

Astronomical Dating of Ur III and Akkad

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To Asger Aaboe, in whose house this study was originally conceived.

Abstract

Through a new comprehensive analysis of the astronomical evidence, in particular of the lunar eclipse omens contained in *Enuma Anu Enlil*, Tablets 20-21, we confirm a previously proposed absolute chronology for the dynasty of Ur III (2160 BC to 2053 BC). This is compatible with the Long chronology for the Hammurapi dynasty (Ammišaduqa year 1 = 1702 BC). In addition, we find two alternative choices for the chronology of the Akkad dynasty (2381 BC to 2200 BC, or 2327 BC to 2146 BC). The first agrees exactly with the traditional Sollberger relative chronology, the other shortens the distance between the dynasties of Akkad and Ur (actually overlapping them), in accordance with the current historical consensus. However, any attempt to accommodate simultaneously also a lower date for the First Dynasty of Babylon would seem to do violence to the presently available astronomical evidence.

1 The available astronomical evidence.

There are five independent pieces of astronomical evidence that can be used at present for establishing or checking the chronology of the second and late third millennium: (a) the Venus Tablet, (b) the OB month-lengths, (c) the Ur III month-lengths, (d) the Ur III eclipse omens, and (e) the Akkad eclipse omens. Among them, (a) and (b) are rigidly linked to year 1 of Ammišaduqa, which must be the same for both. Similarly, (c) and (d) are rigidly linked to year 1 of Amar-Sin. The distances from (a,b) to (c,d) and from there to (e) have some leeway, they are only loosely determined through adding up year counts in kinglists. There are 400 years, give or take a few, between the first years of Amar-Sin and Ammišaduqa. According to Sollberger's relative chronology (1954-56), there are 287 years between the first years of Sargon and Amar-Sin, but according to the current common opinion (Hallo, Steinkeller, Wilcke and others) these are too many: the distance between the last year of Šarkališarri and the first year of Ur-Nammu should be reduced from Sollberger's 80 years to about one generation.

No single source among the above five is comprehensive enough to force a unique date. However, when taken in pairs, they do so. In particular, (a,b) together strongly point to Ammišaduqa year 1 = -1701, the so-called Long Venus chronology. The pair (c,d) leads to a unique date for Amar-Sin year 1 = -2093. This is compatible with the Long Venus chronology, but is independent of the Venus Tablet evidence. Finally, (e) extends the agreement with the Long chronology by being exactly compatible with (c,d) and Sollberger's relative chronology. It also

gives a comparably good solution if the dynasty of Akkad is positioned 54 years later. Thus, the Long chronology is compatible with all five parts of the astronomical evidence, and it is the only such chronology.

Mutual corroboration between the sources is important since the trustworthiness of each of them may be questioned, rightly or wrongly. There is general agreement that the Venus Tablet data are poor: between 20% and 40% of the numbers are affected by gross errors. Though, this can, and probably should, be framed the other way around: at least 60% of the Venus Tablet data are fine. They may or may not be based on actual observations made in Ammišaduqa's time. Though, given that the year formula ("Year of the Golden Throne") for Year 8 of that king is interspersed into a corrupted part of the text after the Venus events of the 8th year, we are forced to assume that at some stage of the transmission a more complete version of the text must have referred to dates from that king's reign. With the eclipse omens, apart from philological problems, there are problems on one hand with the historical attribution of the events in the apodoses, and on the other, whether the protases record actual observations of lunar eclipses preceding those events. Though, there are comforting, unexpected corroborations. For example, the eclipse presaging the downfall of Gutium initially seemed to caused difficulties with the proposed chronology for Ur III, since it matched the first year of Ur-Nammu, rather than pointing to the reign of the historical victor, his predecessor Utuhegal. But then it turned out that Utuhegal and Ur-Nammu appear to overlap, and that an Ur-Nammu year actually is named after that very event.

2 The Old Babylonian evidence.

The Old Babylonian parts (a) and (b) of the evidence have been dealt with in detail by Huber *et al.* (1982). But it may be useful to recapitulate the structure of the arguments and to summarize the conclusions from the Venus and month-length data.

- (a) The Venus Tablet narrows the chronologies down to a small number of discrete choices. Among them, only the 4 or 5 main ones are sort of compatible with our current historical understanding: Ammišaduqa Year 1 = -1701 (Long), -1645 (Middle), -1637 (also Middle), -1581 (Short), -1517 (Supershort). If anything, the list of 20 Venus chronologies given in Table 2.1 below is over-inclusive: unless something is very seriously wrong with the Venus data (e. g. if they do not come from Ammišaduqa's reign), the list must contain the true chronology. Not all chronologies agree equally well with calculation. For example, the two Middle chronologies show systematic, statistically significant deviations: with one, the Venus events are on average two days earlier, with the other, two days later than calculated.
- (b) The OB month-length data permit an independent test of these chronologies: they strongly agree with -1701, mildly agree with -1517, and strongly disagree with the Middle and Short Venus chronologies.

As it seems that historians and archaeologists tend to be confused by either the logical structure of the arguments, or by the astronomy, or by the statistics, or by all three, I shall try to restate the salient points.

First the logical structure. If we take a wide historical range, namely from -1976 to -1362, then at most 20 choices for Ammišaduqa's first year give a more or less acceptable agreement between astronomical calculation and the Venus Tablet data. If the Tablet data contain a genuine kernel, one of these choices must correspond to the correct chronology. But irrespective of whether the Tablet data are genuine or not, we have only two, mutually exclusive, exhaustive possibilities: either (i) one of the 20 chronologies is correct; or (ii) none of them is correct.

Now the statistics. We can test these hypotheses with the help of the OB month-length data. Statistical tests always are styled to reject a hypothesis, and we may test either (i) or (ii). Three things can happen: either the tests reject (i) and by implication we then will accept (ii); or the tests reject (ii) and we accept (i); or the data are inconclusive. In fact, the tests reject (ii): one of the 20 chronologies (namely -1701)

agrees significantly better with the month-length data than what one would expect from the best of 20 randomly selected wrong chronologies, with a P-value (minimal statistical significance level) of about 5%. If we take a narrower historical range, with only 4 candidate chronologies, the P-value is improved to about 1%. An error rate of 1 in 20 (or 1 in 100, respectively) perhaps is not low enough to establish beyond reasonable doubt that one of the Venus chronologies must be correct (in a judicial case involving the death penalty I would prefer a lower value, for example). But it goes a long way, very few historical or archaeological arguments achieve a comparable certainty. Therefore, we do feel justified to believe in (i), to go on and to estimate relative likelihoods of the 20 chronologies. It must be stressed that unless we are reasonably sure that one of the possibilities is correct, a high relative likelihood does not mean much. This was the weak spot of all investigations prior to Huber *et al.* (1982): none of them was able to show that their best fitting chronology was any better than the best among a certain number of wrong chronologies. We find that the Long Chronology -1701 is the most probable among the 20, about 15 times more likely than the runner-up (the Supershort, -1517), and all the others together have to share the remaining 1%. The results are summarized in Table 2.1, adapted from Table 7.2 of Huber *et al.* (1982), with a minor emendation concerning year -1362.

