individual longitudes, whose errors are shown in small squares along the Sys A2 trend-line, are remarkably close to System A's whose average error intersects with Sys A2 barely a year earlier. All these suggest that the text was probably composed not more than shortly after the date of its contents, by which time the zodiac must have been in place. This would seem to confirm the existence of the zodiac by at least −396 and probably somewhat earlier.

We thus have converging evidence from reports of planetary positions, zodiacal nomenclature and orthography, and the A2 longitude scheme in BM 36822 that the

Table 16 BM 36833: longitudes of conjunction compared

Y	M	D	GN2	JY	ARTX2	M	λ*Sys A2	λ*Sys A	λ*Txt S	Modern
−398	12	5	7456.5	−397.1	**6**	**VIII**	256.50	256.67	257.67	257.70
−397	1	4	7457.5	−397.0	**6**	**IX**	**286.50**	286.67		288.05
−397	2	3	7458.5	−396.9	**6**	**X**	**316.50**	316.67		318.03
−397	3	4	7459.5	−396.8	**6**	**XI**	**346.33**	346.67		347.45
−397	4	3	7460.5	−396.7	**6**	**XII**	**14.67**	15.44		16.26
−397	5	2	7461.5	−396.7	**7A**	**I**	**43.00**	43.56		44.55
−397	6	1	7462.5	−396.6	**7A**	**II**	**71.33**	71.69	72.67	72.55
−397	6	30	7463.5	−396.5	**7A**	**III**	**99.67**	99.81		100.50
−397	7	29	7464.5	−396.4	**7A**	**IV**	**128.00**	127.94		128.67
−397	8	28	7465.5	−396.3	**7A**	**V**	**156.33**	156.06		157.29
−397	9	26	7466.5	−396.3	**7A**	**VI**	**185.00**	185.60		186.48
−397	10	26	7467.5	−396.2	**7A**	**VII**	**215.00**	215.60		216.21

zodiac was introduced between −408 and −397. Notable events occurring within this interval include:

- 403 Aug 18 (1 ARTX2 V 13 = GN2 7391): a lunar eclipse concluding the shortest interval (176 days $+16.7^{\text{uš}}$) between eclipses separated by 6 months since –746, used by the author of System A to anchor the theory of lunar anomaly to specific syzygies by linking that syzygy to the Φ-value (2, 8; 53, $20^{\text{uš}}$ ↓) associated with the minimum of W, the function describing the variation of 6 months due to lunar anomaly.
- 401 Jan 15–17 (2A ARTX2 X 26–28): earliest horoscope in BM 53282[33] describing planetary positions as in E_2 ${}^{\text{itu}}$MN (month name) similar to the convention used in BM 36609.
- 401 Jan 18 (2A ARTX2 X 28 = GN2 7048.5): the only total (magnitude 1.04), non-annular, solar eclipse visible at Babylon since before –746. At mid-eclipse Mercury was just past superior conjunction 7.3° east of the sun and Venus was 12.3° west of the sun. Unless obscured by weather this had to have been a dramatic event. The next such eclipse occurred in –135.

[33] Published in Hunger (1999). Brown (2005) notes five implicit birth-dates and proposes the date 10u ARTX2 for the latest birth-date in place of 16U assumed by Hunger on the evidence of BM 36910. Computations suggest reading month VI for the damaged month in obv 1. The text contains planetary and lunar positions for five birth-dates ranging from 2A ARTX2 (−401) to 10u ARTX2 (−394), the latter reflecting a hitherto unattested instance of a VI_2intercalation (contra BM 36910). Positions of the moon and planets are described as "ina E_2 MN (month name)", as in BM 36609 and clearly refer to uniform signs which reflect the same norm and implicit $\Delta\lambda^*$ as the Babylonian sidereal zodiac generally. Thus there appears to have been an alternative, perhaps competing, terminology for describing zodiacal signs, based on the underlying schematic calendar, which persisted until at least −394.

- –401 Feb 2 (2A ARTX2 XI 14 = GN2 7409): the first lunar eclipse visible in Babylon 4267 months after an eclipse occurring within the known historical record, specifically the eclipse on –746 Feb 6 (0 NBNSR XII 14 = GN2 3142). Since column Φ depends on a month-length derived from this interval, Φ was constructed after this date.
- –401 Feb 15 (2A ARTX2 XI 28): Mercury's disappearance in the west (Ω) at $\lambda^* = 340.7°$ and the last entry on BM 37053 obv. (Text M) at $\lambda^* = 343.9°$; hence Text M was composed after this date.
- –401 Jul 29 (3 ARTX2 IV 14 = GN2 7415): the second lunar eclipse visible in Babylon 4267 months after an eclipse during the reign of Nabonassar, in this case the eclipse on –746 Aug 2 (1 NBNSR VI 14 = GN2 3148).
- –398 Nov 21 (6 ARTX2 VIII 14 = GN2 7456): the next lunar eclipse visible in Babylon 4267 months after an eclipse during the reign of Nabonassar, in this case the eclipse on –743 Nov 25 (4 NBNSR IX 14 = GN2 3189); $\lambda^*_{\mathrm{m}} = 63.1°$ (cf A = 61.7°, A2 = 61.5°).
- –398 Dec 5 (6 ARTX2 VIII 29 = GN2 7456.5): the first preserved month of BM 36822.
- –397 May 2 (7A ARTX2 I 29 = GN2 7461.5): the earliest date BM 36822 could have been written.
- –397 May 16 (7A ARTX2 II 14 = GN2 7462): the fourth lunar eclipse visible in Babylon 4267 months after an eclipse during the reign of Nabonassar in this case the eclipse on –742 May 20 (5 NBNSR III 14 = GN2 3189) at $\lambda^*_{\mathrm{m}} = 237.8°$ (cf A = 237.6°s, A2 = 237.2°).
- –397 Oct 26 (7A ARTX2 VII 30 = GN2 7467.5): the last preserved month of BM 36822

In short, within the interval in which the zodiac appears to have been introduced we have: the earliest horoscope indisputably utilizing uniform signs; followed a few days later by an unprecedented and dramatic total solar eclipse 1–3 days later; followed by the construction of column Φ and the theory of lunar anomaly in System A; and finally a lunar eclipse in −397 in which the moon's center at mid-eclipse was $^1/_2°$ directly above the NS θ-Oph, for which the longitudes computed by Systems A, A2 and modern theory are in suggestively close agreement.