Finally the astronomy. Venus phenomena repeat approximately every 584 days (or 20 months minus 7 days), the synodic period of Venus. The Venus Tablet itself contains a schematic insertion describing the phenomena as follows: Venus is 8 months 5 days visible in the morning, then 3 months invisible (at superior conjunction, behind the sun), then 8 months 5 days visible in the evening, then 7 days invisible (at inferior conjunction, between the sun and the earth), etc., see Reiner and Pingree (1975), p. 24. This scheme is not very accurate. The calculated duration of invisibility at inferior conjunction varies with the seasons from as little as 1 day (when Venus passes above the sun at a solar longitude of 320°), to as much as 19 days (when it passes below it at a solar longitude of 160°), while at superior conjunction the duration of invisibility varies from 55 to 70 days; but apparently, the scheme had been used in antiquity to mend some broken passages of the tablet. Now, 5 synodic periods add up to 99 months minus 4 days, close to 8 solar years, and the phenomena are in step with the solar year (but not with the lunar month). In particular, durations of invisibility repeat themselves fairly accurately after 8 years. After 7 or 8 such 8-year periods, the 4-day

shifts add up to a month, plus/minus 2 days, and Venus phenomena are in step also with the lunar months. A shift of 2 days is just about large enough to be

discernible by statistical methods, even with poor data. After a while, the agreement falls apart again.

Since there are 5 synodic periods wrapped within

YEAR	VENUS		MONTH-LENGTHS				TOTAL			
	Ammişaduqa (38 obs.)		Ammişaduqa (21 months)	Ammiditana (13 months)	Hammurapi- Samsuiluna (54 months)	com- bined				
	w	p_{Vs}	m	p_{As}	m	p_{Ad}	m	p_{HS}	p_{ml}	p_{tot}
-1976	1.58	.057	10	.018	6	.019	21	.043	.0015	.0005
-1920	-2.93	.003	13	.003	6	.017	23	.026	.0001	<10 ⁻⁵
-1912	3.63	.0003	10	.018	6	.017	22	.031	.0010	<10 ⁻⁵
-1856	-0.33	.189	14	.002	6	.023	25	.011	<10 ⁻⁴	<10 ⁻⁴
-1800	-4.65	<10 ⁻⁵	10	.018	8	.009	25	.005	<10 ⁻⁴	<10 ⁻⁸
-1792	2.31	.014	7	.112	3	.106	24	.008	.0093	.0007
-1736	-1.84	.037	9	.034	6	.023	20	.077	.0059	.0012
-1765	-2.39	.011	7	.112	5	.032	23	.016	.0057	.0004
-1757	2.28	.015	9	.034	4	.058	21	.043	.0083	.0007
-1701	-0.18	.196	6	.205	1	.306	19	.139	.8674	.9282
-1645	-4.84	<10 ⁻⁵	13	.003	5	.032	23	.014	.0001	<10 ⁻⁸
-1637	2.84	.004	12	.006	8	.005	22	.038	.0001	<10 ⁻⁵
-1581	-2.26	.016	12	.006	5	.030	24	.009	.0001	<10 ⁻⁵
-1525	-5.41	<10 ⁻⁷	9	.034	9	.004	24	.014	.0002	<10 ⁻¹⁰
-1517	-0.02	.199	6	.205	4	.065	21	.045	.0590	.0642
-1538	3.62	.0003	13	.002	4	.054	24	.014	.0002	<10 ⁻⁶
-1482	1.56	.059	7	.112	3	.096	25	.005	.0051	.0016
-1426	-2.99	.002	11	.010	4	.054	21	.070	.0038	<10 ⁻⁴
-1418	4.29	<10 ⁻⁴	8	.061	6	.019	18	.251	.0297	<10 ⁻⁵
-1362	0.10	.198	12	.006	5	.030	19	.144	.0023	.0025

Table 2.1. Relative likelihoods of the Venus chronologies.

- First column: year 1 of Ammişaduqa. Note that there are several, somewhat overlapping cycles with alternating 8- and 56-year spacings.
- Second column: w is a robust, normalized measure of how much the tablet dates are collectively shifted relative to the calculated dates; negative values are early, positive values late. For a correct chronology, one would expect these numbers to be approximately normally distributed, with mean 0 and standard error 1; values exceeding 2.6 are unlikely to occur. p_{Vs} gives relative likelihoods of the different chronologies, calculated on the basis of these w . The calculations are based on a cautiously purged data set, retaining 38 of a total of 50 values.
- The next columns summarize the month-length data; for example, from Ammişaduqa's reign, there are 21 months with 30 days, taken from economic texts, and for the -1701 chronology, $m = 6$ of them disagree with calculation, resulting in a relative likelihood of 0.205 for that chronology.
- The final two columns give likelihoods first for the combined month-lengths, and then for Venus data plus month-lengths. The likelihoods are normed such that the numbers in each column add up to 1.

the 8 year period, it is not possible to operate with the 8-year cycle in a simple fashion, as for example Gasche *et al.* (1998, p. 72) seem to believe – on one hand, one does not get a feasible solution every 8 years, but on the other hand, one also has to consider solutions corresponding to the other four synodic periods inside those 8 years. This causes the 56-64 year cycles to overlap (cf. Table 2.1). In short, in order to check a Venus chronology, it is therefore necessary to calculate all the Venus phenomena for that particular chronology and to check whether it is reasonably compatible with the data. For example, the chronology proposed by Gasche *et al.* (1998), Ammišaduqa year 1 = -1549, and discussed by them on p. 73, is flatly contradicted by the Venus Tablet data. To explain the issues in the simplest possible terms: let us consider the midpoint dates of the calculated invisibility periods near inferior conjunction, half-way between last visibility in the evening and first visibility in the morning. There, the planet cannot possibly be seen by a naked-eye observer under any circumstances. For a correct chronology, the observed invisibility dates at inferior conjunction ought to bracket those midpoint dates. This is not a question of “local conditions” (p. 72) nor of statistics (p. 76)! With the -1549 chronology, they fail to do so for 11 of the 13 inferior conjunctions, and for the remaining two (years 14 and 19), the text is known to be corrupt from internal evidence. With superior conjunctions the effects are less dramatic, but still clearly discernible by statistical methods. Note that the -1538 chronology, which is listed as a low-probability possibility in Table 2.1, and which might fit into Gasche’s historical window, gives a better fit than -1549, but is not related to it through 8-year periods.

With regard to the month-lengths, we note that 29-day and 30-day months alternate irregularly; on average 53% of the months have 30 days, and 47% have 29 days. If an observed sequence of 30-day months is aligned at random (i. e. wrongly) with a calculated sequence, we therefore can expect an agreement rate of 53%. Precisely datable 30-day months in NB and LB economic texts show an agreement rate of 67%, which is annoyingly poor; LB astronomical texts give a higher rate of 90%. We do not have enough OB month-lengths to determine a chronology by them alone, but fortunately, we have enough to test (and reject) the above hypothesis (ii) that all 20 Venus chronologies are wrong.

3 The Ur III month-lengths.

We currently have 228 usable Ur III month-lengths (cf. Huber 1987b), considerably more than what was available to Huber *et al.* (1982). The following Table 3.1 lists the best alignments.

The best agreements occur in the years -2093 and -2005, with 83 misses each. These two are the best alignments also in the more complete list from which the above was extracted, covering all 5000 syzygies between the numbers -15000 = -2213APR10 and -10001 = -1809JUN11.

The statistics of such a table is delicate. For a *single* random wrong alignment of 228 months one expects 111 misses, give or take 8; for the *best* one among 5000 random wrong alignments one expects 83 misses, give or take 2. The statistics of the wrong alignments is well determined, what enters into it is mainly the length of the synodic month (29.53 days) and some properties of the binomial distribution; if one distrusts the applicability of the latter, one can play around the problem by brute force simulation. Technically speaking, “give or take” here denotes plus/minus one standard deviation (SD); the probability of staying within plus/minus one SD is about 68%. If the observed agreement rate 67% of the LB economic texts is taken at face value, then one can expect 75 misses for a correct alignment, give or take 7. But the rate of 67% itself is an estimate; we can take the random uncertainty of the estimate into account by enlarging the SD from 7 to 11. There is a further – but hopefully smaller – uncertainty caused by the possibility of systematic differences between the LB and the Ur III agreement rates. The cut-off point of 93 in Table 3.1 was chosen such that the correct chronology has about a 95% chance to stay below. The relative likelihoods are calculated according to the formula in Huber *et al.* (1982), p. 45, on the basis of the scores. If one adjusts them to take the statistical uncertainty of the estimate of the LB agreement rate into account, the likelihoods are somewhat flattened (adjusted likelihood column).

Clearly, the currently available Ur III month-length material does not suffice to fix the date of Amar-Sin uniquely on its own merits. But it goes a long way; in my opinion, while all entries in the table might qualify as chronological possibilities, only the 6 to 12 best, with scores up to 88 or 89, are good enough to convince. A unique choice among all possibilities is forced by a lunar eclipse omen (EAE Tablet 20, Month III) supposedly pre-saging the death of Amar-Sin’s predecessor Šulgi: among the entries in Table 3.1, only -2093 is preceded by an eclipse matching the description of the omen text. That is, the Ur III month-lengths and

Number	Date	LNy	Score	Likelihood	Likelihood, adj.
-14185	-2147MAR 1	323.3	93	0.0005	0.0019
-14061	-2137MAR11	332.2	93	0.0005	0.0019
-13764	-2113MAR16	337.4	93	0.0005	0.0019
-13725	-2110MAY10	30.3	93	0.0005	0.0019
-13516	-2093APR 3	354.9	83	0.3538	0.3054
-13431	-2086FEB15	310.0	88	0.0128	0.0208
-13392	-2083APR11	3.7	91	0.0017	0.0048
-13294	-2075MAR15	337.0	89	0.0066	0.0126
-13183	-2066MAR 5	328.0	92	0.0009	0.0030
-13082	-2058MAY 5	26.4	93	0.0005	0.0019
-12886	-2042MAR11	333.1	91	0.0017	0.0048
-12860	-2040APR16	8.6	89	0.0066	0.0126
-12847	-2039MAY 5	26.1	92	0.0009	0.0030
-12823	-2037APR14	5.6	90	0.0034	0.0077
-12762	-2032MAR19	341.9	93	0.0005	0.0019
-12651	-2023MAR10	332.8	91	0.0017	0.0048
-12638	-2022MAR29	350.7	92	0.0009	0.0030
-12627	-2021FEB17	311.6	89	0.0066	0.0126
-12625	-2021APR16	8.4	92	0.0009	0.0030
-12614	-2020MAR 7	329.9	84	0.1821	0.1745
-12514	-2012APR 6	359.6	93	0.0005	0.0019
-12429	-2005FEB20	314.6	83	0.3538	0.3054
-12154	-1983MAY16	36.9	89	0.0066	0.0126
-12132	-1981FEB25	320.0	91	0.0017	0.0048
-12106	-1979APR 2	355.7	93	0.0005	0.0019
-11996	-1970FEB22	317.9	92	0.0009	0.0030
-11884	-1961MAR15	337.6	89	0.0066	0.0126
-11760	-1951MAR23	346.5	89	0.0066	0.0126
-11551	-1934FEB14	310.3	87	0.0249	0.0348
-11463	-1927MAR29	351.7	92	0.0009	0.0030
-11426	-1924MAR25	348.1	92	0.0009	0.0030
-11217	-1907FEB16	311.9	88	0.0128	0.0208

Table 3.1. Best Ur III month-length alignments (228 months). Given are the Goldstein number of the New Year syzygy of Amar-Sin year 1, its date in the Julian Calendar, the corresponding solar/lunar longitude, the score (i. e. the number of “misses”, or mismatches, between the observed and the calculated month-lengths), and the relative likelihoods of the chronologies (standardized so that they sum to 1 in the above table). Shown are all dates between -2150 and -1900, with longitudes between 310° and 50°, and scores not exceeding 93.

eclipses together determine a unique chronology. The Venus Tablet does not enter at all into this determination.

On the other hand, if we start with the Venus chronologies and calculate backwards by subtracting 400 years (plus/minus 15) from Ammišaduqa year 1, the only chronology that offers a convincingly high

likelihood in both Tables 2.1 and 3.1 is again the Long one (Ammišaduqa year 1 = -1701, Amar-Sin year 1 = -2093). The next best choice is the Supershort (Ammišaduqa -1517, Amar-Sin -1907); it has 15 times lower likelihoods in either table, and it also suffers from an excessively early begin of Amar-Sin’s year 1.

4 The lunar eclipse omen texts and their pitfalls.

The lunar eclipse omen texts have been published by Rochberg-Halton (1988). A typology of them is still outstanding. Most of them appear to be schematic, illustrating (teaching?) in analytic fashion the ominous influence of specific eclipse features. For example, EAE Tablet 17 begins: "If an eclipse occurs on the 14th of Nisannu in the evening watch and is red, it begins (anywhere) and clears in the west: the king of Amurru is well on account of that red eclipse, there will be famine in that land." The next omen is identical, except that west is replaced by north and Amurru by Akkad; omens with east = Subartu and south = Elam follow. The text then works through the different colors. Clearly, omens of this kind do not refer to identifiable events and are useless for dating purposes. On the other hand, the omens of EAE Tablets 20 and 21 are so detailed and unsystematic that they appear to contain actual records of observations. Though, also they have been subjected to systematization in varying degrees, Tablet 21 seemingly more so than Tablet 20, and the texts must be used with caution.

The omens mention countries, but unfortunately not names of individual kings, and any single omen may fit more than one transition.

Most instructive ancient explanations about what is relevant (and hence systematically recorded in the protases of the omens) are contained in a Neo-Assyrian report (Hunger 1992, No. 316):

"I could not let the king my lord hear the words about the eclipse from my mouth. Now in compensation I send a written report to the king my lord."