In conclusion, the zodiac could have been introduced at any time during the evidential gap from −408 to −397. It is not impossible that its introduction was motivated by the development of individual horoscopes near the beginning of this gap. However, it seems more likely that its introduction was related to the flurry of activity and events between −401 and −397, possibly triggered by the total solar eclipse early in −401, and including the invention of elements of the System A lunar theory which required a consistent scale for the calculation of positions. On balance, the uniform zodiac appears to have been introduced within very few years of −400.

Appendices

Appendix A. Babylonian and Ptolemy's sidereal longitudes compared

Core	Modern (−500): Δλ* = 10.00				Babylonian			Ptolemy		Ptol
#	Name	λ*(mod)	β	Mag	λ* (Bab)	Source	δΔλ*	+2;20		δΔλ*
1	**η Psc**	**2.10**	**5.24**	**3.6**	**3.33**	**rsw**	**1.23**	**3**		**0.90**
2	β Ari	9.28	8.31	2.6	10	grk	0.72	10		0.72
3	α Ari	12.98	9.77	2.0	13	ph+,grk	0.02	13		0.02
4	**17 Tau**	**34.70**	**3.91**	**3.7**	**33**	**pjh**	**−1.70**	**34**	**30**	**−0.20**
5	α Tau	45.03	−5.64	1.0	45	grk	−0.03	45		−0.03
6	β Tau	57.85	5.18	1.7	57	ph+,grk	−0.85	57		−0.85
7	ζ Tau	60.06	−2.52	3.0	60	pjh,grk	−0.06	60		−0.06
8	η Gem	68.71	−1.22	3.4				68	50	0.12
9	μ Gem	70.58	−1.15	2.9				70	50	0.25
10	γ Gem	74.39	−7.02	2.0				74	20	−0.05
11	α Gem	85.63	9.91	1.9	85	pjh+	−0.63	85	40	0.04
12	**β Gem**	**88.90**	**6.49**	**1.2**	**90**	**pjh**	**1.10**	**89**		**0.10**
13	δ Cnc	103.97	−0.03	3.9				103	40	−0.30
14	ε Leo	115.97	9.52	3.0	115	pjh+	−0.97	115	30	−0.47
15	α Leo	125.27	0.36	1.4	125	pjh+	−0.27	124	50	−0.44
16	ρ Leo	131.67	0.02	3.8				131	30	−0.17
17	**θ Leo**	**138.66**	**9.64**	**3.3**	**142**	**ajs**	**3.34**	**138**	**40**	**0.00**
18	β Vir	151.89	0.64	3.6	151	ajs,pjh	−0.89	151	20	−0.56
19	γ Vir	165.76	2.96	2.9	165	ajs	−0.76	165	30	−0.26
20	**α Vir**	**179.15**	**−1.89**	**1.0**	**178**	**ajs,pjh**	**−1.15**	**179**		**−0.15**
21	α Lib	200.41	0.63	2.7	200	ajs	−0.41	200	20	−0.08
22	β Lib	204.61	8.74	2.6	205	ajs,pjh	0.39	204	30	−0.11
23	β Sco	218.46	1.30	2.6				218		−0.46
24	α Sco	225.05	−4.25	1.1	225	grk	−0.05	225		−0.05
25	α Oph	236.67	−1.52	3.2	237	pjh	0.33	236	40	0.00
26	**β Cap**	**279.30**	**4.87**	**3.1**	**281.50**	**rsw**	**2.20**	**279**	**40**	**0.37**
27	**γ Cap**	**297.05**	**−2.35**	**3.7**	**298.50**	**rsw**	**1.45**	**297**	**10**	**0.12**
28	**δ Cap**	**298.80**	**−2.40**	**2.9**	**300**	**pjh,rsw**	**1.20**	**298**	**30**	**−0.30**
						Avg	0.19	Avg		−0.07
						Avedev	0.93	Avedev		0.25

Major Babylonian NS errors shown in bold

Appendix B. Sign-entry data from Almanacs

Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$
SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b	
147	I	27		V	e	90	79.11	195	VI	8		J	e	240	229.10	233	X	6		J	e	330	319.46
147	II	27		V	e	120	106.63	200	III	21		E	m	90	79.32	233	X	25		V	m	270	257.43
147	III	20		M	e	180	170.11	200	IX	21		V	m	270	262.82	233	X	28		M	m	270	261.72
147	V	15		M	e	210	204.26	200	X	26		M	e	30	19.08	233	XII	1		E	m	330	316.31
147	VI	29		M	e	240	235.25	201	I	18		E	e	60	50.11	233	XII	28	d	V	m	330	324.95
147	VII	5		V	m	150	138.56	201	II	8	d	M	e	90	80.38	234	I	4	r	S	e?	210	199.65
147	VIII	5		V	m	180	171.08	201	V	4		V	e	180	170.47	234	I	17		M	m	330	320.60
147	VIII	8		M	e	270	264.33	201	V	22		J	m	90	79.84	234	I	20		V	m	360	350.68
147	VIII	29		J	m	240	230.15	201	VI	1		V	e	210	200.87	234	I	22		E	e	60	50.06
147	IX	1		V	m	210	200.53	201	VII	1		V	e	240	230.69	234	II	12		J	m	360	347.45
147	IX	14		M	e	300	291.62	201	VIII	17		M	m	210	203.00	234	II	16		V	m	30	20.35
147	IX	26		V	m	240	230.86	201	IX	12	r	J	e	90	79.31	234	II	28		M	m	360	349.58
147	X	21		V	m	270	260.30	201	IX	25		E	e	300	285.90	234	III	12		V	m	60	51.62
147	X	24		M	e	330	321.75	201	IX	29		M	m	240	233.10	234	IV	7		V	m	90	80.83
147	XI	14		V	m	300	288.60	201	XI	29	r	S	e	180	170.72	234	IV	17		M	m	30	20.63
147	XII	7		M	e	360	353.16	201	XII	17		M	m	300	289.60	234	V	2		V	m	120	111.63
147	XII	9		V	m	330	318.13	201	XII	29		V	m	330	317.79	234	V	29		S	e	210	198.57
183	I	14		V	m	360	348.17	209	I	19		V	e	60	48.99	234	VI	28	r	J	e	360	347.95
183	IV	8		E	e	120	109.47	209	II	5		M	e	150	138.78	234	VII	13		E	m	180	172.88
183	IV	30		E	e	150	141.46	209	II	15		V	e	90	79.40	234	VIII	8		V	e	240	229.99
183	VI	14		V	e	180	170.93	209	II	30		E	m	60	53.90	234	IX	3		V	e	270	260.04
183	VI	16		E	m	150	141.01	209	III	10		V	e	120	109.56	234	IX	28		V	e	300	291.19

Appendix B. continued

Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$
SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b	
183	VIII	2		V	e	240	229.41	209	IV	5		M	e	150	138.15	234	X	1		E	e	300	284.41
183	VIII	25		V	e	270	257.89	209	IV	5		V	e	180	170.38	234	X	15		J	e	360	348.60
183	VIII	27		M	e	330	318.11	209	V	21		M	e	210	200.95	234	XI	16		V	e	360	348.71
183	IX	10		E	e	270	258.69	209	VI	1		V	e	210	201.02	234	XII	1		M	e	60	50.87
183	IX	21		V	e	300	288.57	209	VI	30		V	e	240	230.41	234	XII	13		V	e	30	19.32
183	IX	22		S	e	300	290.03	209	IX	18		M	e	300	288.50	236	I	25		M	m	360	350.06
183	X	15		M	e	330	317.46	209	X	9		E	m	270	258.51	236	I	26		M	m	360	350.80
183	X	15		V	e	360	348.14	209	X	25		S	m	270	259.44	236	II	26		V	e	90	78.01
183	X	20		E	m	270	258.37	209	X	27		M	m	270	256.48	236	II	29		J	m	60	48.86
183	XI	13		V	e	360	348.62	209	X	28		V	e	330	319.72	236	III	9		M	m	30	20.72
183	XII	8		M	e	30	21.27	209	XI	1		E	m	300	287.90	236	III	21		E	e	120	108.50
183	XII	14		E	e	360	347.27	209	XI	28		V	m	300	285.99	236	III	21		V	e	120	108.68
183	XII	15		J	m	270	259.32	209	XII	5		E	e	360	349.16	236	III	22		E	e	120	110.17
183	XII	16		V	e	30	21.66	209	XII	28		V	m	330	318.11	236	IV	15		V	e	150	138.08
183	XII2	24	d	M	e	60	50.79	233	III	17		M	e	120	111.04	236	IV	25		M	m	60	50.35
195	II	2		S	e	90	80.04	233	IV	4		V	e	150	144.13	236	V	11		V	e	180	169.77
195	III	30		M	m	90	80.72	233	VII	28		E	m	210	202.13	236	VI	3		E	m	150	143.41
195	IV	19		E	e	150	139.72	233	VIII	4		M	m	210	201.02	236	VI	8		V	e	210	201.19
195	V	23		V	m	120	107.27	233	IX	9	r	V	m	240	230.23	236	VI	29		M	m	90	80.60
236	VII	2		V	e	240	229.80	254	XII2	18		E	e	30	21.30	355	VI	14		M	m	150	140.42
236	VII	28	d	V	e	270	259.93	254	XII2	26		V	m	360	349.27	355	VI	21		V	m	150	140.47
236	VIII	25	r	M	e	90	80.99	282	IX	1		M	m	240	231.55	355	VII	16		V	m	180	170.75

Appendix B. continued

Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$
SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b	
236	VIII	26		V	e	300	289.06	297	VI	12		V	e	210	199.79	355	VIII	11		V	m	210	200.44
236	IX	4		S	m	240	229.64	300	II	2		M	m	360	348.74	355	IX	5		V	m	240	230.38
236	X	5		V	e	330	318.39	300	II	15		V	e	60	48.15	355	IX	8		E	m	240	233.39
236	X	8		E	m	270	263.35	300	III	11		V	e	90	78.78	355	IX	19		M	m	210	199.21
236	X	24	r,d	V	e	330	319.13	300	III	25		J	e	180	169.96	355	IX	29		E	m	270	260.36
236	XI	28		E	e	360	349.35	300	IV	6		V	e	120	109.34	355	IX	29		V	m	270	261.58
236	XII	14		M	e	90	78.94	300	V	3		M	m	60	50.60	372	I	2		V	e	30	17.61
236	XII	30		V	m	330	318.70	300	VII	20		E	m	180	170.60	372	I	4	r	J	e	210	200.27
244	II	22		E	e	90	79.89	301	III	14		V	m	60	51.16	372	I	15		M	e	60	48.81
244	II	25		V	e	90	79.79	301	IV	16		E	e	150	139.33	372	II	22		V	e	90	78.84
244	III	14		E	e	120	112.21	301	V	4		V	m	120	110.39	372	III	18		V	e	120	109.24
244	IV	15		V	e	150	139.81	301	V	4		M	e	180	170.17	372	IV	13		V	e	150	139.39
244	IV	27		E	m	120	109.12	301	V	8	r	S	e	300	289.43	372	V	9		V	e	180	169.18
244	V	2		M	m	120	110.23	301	V	28		V	m	150	140.13	372	V	14		J	e	210	199.17
244	VI	21		M	m	150	140.43	305	II	21		V	e	90	79.53	372	V	20		E	e	180	166.54
244	IX	4		E	m	240	230.60	305	II	26		E	e	90	79.25	372	VI	5		V	e	210	199.51
244	IX	8		J	e	300	288.79	305	III	20	d	M	e	120	113.93	372	VI	11		M	m	150	141.39
244	XI	29		M	m	240	230.59	305	III	26		V	e	180	171.35	372	VI	12		M	m	150	142.03
244	XII	29		V	m	330	319.06	305	IV	14		V	e	150	140.56	372	VII	3		V	e	240	229.71
245	II	29		V	m	30	19.26	305	V	16		M	e	210	200.88	372	VII	8	d	E	m	180	169.65
245	III	26		V	m	60	50.29	305	VI	12		V	e	210	200.41	372	VII	28		M	m	180	171.12
245	IV	25	x	V	m	150	83.54	305	VI	28		M	e	240	229.80	372	VIII	3		V	e	270	259.53