"The evil of an eclipse affects the one identified by the month, the one identified by the day, the one identified by the watch, the one identified by the beginning, where (the eclipse) begins and where the moon pulls off its eclipse and drops it; these (people) receive its evil."

Thus, there are six items relevant for the interpretation of an eclipse: (1) the month, (2) the day, (3) the watch in which the eclipse begins and (4) the watch in which it ends, (5) the entry point of the shadow, and (6) the exit point.

The astrologer goes on to explain that the side of the moon where the eclipse begins indicates for whom the sign is evil, while the side where it clears indicates for whom it is good. The beginning of the eclipse (with its evil consequences) may have been more important than its end, and it also may have been reported with more care and more systematically.

From the astrologer's statement: "If the eclipse is total, it is a sign for all lands", it follows by implication that an eclipse need not be total in order to portend evil consequences for a particular land. His remark: "The beginning, where (the eclipse) began, we do not know" is interesting. According to modern calculation the moon rose totally eclipsed, so the entrance angle was not observable (eclipse of -677MAY22).

For eclipse omens to be useful to astrologers, their protases must have just the right amount of imprecision and match neither too few nor too many eclipses. In consequence, the observational origin of an omen may not be uniquely identifiable. Any given omen description may be a deliberate conflation of several similar eclipses with similar consequences, and there may be accretions: observations and comments by later astrologers may creep into the texts. As a consequence, not all of the variants and inconsistencies of the texts need to be copying errors. Some of the variants (e. g. in 21-I or 21-VI) explicitly suggest the presence of such conflagrations or accretions.

EAE Tablets 20 and 21 begin all 25 of their principal protases with "If an eclipse occurs on day 14 of month MN". Tablet 21 adds (brief) variants on the consequences of each eclipse, if it occurs on day 15, 16, 20 or 21. This is curious for various reasons. Only about half of all lunar eclipses occur on day 14. It can be seen from an extensive table of lunar eclipses, such as the one given in Appendix B, that 27% of the eclipses happen on day 13, 46% on day 14 and 27% on day 15. Other days are extremely rare. If weather interferes with the observation of the lunar crescent at the beginning of the month, the range of days might be stretched towards either side by a day or two at most. Thus, we must assume that in the principal protasis the day has been artificially styled to be the 14th. It is curious that day 13 is never mentioned in these two tablets, and omens concerned with eclipses occurring on the impossible days 20 and 21 are even more baffling. We must conclude that "day 14" conveys no useful information. Still, it is conceivable that a few secondary protases contain relevant (observational) information about the day, in particular the one in Tablet 21-VI (see below).

The six items are also the main ones recorded in the Late Babylonian eclipse observations, but with a rather different terminology. Rochberg-Halton has not really succeeded in elucidating the details of the terminology of the omen texts. It certainly is not as rigidly standardized as the later one, and in any case, if one tries to do elucidate it on the basis of tentative eclipse identifications, one runs the danger of reading the results of modern calculations into the texts.

Moreover, omens texts are messy. In the case of the Venus Tablet (EAE Tablet 63) I had estimated that between 20% and 40% of the numbers are grossly wrong (Huber *et al.* 1982, p. 14). Sometimes, one can recognize and distinguish between copying errors (slips of the eye or of the hand, e. g. copying a few signs from an adjacent line) and ancient erroneous reconstructions of broken passages. Transmission errors are to be expected in view of the large distance in time (1000-1500 years) between the actual observations and the earliest available copies of the omen texts, and once an error has crept in, it is hard to notice and even harder to correct. In the eclipse texts, only very few errors (fewer than in the case of the Venus Tablet) are recognizable by the fact that they correspond to astronomical impossibilities. Clear cases are some entrance or exit angles in Tablet 20, Month XI, and Tablet 21, Month IV (eclipses cannot begin in the West or end in the East).

The identification of places and historical events is tenuous. Parts of the apodoses may be later interpolations. I am inclined to interpret place names literally and assume that "Akkad" and "Ur" mean Akkad and Ur, or perhaps more precisely: pertaining to the dynasties of Akkad and Ur. Though, there are puzzles. One omen (Tablet 20, Month XI) says: "The prediction is given for Babylon. The destruction of Babylon is near. Ur will take away the rule of Babylon. Ur will take supremacy over Babylon." If this passage refers to the end of the Hammurapi dynasty, then what is referenced by "Ur"? Or is "Babylon" a later substitution for "Akkad"? I am leaning towards the latter interpretation, simply because the other omens in EAE 20 and 21 all seem to belong to a time range of about two centuries extending over the later part of the dynasty of Akkad and the Third dynasty of Ur; the fall of Babylon is 400 years later.

We cannot expect the ancient observations to be highly accurate. Even in the Late Babylonian period, time measurements were quite inaccurate, unless the events in question occurred near sunset or sunrise, and the measured time intervals were short. The only estimated time interval in our omen texts occurs in Tablet 20, Month I, where a timing of 1/3 of the watch is given (with the variant 2/3). Correspondingly, we cannot expect that events occurring in the middle of the night were timed more precisely than that, and rounding to the nearest multiple of 1/3 of a watch means a round-off error of 1/6 of a watch, or about 0.7 hours, not to mention measuring errors. This concerns in particular also the begin and end of the middle watch. In Tablet 21, Month XII, the eclipse is said to last from the first to the third watch but calculates to be shorter than the middle watch; this discrepancy thus might have been caused not only by

an incorrect eclipse identification or by a scribal error (e. g. third for second watch), but even by mere inaccuracies of the ancient timings.

At any given location on earth about one lunar eclipse per year will be observed, but only about one in 24 will conform to the three principal items of a Babylonian eclipse description (given the vagaries of the ancient intercalations, the month narrows the choices down by a factor of about 4; the watch of the night by a factor 3; and a crude entrance angle by a factor 2: $4 \times 3 \times 2 = 24$). Scribal and observational errors have much the same effect as an erroneous chronology or an error in ΔT (see below): the good agreement is destroyed.

Thus, if we are checking an omen referring to a specific change of reign against a precise chronology (i. e. a chronology tentatively fixed within the year by other means), then a single omen referring to that transition of reign suffices to reach statistical significance: the probability of hitting by mere chance a lunar eclipse sitting in the right spot and matching the description is below 5%.

However, if the chronology is only approximately known beforehand, say within plus/minus 10 years, and if we try to fix the chronology by means of omen texts, we are in trouble. If we are given a 20-year window, it is quite likely that we will find an eclipse in it that matches the given omen description, even if the chronology is wrong.

The situation is similarly unfavorable, if the chronology to be tested is precisely specified (i. e. within a year), but the omen in question might refer to any one of several transitions of reign, say to one of eight as in the dynasty of Akkad.

To phrase it conversely: a valid confirmation of a chronology is possible if we have a *single omen* to be matched to a *unique transition of reign*, provided a *precise* chronology has been suggested by *independent means*. It does not matter what these independent means are and whether they themselves might be considered questionable: if they are invalid indeed, then the chronology has little chance of being right and being confirmed. A confirmation may also be possible if we have *several omens*, which then have to match *several transitions, precisely spaced* in time. But clearly, a little luck will be needed – without it, the case may remain inconclusive.