Appendix B. continued

Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$
SE	M	D	**	P	T	λ^*-b		SE	M	D	**	P	T	λ^*-b		SE	M	D	**	P	T	λ^*-b	
245	V	7		E	m	120	112.24	305	VIII	16		E	e	210	199.40	372	IX	13	d	M	m	210	200.55
245	V	17	d	V	m	120	110.29	305	IX	16		M	e	300	288.87	372	X	12		J	m	240	229.18
245	IX	24		J	e	330	318.73	305	X	10		V	m	240	226.25	372	XI	12		E	m	300	287.34
247	I	22		V	m	30	17.98	305	X	26		M	e	330	319.02	372	XII	2		V	m	300	286.93
247	I	25		J	m	30	17.83	305	XI	12		V	m	270	258.51	372	XII	15		M	m	270	260.12
247	IV	6	x	E	m	90	98.46	305	XI	21		E	e	360	349.37	372	XII	16		M	m	270	260.76
247	V	23		E	e	180	173.07	305	XI	21		J	e	300	291.65	385	I	6		V	e	60	49.74
247	V	27		V	e	180	169.13	305	XII	7		M	e	360	349.05	385	I	14		E	e	60	50.64
247	VIII	10		V	e	270	258.13	342	I	1		V	e	60	50.67	385	II	2		V	e	90	79.57
248	I	29	x	E	e	90	44.46	342	XI	14		V	m	300	289.05	385	II	28		V	e	120	109.86
248	II	29		V	m	30	16.81	342	XII	12		V	m	330	322.16	385	IV	27		V	e	180	172.35
248	VI	5		V	m	120	109.86	347	VIII	20		E	e	270	256.28	385	V	12		M	m	120	110.89
248	X	7		V	m	270	261.15	355	I	14		J	e	60	49.42	385	VII	2		M	m	150	140.54
248	X	24		E	m	270	261.75	355	III	5	r	V	m	60	48.00	385	VII	4		E	m	180	172.23
248	XII2	2		M	m	300	289.99	355	III	13	d	V	m	60	49.62	385	IX	1		V	m	210	201.95
254	I	21		V	e	60	49.47	355	IV	23		V	m	90	77.69								

Appendix C. Sign-entry data from Diaries

Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$
SE	M	D	**	P	T	λ^*-b		SE	M	D	**	P	T	λ^*-b		SE	M	D	**	P	T	λ^*-b	
99	X	9		V	e	240	232.51	174	II	30		M	m	30	20.61	204	XII	23		V	m	330	315.54
107	I	10		V	e	60	50.05	174	IV	16		M	m	60	50.78	204	XII	28		M	e	90	78.98
108	VIII	23		V	e	300	288.79	174	X	5		V	m	240	231.41	206	I	2		V	e	60	50.19
118	VII	5		M	m	150	140.24	175	VI	30		S	e	210	200.05	206	I	3		M	m	360	348.32
118	X	15		M	m	210	201.34	175	XII2	16		E	e	30	23.88	206	I	27		V	e	90	79.66
118	XII	9		V	m	300	289.33	177	VI	9		E	m	150	142.19	206	II	13		E	e	90	81.22
118	XII	15		E	e	360	354.23	177	VII	4		V	e	240	229.18	206	II	24		V	e	120	109.31
122	II	12		V	m	30	18.46	177	XII	7		V	m	300	288.79	208	II	6		E	e	60	51.51
122	II	6		M	e	90	81.14	179	VII	1		V	m	150	140.79	215	I	7		V	m	360	350.26
125	XI	5		V	m	330	316.71	179	VII	28		V	m	180	171.15	215	IX	14		V	e	300	289.18
128	IV	11	x	E	m	90	92.58	179	VII	21		M	e	270	259.54	216	I	6		E	e	30	22.61
129	VIII	12		V	e	270	257.37	182	VI	14		M	m	150	141.08	217	I	18		V	e	60	49.55
129	VIII	10	r	S	e	360	349.08	186	V	12		E	m	120	109.44	218	V	7		V	m	120	112.57
129	XI	18	r	M	e	150	138.07	186	I	2		V	m	330	317.17	221	XI	7		J	e	330	318.91
130	IV	3		V	m	90	81.07	186	I	29		V	m	360	348.08	221	XI	13		V	e	330	319.68
130	IV	15		J	m	90	78.76	187	II	13		E	e	90	79.28	224	VI	10		V	m	120	109.76
130	IV	26	x	E	e	150	152.79	187	III	15	r	V	m	120	111.87	224	XII2	21		V	e	30	19.48
133	V	11		M	m	120	111.01	187	IX	17		V	m	240	230.77	225	II	11		V	e	90	80.45
133	XII	26		V	e	30	21.41	187	X	11		V	m	270	260.37	225	IV	27		E	m	120	112.43
133	XII	7		E	m	330	314.19	188	III	8		V	e	90	78.31	226	X	23		V	e	330	319.06
138	X	15		V	e	330	319.50	188	V	23		V	e	180	169.18	226	X	23		M	e	330	319.24
138	X	20		J	e	330	320.12	189	II	7		M	m	360	347.02	228	III	23		V	e	120	108.12

Appendix C. Continued

Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$	Text							$\lambda_t - p(-500)$
SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b		SE	M	D	**	P	T	λ*-b	
155	VIII	29		V	m	210	200.92	189	VII	8		M	m	90	79.04	229	X	19		E	m	270	258.48
157	IV	15		V	m	90	81.80	192	II	22		M	e	150	140.63	229	X	17		V	e	300	290.30
158	V	6		V	e	180	171.32	193	VII	3		V	e	240	230.91	229	XII2	1		V	e	30	19.22
162	VII	29		M	e	270	261.60	194	XI	26		V	e	360	349.96	234	II	16		V	m	30	20.36
167	VIII	7		M	e	180	170.20	194	XII	10		M	e	360	346.12	234	III	12		V	m	60	51.61
167	VIII	22		E	m	210	205.53	199	VII	26		M	m	180	170.63	234	IV	7		V	m	90	80.83
170	III	20		M	m	360	346.93	200	I	14		E	e	60	52.03	234	IV	16		M	m	30	20.05
171	I	19		M	e	90	81.05	200	II	10		M	m	330	315.67	234	V	2		V	m	120	111.62
171	I	21		V	e	90	78.42	203	I	16		V	e	90	78.47	234	VII	13		E	m	180	172.87
171	VII	3		V	m	150	140.68	203	IV	12		E	e	150	141.75	234	XI	15		E	m	300	287.02
171	VII	21		J	e	240	229.16	204	VIII	3		E	e	240	232.71	238	III	23		M	m	60	50.62
171	X	28		M	m	270	260.35	204	IX	13		E	m	240	229.35	239	**VII**	18	m	V	e	240	229.34
171	XI	7		V	m	300	287.71	204	XII	2	r	V	m	330	316.76								

Appendix D. Positional reports: −463 to −429

Row	Source	Reign	Yr	Mo	Day	JD	Jy	Jm	d	h	λ*p	phen	P	rel place	Name	*,C,	(x)S	Calc date, λ*p
1	D-463	ARTX1	1	VI	23	1552220	−463	SEP	30	sr	182	Γ	Sat	$^{ar}2$	ABSIN	*	xS	VI 27 @ 182
2	H5,56B	ARTX1	4	VII	13	1553331	−460	OCT	15	ss	222	Ω	Ven	*ina*	GÍR-TAB			VII 12 @ 223
3	H5,56B	ARTX1	5 A	IV	22	1553606	−459	JUL	17	sr	112	Σ	Ven	$^{ar}2$	ALLA	*	xS	IV 21 @ 111
4	H5,56B	ARTX1	5 A	VI	26	1553669	−459	SEP	18	ss	190	Ξ	Ven	*ina* SAG	RÍN		xS	VI 24 @ 187
5	H5,56A	ARTX1	6	XI	4	1554179	−457	FEB	10	sr	316	Σ	Ven	*ina*	GU			XI 4 @ 316
6	H5,56A	ARTX1	7	I	16	1554250	−457	APR	22	ss	43	Ξ	Ven	*ina* IGI	LU!	*	xS	I 13 @ 39
7	H5,56A	ARTX1	10 A	III	26	1555411	−454	JUN	26	ss	104	Ξ	Ven	$^{ar}2$	ALLA	*	xS	III 27 @ 106
8	H5,56A	ARTX1	10 A	XII	27	1555678	−453	MAR	20	ss	364	Ξ	Ven	*ina*	KUN^{me}		xS	XII 26 @ 365
9	H5,56A	ARTX1	10 A	XII	28	1555679	−453	MAR	21	sr	363	Ω	Ven	*ina*	KUN^{me}		xS	XII 27 @ 364
10	D-453	ARTX1	11	X [XI]$^{?}$	28	1556005	−452	FEB	10	sr	301	Γ	Mer	ina TIL	GU-LA	date err		XI 30 @337
11	D-453	ARTX1	11	X	29	1556006	−452	FEB	11	ss	116	Σ	Jup	ALLA *ina* IGI	SAG UR-A	date err		XI 30 @ 337
12	D-453	ARTX1	11	X	29	1556006	−452	FEB	11	ss	335		Ven	*ina*	KUN^{me}			Jup XI better
13	D-453	ARTX1	11	X	29	1556006	−452	FEB	11	ss	298		Sat	*ina*	MÁŠ			XI better for J
14	D-453	ARTX1	11	X$^{?}$	29 $^{?}$	1556006	−452	FEB	11	ss	301		Mer	*ina*	GU			V, S fits X
10.1	D-453	ARTX1	11	[XI]	28	1556034	−452	MAR	11	sr	334	Σ	Mer	*ina* TIL	D		xS	contrag?-Mer
11.1	D-453	ARTX1	11	[XI]$^{?}$	29	1556035	−452	MAR	12	ss	114		Jup	*ár* ALLA *ina*	IGI SAG UR-A	*	xS	?-Mer in XI
15	H5,56B	ARTX1	12	VII	9	1556251	−452	OCT	13	ss	219	Ω	Ven	*ina*	GÍR-TAB			VII 7 @ 220
16	H5,56B	ARTX1	12	VII	22	1556264	−452	OCT	26	sr	212	Γ	Ven	*ina*	RÍN		xS	VII 22 @ 212
17	H5,56B	ARTX1	13 A	IV	20	1556527	−451	JUL	16	sr	111	Σ	Ven	*ina*	ALLA			IV 17 @ 107
18	H5,56B	ARTX1	13 A	VI	24	1556590	−451	SEP	17	ss	189	Ξ	Ven	*ina*	RÍN			VI 21 @ 185
19	H5,56A	ARTX1	14	II	8 $^{?}$	1556841	−450	MAY	26	ss	73	Ω	Ven	*ina*	MAŠ-MAŠ			II 8 @ 72
20	H5,56A	ARTX1	14	II	21	1556854	−450	JUN	8	sr	65	Γ	Ven	*ina*	MAŠ-MAŠ			II 18 @ 66
21	H5,56A	ARTX1	15	I	6	1557164	−449	APR	14	ss	34	Ξ	Ven	*ina*	HUN	?C	xS	I 8 @ 36