5 On astronomical calculations.

The eclipse calculations in this paper are based on programs originally devised by Morrison and Stephenson. Given the low precision of the early obser-

vations, the principal and only serious problem inherent in the astronomical calculations are clocktime errors caused by the irregular rotation of the earth. Following Morrison and Stephenson (1982), I have assumed that the Moon's tidal acceleration is $-26''/\text{cy}^2$ and that the difference between Ephemeris Time (ET) and Universal Time (UT) can be represented by

$$\Delta T = ET - UT = 32.5 t^2 \text{ sec,}$$

with t measured in centuries since 1800 AD. ET is the uniform time scale used by the purely gravitational theories of sun and moon, while UT is our "ordinary" time, based on the rotation of the earth. More refined formulas, such as that given in Stephenson and Morrison (1984), render the variation in ΔT more accurately for medieval time periods, but are risky to use for extrapolation purposes. The above formula is known to give very accurate results for the last five centuries BC, and it also closely agrees with the tables of Neugebauer and Hiller (1934). The coefficient $c = 32.5$ was determined from a least squares fit to timed lunar eclipses observed in Babylon. It has an estimated standard error of 0.3, and it is tightly constrained from above: increasing it to 32.6 would destroy totality of a solar eclipse observed as total in Babylon (-135 April 15). An increase in the value of ΔT decreases the calculated times of all eclipse phases by the same amount.

The above formula for ΔT corresponds to a regular and systematic slow-down of the rotation of the earth caused by tidal friction, increasing the length of day by approximately 2 milliseconds each century. But we now know that there are sizeable irregular fluctuations in the length of day, and if we want to extrapolate beyond 500 BC, we must take them into account. These fluctuations can be estimated from modern and historical data, cf. Stephenson and Morrison (1995) and Huber (1999). If the kind and size of these fluctuations have remained the same throughout the historical period, then by 2000 BC, astronomical calculations are affected by a standard extrapolation error in ΔT of approximately 1 hour (Huber 1999), or about 0.2-0.3 watches, depending on the length of the watch. This is 10 times larger than the error caused by the uncertainty in c , but it still is reassuringly small, cf. the remarks in Huber *et al.* (1982), p. 5 and p. 37, on the effects of clocktime errors.

Extrapolation is always tricky, and unexpected things can happen. If there should have been a systematic change in the length of the day sometime between 2000 BC and 500 BC, large enough to accumulate to a change in ΔT of, say, 4 hours by 2000 BC, then most of our astronomical calculations would be in serious trouble: the eclipses would be shifted to a different watch, and also the comparisons

between observed and calculated month-lengths would be upset. Only the Venus data would remain relatively unaffected. To give a quantitative illustration of a hypothetical scenario, just suppose that sometime between 1000 and 500 BC there was a modest climate change, melting between one and two percent of the ice in the polar ice caps, and thereby raising the sea level by one meter. A crude back-of-the-envelope calculation shows that raising the sea level by 1 meter increases the rotational moment of inertia of the earth by a fraction 10^{-7} . Through preservation of angular momentum, this increases the length of day by the same proportional fraction, that is by about 10 *ms* (the effect is familiar from ice skaters doing a pirouette). In the 1000 years between 2000 and 1000 BC, such a change in the length of day accumulates to a clocktime difference of 1 hour against our formula. To obtain a clocktime error of 4 hours, we thus would need a change in the sea level of about 4 meters. Fortunately, in the critical period from 3000 BC to the present, sea levels seem to have remained remarkably constant, even though in the immediately preceding prehistoric times there had been very substantial changes of tens(!) of meters; see Nützel (1976) for a discussion of sea level changes in the context of Mesopotamian archaeology. Though, this is not entirely certain, and of course we cannot exclude that there might have been other, hitherto unsuspected and therefore overlooked accidents affecting the rotation of the earth before 500 BC. However, anything causing a massive clocktime error would almost certainly destroy the nice interlock we have found between the five different pieces of the astronomical evidence, and this rather argues against such an accident.

6 Comparison of omen texts with calculation.

We must set up some, admittedly arbitrary, criteria when the agreement between observation and calculation shall be deemed acceptable. The year begins near the vernal equinox; we shall assume compatibility with the eclipse description if the calculated longitude of the sun at the New Year syzygy (LNY) falls between 315° and 45° . A 90° range may seem large, but we do not know the target value one was aiming for in that period. It seems that in times of political or military disturbances one sometimes forgot to intercalate, and in the OB period there is at least one known case of four consecutive intercalary years (Hammurapi 32-35, cf. Huber *et al.* (1982), p. 8); four intercalations in four years shift the LNY forward by 72° . For the NB and LB period (from

-747 onward) the attested range is 325° to 31° (*ibid.* p. 9). If the Long chronology is correct, the range for Hammurapi is 298° to 14°, for the other OB reigns 322° to 48°, and for Ur III 328° to 41° (*ibid.* p. 66ff.).

The entry and exit points of the eclipses are a headache. In the Neo- and Late-Babylonian astronomical texts (cf. Huber 1973), the entrance and exit angles of the shadow are recorded in terms of octant directions (N, NE, E, SE, S, SW, W, NW). These observed directions seem to be meant in the equatorial system, but the observations are not very accurate. Entrance and exit angles of the shadow are reckoned counter-clockwise from North (0°) to East (90°), South (180°) and West (270°). As seen from the observer, East is on the left(!) side of the lunar disk. Computed entrance angles range from slightly less than 0° (North) to 90° (East) and to slightly more than 180° (South), and exit angles from slightly less than 180° to slightly more than 360°. Fewer than half of those LB directions agree within the nominal precision of 22.5° with modern calculation, and about a sixth (10 out of 61) deviate by more than 45°. Clearly, the observational accuracy was much poorer than the precision of recording.

I conjecture that the entry and exit directions of the omen texts contain remnants of two rather different earlier schemes. One scheme partitions the lunar disk into North half versus South half, and into leading edge (AN.TA “above”, on the left side) versus trailing edge (KI.TA “below”, on the right side), in rough analogy to the use of these terms in the OB grammatical texts, where they denote prefixes and postfixes, respectively. In Tablet 20, Recension A, the shadow is always entered AN.TA and left KI.TA, as it should be if this interpretation is correct, in Recension B there are a few exceptions (scribal errors?). Already in Tablet 20 this scheme is confounded with another one based on the four cardinal directions (S, N, E, W, sometimes rendered by the numbers 1, 2, 3, 4, in this order). In EAE 21, the latter system is used exclusively. In both schemes, the disk is divided in four quarters, but in the first, the dividing lines between the quarters would be north-south and east-west, in the other, along 45°-lines. It is not yet clear whether these directions are meant relative to an equatorial system (as in the LB eclipse observations), or an ecliptical, or a horizon system.