Appendix D. Continued

Row	Source	Reign	Yr	Mo	Day	JD	Jy	Jm	d	h	λ*p	phen	P	rel place	Name	*,C,	(x)S	Calc date, λ*p
22	H5,56A	ARTX1	18	III	18	1558327	−446	JUN	20	ss	98	Ξ	Ven	*ina*	ALLA			III 23 @ 104
23	H5,56A	ARTX1	18	XII	21	1558596	−445	MAR	16	ss	363	Ω	Ven	*ina* TIL	KUN^{me}		xS	XII 21 @ 363
24	H5,56A	ARTX1	18	XII	26	1558601	−445	MAR	21	sr	360	Γ	Ven	*ina* TIL	KUN^{me}			XII 22 @ 362
25	H5,56B	ARTX1	21 A	VI	16	1559506	−443	SEP	11	ss	182	Ξ	Ven	*ina* TIL	AB-SIN$_2$			VI 16 @ 182
26	H5,56A	ARTX1	23	I	4	1560085	−441	APR	13	sr	33	Ξ	Ven	*ina*	LU	?C	xS	I 5 @ 34
27	H5,56A	ARTX1	26	XII	18	1561516	−437	MAR	14	ss	360	Ω	Ven	*ina*	KUN			XII 18 @ 360
28	H5,56A	ARTX1	26	XII	21	1561519	−437	MAR	17	sr	358	Γ	Ven	*ina*	KUN^{me}			XII 19 @ 359
29	H5,56A	ARTX1	30	XII	28	1563003	−433	APR	9	ss	29	Ξ	Ven	*ina*	*GU$_4$−AN*			I 1 @ 32
30	H5,56	ARTX1	34	III	19 ?	1564175	−430	JUN	24	ss	104	Ξ	Ven	*ina*	ALLA			III 15 @ 99
31	H5,56	ARTX1	34	XII	13	1564435	−429	MAR	11	ss	359	Ω	Ven	*ina*	KUN^{me}			XII 14 @ 358
32	H5,56	ARTX1	38A	XI	20?	1565860	−425	FEB	3	sr	309	Σ	Ven	*ina*	GU			XI 19@308
33	H5,56	ARTX1	38A	XII2	25	1565924	−425	APR	8	ss	28	Ξ	Ven	*ina*	LU			XII2@29
34	D-418	DARI2	5A	I	30	1568497	−418	APR	24	ss	74		Jup	*ina* SAG	MAŠ-MAŠ		xS	
35	D-418	DARI2	5A	I	30	1568497	−418	APR	24	ss	70		Ven	*ina* SAG	MAŠ-MAŠ		xS	
36	D-418	DARI2	5A	I	30	1568497	−418	APR	24	ss	137		Mars	*ina*	UR-A			
37	D-418	DARI2	5A	I	30	1568497	−418	APR	24	ss	357		Sat	*ina*	KUN^{me}			
38	D-418	DARI2	5A	I	29	1568496	−418	APR	23	ss	54	Ω	Mer	*ina*	GU$_4$-AN			II 5@53
39	D-418	DARI2	5A	II	22	1568519	−418	MAY	16	sr	64		Ven	*ar$_2$*	GIGIR	*	xS	
40	D-418	DARI2	5A	II	29	1568527	−418	MAY	23	ss	80		Jup	*ina*	MAŠ-MAŠ			
41	D-418	DARI2	5A	II	29	1568527	−418	MAY	23	ss	150		Mars	*ina qit*	UR-A			
42	D-418	DARI2	5A	II	29	1568527	−418	MAY	23	ss	362		Sat	*ina* TIL	KUN^{me}		xS	
43	D-418	DARI2	5A	III	29	1568556	−418	JUN	22	sr	56		Ven	*ina*	^{múl}GIGIR			
44	D-418	DARI2	5A	XI	20	1568784	−417	FEB	5	sr	312	Σ	Ven	*ina*	GU			XI 15@306

Appendix D. Positional Reports (cont'd.): −425 to −409

Row	Source	Reign	Yr	Mo	Day	JD	Jy	Jm	d	h	λ*p	phen	P	rel place	Name	*,C,	(x)S	Calc date, λ*p
45	D-418	DARI2	5A	XII	[24]	1568817	−417	MAR	10	ss	365	Ξ	Mer	*..q]it*	$\mathrm{KUN}^{\mathrm{me}}$		xS	XII 24@365
46	D-418	DARI2	5A	XII	29	1568822	−417	MAR	15	ss	96		Jup	*ina* IGI	ALLA	*	xS	
47	D-418	DARI2	5A	XII	29	1568822	−417	MAR	15	ss	14		Mer	*ina*	HUN-GÁ			
48	D-418	DARI2	5A	XII	29	1568822	−417	MAR	15	ss	364		Sat	*ina qit*	$\mathrm{KUN}^{\mathrm{me}}$		xS	
49	D-418	DARI2	5A	XII2	1	1568823	−417	MAR	16	ss	364	Ω	Sat	*ina qit*	$\mathrm{KUN}^{\mathrm{me}}$		xS	XII26@365
50	H5,56	DARI2	5A	XII2	$20^{?}$	1568842	−417	APR	4	ss	23	Ξ	Ven	*ina*	LU			XII2 23@27
51	D-418	DARI2	5A	XII2	29	1568851	−417	APR	13	ss	99		Jup	*ina* SAG	ALLA			
52	D-418	DARI2	5A	XII2	29	1568851	−417	APR	13	ss	35		Ven	*ina*	HUN-GÁ	?C	xS	
53	AO17649	DARI2	13	IV	30	1571509	−410	JUL	23	sr	108	Γ	Sat	*ina*	ALLA			IV 30@107
54	AO17649	DARI2	13	VII	22	1571591	−410	OCT	13	ss	322	Ψ	Jup	*ina*	GU			VII 21@322
55	AO17649	DARI2	13	IX	15	1571643	−410	DEC	4	sr	242	Γ	Mer	ar_2	SI_4	*	xS	IX 14@242
56	AO17649	DARI2	13	XI	2	1571689	−409	JAN	19	sr	292	Σ	Mer	*ina*	MÁŠ			X 29@288
57	AO17649	DARI2	13	XI	14	1571701	−409	JAN	31	sr	307	Σ	Ven	*ina* IGI	GU	*	xS	XII 12@304
58	AO17649	DARI2	13	XII	2	1571718	−409	FEB	17	ss	342	Ω	Jup	*ina*	KUN			XII 4@342
59	AB251	DARI2	14	I	14	1571789	−409	APR	29	ss	214		Moon	*šaplat*	SI GIR TAB	*	xS	
60	AB251	DARI2	14	I	14	1571789	−409	APR	29	ss	358		Jup	*ina*	$\mathrm{KUN}^{\mathrm{meš}}$			
61	AB251	DARI2	14	I	14	1571789	−409	APR	29	ss	55		Ven	*ina*	GU_4-AN			
62	AB251	DARI2	14	I	14	1571789	−409	APR	29	ss	110		Sat	*ina*	ALLA			
63	AB251	DARI2	14	I	14	1571789	−409	APR	29	ss	86		Mars	*ina*	MAŠ-MAŠ			
64	H5,59	ARTX2	8	V	18 ?	1576666	−396	SEP	3	sr	150	Γ	Mars	*ina*	A			VIII 5@151
65	H5,59	ARTX2	9	VI	25 ?	1577057	−395	SEP	30	ss	336	Ψ	Mars	*ina*	*zib*			VI 25@335
66	H5,59	ARTX2	10 A	IV	8	1577335	−394	JUL	5	ss	123	Ω	Mars	*ina* TIL	ALLA	xC	~S	IV 7@122
67	H5,59	ARTX2	15	V	24	1579211	−389	AUG	24	sr	147	Σ	Mer	*ina* TIL	[A]			V 22@143

Appendix D. Positional Reports (cont'd.): −396 to −384

Row	Source	Reign	Yr	Mo	Day	JD	Jy	Jm	d	h	λ*p	phen	P	rel place	Name	*,C,	(x)S	Calc date, λ*p
68	H5,59	ARTX2	15	[IX]	30	1579335	−389	DEC	26	sr	268	Σ	Mer	*ina*	PA			IX 29@267
69	H5,59	ARTX2	15	XI	1 ?	1579366	−388	JAN	26	ss	322	Ξ	Mer	*ina*	GU			XI 1@322
70	H5,59	ARTX2	15	XI	25 n	1579390	−388	FEB	19	ss	343	Ω	Mer	*ina*	*zib*			XI 24@343
71	H5,59	ARTX2	15	XII	28	1579422	−388	MAR	22	sr	339	λ	Mer	*ina*	*zib* ^{me}			XII 16@332
72	H5,59	ARTX2	16 U	I	13 n	1579437	−388	APR	6	sr	358	Σ	Mer	*ina* TIL	*zib*			I 16@363
73	H5,59	ARTX2	16U	II	18	1579471	−388	MAY	10	ss	65	Ξ	Mer	*ina* SAG	MAŠ-MAŠ			II 17@63
74	H5,59	ARTX2	16 U	IV	1	1579513	−388	JUN	21	ss	110	Ω	Mer	*ina*	ALLA			IV 1@108
75	H5,59	ARTX2	16 U	IV	27	1579539	−388	JUL	17	sr	100	Γ	Mer	*ina* SAG	ALLA	?C	xS?	IV 26@99
76	H5,59	ARTX2	16 U	V	16	1579558	−388	AUG	5	sr	128	Σ	Mer	*ina* SAG	A	xC	S	V 15@126
77	H5,59	ARTX2	16 U	VII	13	1579643	−388	OCT	29	sr	205	Γ	Mer	2 2/3k ar_2	RÍN *šá* ULÙ	*	xS	VII 11@206
78	H5,59	ARTX2	17	II	15	1579852	−387	MAY	26	sr	43	Λ	Mars	*ina*	MÚL.MÚL	xC	S	II 15@43
79	H5,60	ARTX2	18 A	XII2	18	1580534	−385	APR	8	sr	360	Γ	Jup	*ina* TIL	*zib* ^{me}			XII2 15@360
80	H5,59	ARTX2	19	III	22 ?	1580627	−385	JUL	10	ss	124	Ξ	Mer	*ina*	A			III 22@124
81	H5,60	ARTX2	19	IV	19	1580654	−385	AUG	6	ss	18	Φ	Jup	SIG SAG	HUN (13)	*	xS	IV 16@18
82	H5,59	ARTX2	19	V	1	1580665	−385	AUG	17	ss	172	Ω	Mer	*ina*	ABSIN			V 2@172
83	H5,59	ARTX2	19	VIII	11 ?	1580763	−385	NOV	23	ss	262	Ξ	Mer	*ina*	PA			VIII 11@262
84	H5,59	ARTX2	19	IX	12 ?	1580794	−385	DEC	24	sr	264	Λ	Mer	*ina*	PA			IX 12@264
85	H5,59	ARTX2	19	X	25	1580836	−384	FEB	4	sr	301	Σ	Mer	*ina*	MÁŠ			X 27@305
86	H5,59	ARTX2	19	XII	29	1580899	−384	APR	7	ss	31	Ω	Mer	*ina*	LU			XII 28@31
87	H5,60	ARTX2	20	II	6	1580935	−384	MAY	13	sr	37	Γ	Jup	*ina* SAG	MÚL.MÚL	xC	S	II 4@36
88	H5,59	ARTX2	20	IV	29	1581018	−384	AUG	4	ss	156	Ω	Mer	*ina*	A!			IV 27@156
89	H5,59	ARTX2	20	V	22	1581040	−384	AUG	26	sr	141	Γ	Mer	*ina* TIL	[A]			V 21@141
90	H5,59	ARTX2	20	VI	15	1581063	−384	SEP	18	sr	171	Σ	Mer	*ina*	ABSIN			VI 15@171