Somewhat arbitrarily we shall take North to correspond to a calculated angle <90° or >270°; South to an angle between 90° and 270°; East to an angle between 45° and 135°, West to an angle between 225° and 315°. If, as conjectured above, one of the older schemes did not use the East-West directions, it might be advisable to expand the North and South regions a little beyond the 90°-270° border in order to allow for observational errors. A closer look at the table in Appendix B reveals that the vast majority of total eclipses has entrance angles between 45° and 135°, and exit angles between 225° and 315°. If an eclipse begins in the North and ends in the South, or vice versa, then it is almost always total.

Appendix B contains a calculated list of eclipses, specifically arranged to facilitate comparisons with the omen texts. The solar/lunar longitude at the beginning of the month has been recoded into an approximate month number; the integer part of the month number given there should not deviate by more than one unit from the month recorded in the omen. Begin and end of the eclipses are given in units of watches of the night. The uncertainty in ΔT is such that a deviation of give-or-take 0.3 watches must be expected, while a deviation larger than 0.6 watches is unlikely. This is of the same order as the ancient timing errors. At least within observational accuracy, the extrapolation error in ΔT is constant throughout the period under consideration.

Tables 6.1 to 6.3 give a summary overview of our identification of the ominous eclipses described in those tablets and referring to transitions of reigns.

Among the 25 omens in Table 6.1, 10 refer to potentially datable transitions of reign; they are numbered in the order in which they shall be discus-

Month	EAE 20 Omen concerning	EAE 21 Omen concerning
I	Akkad (8)	Akkad (9)
I.2	Akkad, Elam	—
II	Ur (3)	Elam
III	Ur (1)	Dilmun
IV	Ur (4)	Guti (7)
V	Eshnunna	Eshnunna
VI	Akkad	Akkad (10)
VII	Mutabal	Elam
VIII	Eridu	King of the World (5)
IX	Der	Der
X	Subartu	Anshan and Subartu
XI	Babylon, Ur (6)	Amurru
XII	Amurru	Ur (2)

Table 6.1. The omens of Enuma Anu Enlil Tablets 20 and 21.

sed. The remaining omens cannot be chronologically linked to transitions of reign in Ur III or Akkad, either because they do not refer to transitions, or because we lack synchronisms.

(1), (2) are singled out, being linked to uniquely identifiable Ur events.

(3), (4), (5) are other Ur events.

(6) possibly refers to an Ur event.

(7) is linked to Utuhegal's victory over the Guti.

(8), (9), (10) are Akkad events.

All 10 of the numbered omens, with the exception of (3), can be matched more or less convincingly in a coherent chronological framework to at least one eclipse

Kings of Akkad and their first year:	Chronology: Huber/Sollberger	+54 years	Omen
Sargon	-2380	-2326	
Rimuš (son of Sargon)	-2324	-2270	
Maništusu (elder brother of R.)	-2315	-2261	
Naramsin (son of Maništusu)	-2300	-2246	20-I, 21-VI
Šarkališarri (son of Naramsin)	-2263	-2209	20-I
Igigi, Nanum, Imi, Elulu	-2238	-2184	21-VI, 21-VIII?
Dudu	-2235	-2181	20-I, 21-VI
Šu-DURUL (son of Dudu)	-2214	-2160	20-XI?, 18-XI?
end of Dynasty	-2199	-2145	21-I

Table 6.2. Kings of Akkad, proposed chronologies, and omens identified with eclipses immediately preceding the accession of these kings. The earlier Akkad chronology is obtained by backreckoning from AS 1 = -2093, using Sollberger's relative chronology. The later one is designed to narrow the gap between Šarkališarri and Ur-Nammu (see Section 6.5).

Kings of Ur III:	(first) year	Omen
Ur-Nammu/Utuhegal	-2159	21-IV, 20-XI?
death of Utuhegal(?)	-2149	20-IV, 21-VIII
Šulgi (son of Ur-Nammu)	-2141	
Amar-Sin (son of Šulgi)	-2093	20-III
Šu-Sin (son of Amar-Sin)	-2084	
Ibbi-Sin (son of Šu-Sin)	-2075	
end of Dynasty	-2052	21-XII

Table 6.3. Kings of Ur III, proposed chronology, and omens identified with eclipses immediately preceding the accession of these kings (cf. Boese and Sallaberger (1996) for the filiation).

preceding a transition of reign. Omens (4) to (7) turn out to be intriguing: if their attribution is correct, they have to do with the beginning of the dynasty of Ur, and they have consequences for our interpretation of the history of Utuhegal and Ur-Nammu.

In the following subsections, the relevant parts of the eclipse descriptions were excerpted from Rochberg-Halton's translations – namely the month, entrance and exit angles of the shadow, and the watches of the night during which the eclipse begins and ends. For further details of the texts, see Rochberg-Halton (1988).

In Appendix C, the main candidates for the eclipses (1) to (10) are listed separately. They were extracted from the table in Appendix B by a computer search. The reason for doing this was that searching a long list of eclipses by eye is error-prone, one too often slips and overlooks good matches. On the other hand, setting up the extraction criteria for the computer is tricky: if the eclipse description is interpreted too strictly, we may miss promising candidates for identification, if it is interpreted too leniently, our net will catch too many unlikely possibilities,

and we again have a long list with too much chaff to peruse. In any case, the reader is advised to pay attention also to the complete list in Appendix B, since scribal errors in the description will upset any single-minded automated search. I decided to use the following conventions. Times for the beginning and end were extended by 0.4 watches, in order to account for clocktime errors in the modern calculation and for ancient timing errors. Similarly, entrance and exit angles were extended by 5° on each side in the case of two-sided intervals (east, west), by 10° in the case of one-

sided regions (north, south); the rationale behind this was discussed earlier in this section. The magnitude was ignored.

6.1 The two main Ur III eclipses.

Only two omens permit a relatively certain identification with specific historical events: EAE 20-III is generally taken to refer to the death of Šulgi (cf. Sollberger 1954-56, p. 22), and EAE 21-XII refers to the end of the dynasty. These two eclipses were already discussed in Huber (1987a).

Tablet 20, Month III.

- (1) If an eclipse occurs on the 14th day of Simānu, and the god in his eclipse becomes dark on the side east above, and clears on the side west below. (The eclipse) “pulls out” (*issuh*) the first watch and touches the middle watch (so Recension A; B has: “equalizes” (*imšul*) the first watch). The king of Ur, his son will wrong him, and the son who wronged his father, Šamaš will catch him. He will die in the mourning place of his father. The son of the king who was not named for the kingship will seize the throne.

-2094JUL25: mismatch day.

The literal translations of the critical terms *issuh* and *imšul* given above are mine. The meaning of these passages is far from certain. R.-H. translates: “(the eclipse) passes the first watch”, and “(the eclipse) is half”, respectively. Literally, *nasāhu* means “to pull out”, whence it is used for excerpting a text, and it can for example mean “to start off” (on a journey, by pulling out the tent poles). It should not be translated “to pass”, since this term (DIB = *eṭēqu*) in later eclipse texts is used in a rigorous technical sense and refers to cyclical eclipse possibilities that do not materialize as actual eclipses. The other verb, *mašālu* “to be, or to make, equal” can, but need not, be taken in the sense of making two equal parts, and if so, it is far from clear whether in this connection it halves the watch, or whether half of the lunar disk is darkened. Actually, I conjecture that Rec. A intimates that the eclipse “took out” the entire first watch (or perhaps, that it started together with the first watch), while Rec. B seems to express that the eclipse was coextensive with the first watch. A further argument in favor of the latter interpretation is the following. The omens in EAE 20 and 21 otherwise regularly give not only the watch when the eclipse begins, but also the watch when it ends. In

this case, Recension A does so by explicitly mentioning the middle watch, while Recension B seemingly refers only to the first watch (unfortunately, the text is broken). Thus, the phrase *barārīta imšul* somehow must implicitly specify both the beginning and the end of the eclipse relative to the first watch.