Appendix D. Positional Reports (cont'd.): −384 to −381

Row	Source	Reign	Yr	Mo	Day	JD	Jy	Jm	d	h	λ*p	phen	P	rel place	Name	*,C,	(x)S	Calc date, λ*p
91	H5,59	ARTX2	20	VIII	10	1581117	−384	NOV	11	ss	254	Ξ	Mer	*ina*	PA			VIII 6@248
92	H5,59	ARTX2	20	VIII	22	1581129	−384	NOV	23	ss	262	Ω	Mer	*ina*	PA			VIII 23@264
93	H5,59	ARTX2	20	IX	10	1581146	−384	DEC	10	sr	246	λ	Mer	*ina*	PA			IX 7@247
94	D-384	ARTX2	20 A*	IX	10	1581146	−384	DEC	10	sr	246	Λ	Mer	*ina*	*Pa-b* [*il-sag*]			IX 7@247
95	D-384	ARTX2	20 A*	IX	30?	1581166	−384	DEC	30	ss	44		Jup	*ina*	**GU4-AN**			
96	D-384	ARTX2	20 A*	IX	1	1581137	−384	DEC	1	ss	270		Ven	*ina*	MÁŠ			
97	D-384	ARTX2	20 A*	IX	30	1581166	−384	DEC	30	ss	306		Ven	*ina*	GU			
98	D-384	ARTX2	20 A*	IX	30	1581166	−384	DEC	30	ss	60		Sat	*ina*	GIGIR	C	xS	
99	D-384	ARTX2	20 A*	IX	30	1581166	−384	DEC	30	ss	260		Mer	*ina*	PA			
100	D-384	ARTX2	20 A*	IX	30	1581166	−384	DEC	30	ss	325		Mars	*ina*	GU			
101	H5,59	ARTX2	20 A*	X	19	1581185	−383	JAN	18	sr	288	Σ	Mer	*ina*	MÁŠ			X 22 @ 293
102	H5,59	ARTX2	20 A*	XI	21	1581216	−383	FEB	18	ss	344	Ξ	Mer	*ina*	*zib*			XI 22 @ 346
103	H5,59	ARTX2	20 A*	XII	19	1581244	−383	MAR	18	ss	12	Ω	Mer	*ina*	LU			XII 19 @ 12
104	H5,60	ARTX2	21*	I	16	1581299	−383	MAY	12	ss	63	Ω	Jup	ar_2	GIGIR	*	xS	I* 17 @ 63
105	H5,59	ARTX2	21*	II	8	1581321	−383	JUN	3	ss	86	Ξ	Mer	SIG	MAŠ-MAŠ	*	xS	II* 9 @ 88
106	H5,59	ARTX2	21*	III	22	1581365	−383	JUL	17	ss	139	Ω	Mer	*ina*	A			III* 23 @ 139
107	H5,59	ARTX2	21*	IV	15	1581387	−383	AUG	8	sr	125	Γ	Mer	*ina*	A			IV* 17 @ 125
108	H5,59	ARTX2	21*	V	7	1581409	−383	AUG	30	sr	151	Σ	Mer	*ina* TIL	A			V* 8 @ 152
109	H5,59	ARTX2	21*	VII	3	1581464	−383	OCT	24	ss	236	Ξ	Mer	*ina*	GÍR-TAB			VII* 1 @ 234
110	H5,59	ARTX2	21*	VII	16	1581477	−383	NOV	6	ss	246	Ω	Mer	*ina*	PA			VII* 16 @ 246
111	H5,59	ARTX2	21*	VIII	3	1581494	−383	NOV	23	sr	230	Γ	Mer	*ina*	GÍR-TAB			VIII* 1 @ 231
112	H5,59	ARTX2	21*	IX	12	1581533	−382	JAN	1	sr	272	Σ	Mer	*ina*	PA			IX* 15 @ 277

Appendix D. Continued

Row	Source	Reign	Yr	Mo	Day	JD	Jy	Jm	d	h	λ*p	phen	P	rel place	Name	*,C,	(x)S	Calc date, λ*p
113	H5,59	ARTX2	21*	X	15	1581565	−382	FEB	2	ss	328	Ξ	Mer	*ina*	GU			X* 17 @ 331
114	H5,59	ARTX2	21*	XI	10	1581589	−382	FEB	26	ss	354	Ω	Mer	*ina*	*zib*			XI* 12 @ 353
115	D-382	ARTX2	22	III	1	1581698	−382	JUN	15	ss	96		Ven	*ina*	ALLA			
116	D-382	ARTX2	22	III	29	1581726	−382	JUL	13	ss	102		Jup	*ina*	ALLA			
117	D-382	ARTX2	22	X	29	1581934	−381	FEB	6	ss	111		Jup	*ina*	ALLA			
118	D-382	ARTX2	22	X	29	1581934	−381	FEB	6	ss	351		Ven	*ina*	*zib* me			
119	D-382	ARTX2	22	X	29	1581934	−381	FEB	6	ss	88		Sat	*ina*	MAŠ-MAŠ			
120	D-382	ARTX2	22	X	29	1581934	−381	FEB	6	ss	337		Mer	*ina*	GU		xS	

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