The prime candidates for this eclipse description are listed in Appendix C. I chose the search criteria such that also eclipses “halving” the watch would be caught (this found the eclipses of -1914 and -1907). If we accept that Amar-Sin year 1 begins in -2093, as suggested by the month-length data, then this eclipse (1) must have occurred in -2094 (i. e. in Šulgi’s last year, since he died at the end of Month X or at the beginning of Month XI).

Tablet 21, Month XII.

- (2) If an eclipse occurs on the 14th day of Addaru, and it begins in the south and clears in the north; it begins in the evening watch and clears in the morning watch. You observe his eclipse and bear in mind the south. The prediction is given for the king of the world: The destruction of Ur. [..... will be] destroyed, variant: an order to destroy its city walls will be given. While the barley is being heaped up, the devastation of the city and its environs (will occur).

-2052APR13: mismatch day, end (0.4 watches), exit (10°).

This eclipse (2) must have occurred in the last month of Ibbi-Sin’s second-but-last year (year 23). In any case, it follows from Šulgi’s death date and the regnal year counts that the distance between the two eclipses (1) and (2) must be 42 years. There is a single pair of eclipses having this distance and matching the dates required by the month-lengths: (-2094JUL25 and -2052APR13). There is one other pair having the required distance of 42 years: (-2018JUN26 and -1976MAR15), but it disagrees with the month-length data.

According to calculation for -2052, the eclipse ends in the second rather than in the third watch, as stated in the omen. In fact, the calculated duration of the eclipse (3.08h) is less than the duration of a watch (3.88h). The nearest compatible eclipses lasting a watch of the night or more are -2062MAY 4 and -2015APR24. I conjecture that either the description of the end of the eclipse is in error, or, perhaps more likely, that the estimated timing of the eclipse is inaccurate. The eclipse of -2052 is one of the few among our identifications that is not total (magnitude 0.63). This does not necessarily speak against the

identification, cf. the comments near the beginning of Section 4, but perhaps one might argue that an eclipse predicting the downfall of the “king of the world”, and hence supposedly affecting all lands, ought to be total.

Gasche *et al.* (1998, p. 75) claim to have found a pair of eclipses (-1953JUN27 and -1911MAR16) that “fit the ancient descriptions at a higher confidence level” than the (-2093, -2052) pair. My computer search for eclipses matching the Simanu and Addaru omens had missed their pair. I was therefore puzzled and re-checked. The problem with the -1953 eclipse is that it begins too early: according to calculation the moon rises totally eclipsed at 19.00 local time (a few minutes before sunset). The Babylonian first watch of the night begins at sunset, not at a fixed 18.00, as the authors intimate; 18.00-22.00 is valid at the equinoxes only. The entrance angle thus was not even observable (cf. the remark of an ancient astrologer, quoted in Section 4). The -1911 eclipse had slipped through my net because it starts in the north-east (66°, Gurzadyan’s calculation is in error), rather than in the south, and moreover it ends very early, already at the end of the first watch.

6.2 Other Ur III eclipses.

Three more omens predict transitions of reign in the dynasty of Ur: 20-II, 20-IV and 21-VIII. None of them is unambiguously attributable.

If the chronology of Ur III, as proposed here, is correct, and if the omens of EAE 20 and 21 refer to real events, all omens predicting a change of reign in this dynasty should fit into a suitable time slot. If they do, they add some strength to the chronology. If not, they cast some doubt on it.

Tablet 20, Month II.

- (3) If an eclipse occurs on the 14th day of Ayaru, and the god in his eclipse becomes dark on the side north above, and clears on the side south below. the first watch The prediction is given for Ur. [The king(?)] of Ur’s reign will end.

I have not been able to find a convincing match for this eclipse description between -2200 and -1850, irrespective of transitions of reign (cf. Appendix C). Perhaps some items in the damaged eclipse description are erroneous.

Tablet 20, Month IV.

- (4) If an eclipse occurs on the 14th day of Du’ūzu, and the god in his eclipse becomes dark on the side east above, and clears on the side south

below. The eclipse equalizes the first watch In Du’ūzu (the eclipse occurs) not at its calculated time (i. e. prematurely?). The king who ruled will die. The prediction is given for Ur. The grandson, descendant of the king, will seize the throne. The king together with his clan will be killed.

-2094JUL25: mismatch day, exit (15°).

Transition Šulgi - Amar-Sin.

-2149JUL 4: the moon rises partially eclipsed, otherwise all items match.

Transition of kingship from Utuhegal to Ur-nammu(?).

This omen is curious. The description of the eclipse is almost identical to that of 20-III, only the exit angle differs (south instead of west). Perhaps part of the eclipse description was erroneously copied from the one preceding it on the tablet, 20-III? Or perhaps the same eclipse was observed twice in two cities with divergent calendars? Though, the poorly matching exit angle of 20-IV would seem to argue against the second explanation.

The apodose is even more puzzling. To our knowledge, there is no succession from a king to his grandson in Ur III: all kings, except the founder of the dynasty, appear to be sons of their immediate predecessors, cf. Boese and Sallaberger (1996). If the qualification “grandson, descendant of the king” is historically accurate, it can only refer to the founder of the dynasty, Ur-Nammu, and to the moment in time when he became king. The genealogy of Ur-Nammu is uncertain; he may have been a brother of Utuhegal.

For the Ur III period (i. e. from -2159 to -2052) there are only two good matches of the description with eclipses, irrespective of changes of reign, namely -2149JUL 4 and -2105AUG26. See Appendix C; the other candidates in that list are unacceptably late, if, as argued above in connection with eclipse (1), *imšul* means that the eclipse was more or less coextensive with the watch. The former eclipse indeed falls into the time of Ur-Nammu, and, if our interpretation of the circumstances surrounding the Guti eclipse (7) is correct (see below), it would actually correspond to the year when Utuhegal died.

Tablet 21, Month VIII.

- (5) If an eclipse occurs on the 14th day of Arah-samna, and it begins in the north and clears in the south, var[iant:]; it begins in the middle watch and clears in the morning watch, variant: when it (i. e. the sun) rises. You observe his eclipse and [bear in mind the north]. The

prediction is given for the king of the world: Either the king will die, or a large army will fall, or a large army will revolt.

- 2084JAN10: mismatch month, day, entry (22°).
Transition Amar-Sin – Šu-Sin, but eclipse occurs after Amar-Sin's death.
- 2185DEC 7: mismatch entry (7°), end (0.1 watches).
Death of Šarkališarri in the (S -2326) chronology.
- 2149JAN 8: mismatch exit (7°).
Death of Utuhegal(?).

The term “king of the world” seems to refer to Ur, as for example in the omen of 21-XII. In our chronology, Šu-Sin's first year begins in March -2084, thus the (poorly matching) eclipse of -2084JAN10 initially seemed to correspond to the transition Amar-Sin – Šu-Sin. But Amar-Sin died early in his 9th year, in month I or II, before II 9 (Sallaberger, personal communication). This renders this identification impossible: the death occurred several months before the eclipse. But as the expression “king of the world” is ambiguous, alternative identifications of this omen might be with the eclipse of -2185DEC7 (death of Šarkališarri), and with the one of -2149JAN8 (death of Utuhegal(?), see the preceding eclipse (4), and also eclipse (7) below).

6.3 The “Babylon” eclipse.

Tablet 20, Month XI.

- (6) If an eclipse occurs on the 14th day of Šabaṭu, and the god, in his eclipse, becomes dark on the side south above, and clears on the side east below; (the eclipse) begins the last watch, and he (the moon) is seen with the sun. His horns bend (toward?) the sky. He did not cover his entire *šurinnu*, and disappeared. Observe his eclipse, the god who in its eclipse became bright and disappeared. The prediction is given for Babylon: The destruction of Babylon is near. The king to whom they said “yes”, his people will be scattered. His reign will end Ur will take away the rule of Babylon. Ur will take supremacy over Babylon.

The details of the eclipse description are open to interpretation; apparently, the eclipse began in the third watch, and the beginning of the clearing could be observed (even though the direction given is grossly wrong), and it set eclipsed(?). The passage about the *šurinnu* could mean just about anything, from the moon not being entirely covered (partial

eclipse) to the moon setting before becoming totally uncovered. The apodose is curious. On the face of it, it seems to refer to the end of the Hammurapi dynasty, but then, what is referenced by “Ur”? Or, maybe “Babylon” is a later substitution for “Akkad”. Or perhaps the statement even is to be interpreted literally: it might refer to an otherwise unknown destruction of Babylon, just before the Third Dynasty of Ur took over. With the latter two interpretations, the following eclipse is a candidate:

- 2160FEB 9: mismatch day, beginning (0.2 watches);
exit in the east is astronomically impossible and must be a scribal error.
Impending change of the ruling dynasty from Akkad(?) to Ur.

Some time after I had made this tentative identification, I realized that EAE-18 might contain a reference to this same eclipse. Initially, I had discarded EAE-18 as being too schematic to be used for dating purposes, but the following passages are suggestively specific (Rochberg-Halton (1988), 151f.):

If an eclipse occurs in Šabaṭu in the morning watch, the king of Amurru, var. a great king (and) the king of Gutu [will experience] bad luck. ...

If the eclipse occurs on the 15th of Šabaṭu, the land [...] and famin[e ...]; the king of Akkad will die and the untrue son of the king [will seize the throne(?)]. ...

Note that this eclipse would occur in the year before the downfall of the Gutu (see next section), and that according to the later chronology for Akkad (S -2326) it also corresponds to the transition from Dudu to his son Šu-DURUL.

6.4 The “Gutu” eclipse.

The following omen 21-IV is commonly associated with the victory of Utuhegal over the Gutu king Tirigan (cf. *Cambridge Ancient History*, 3rd Ed., Vol. I, Part 2, p. 462).

Tablet 21, Month IV.

- (7) If an eclipse occurs on the 14th day of Du'ūzu, and it begins in the west and clears in the south, variant: north; it begins in the evening watch and clears in the middle watch. You observe his eclipse and bear in mind the west. The prediction is given for the king of Gutu: The downfall of Gutu in battle. The land will

be totally laid waste.

-2159JUL24: mismatch day; entry in the west is astronomically impossible and must be a scribal error.

This eclipse should correspond to Utuhegal's accession, but if our chronology of Ur III (Amar-Sin year 1 = -2093) is correct, it occurs in Ur-Nammu's first year! The nearest preceding eclipse that might fit the description is much too early, it falls in -2188 (the fit is not perfect, it escaped the search of Appendix C). Initially, I wondered whether this argued against the chronology or merely against the identification of the eclipse.

But it turns out that a year name from the time of Ur-Nammu indicates that the destruction of Gutium actually took place in his time, see Sigrist and Damerow (1997), Ur-Nammu Year k. Furthermore, it appears that Ur-Nammu initially was governor of Ur, installed there by Utuhegal, and that he did not become king in the first year of his traditional year count, probably not before his fourth year (personal communication by W. Hallo). Therefore, the identification is to be accepted. Apparently, Utuhegal as king in Uruk and Ur-Nammu as governor in Ur start more or less simultaneously, shortly before the defeat of the Guti. Note furthermore that Utuhegal according to his inscription (ETCSL 1997) appears to have claimed kingship of Uruk and of the four quarters before he set out to battle with Tirigan and to bring back the kingship of Sumer. One may conjecture that Ur-Nammu took over the kingship in Ur only after Utuhegal's death (who died by a drowning accident, according to an omen), but that the king lists count his years from the beginning of his governorship. According to the kinglists, Utuhegal reigned 10 years, so he would have died ca. -2149, which matches the eclipses 20-IV and 21-VIII, discussed above under the numbers (4) and (5).

If the identification of this eclipse and the interpretation of the consequences are correct, this obviously affects also the relative chronology of Akkad and Ur III, to be discussed further below.

6.5 Transitions of reign in Akkad.

I had previously noticed (Huber 1987a) that if one extends the Ur III chronology by backreckoning from Amar-Sin year 1 = -2093 to the Akkad dynasty, using the relative chronology of Sollberger (1954-56), see Appendix A, then one of the omens (EAE 20-I) matches three similar eclipses, two of them preceding consecutive changes of reign (from Maništusu to Naramsin,

and from Naramsin to Šarkališarri). I had then speculated that the terrifying occurrence of two very similar eclipses, preceding the deaths of two consecutive kings, might have given birth to omen astrology.

Actually, I had not realized then that there are not one, but three omens predicting changes of reign in Akkad: 20-I, 21-I and 21-VI. With the same chronology, an even more amazing coincidence emerges: there are eight total lunar eclipses preceding a change of reign in the dynasty of Akkad, and the three omens together match all but one of them (cf. Tables 6.1 and 6.2). If one throws in the omen 18-XI, even the remaining change is matched. Unfortunately, none of the omens refers to a uniquely identifiable event. It is perhaps possible to narrow the choices down somewhat: 20-I, 21-VI and 18-XI concern a father-son transition (i. e. one of the four: Sargon – Rimuš, Maništusu – Naramsin, Naramsin – Šarkališarri, and Dudu – Šu-DURUL); 21-I is not explicitly concerned with a father-son transition (and thus by implication may refer to one of the four others: the brother-brother transition Rimuš – Maništusu, those to and from the disturbed period with four contenders for kingship, and to the end of the dynasty). Admittedly, this argumentation is tenuous, and the type of transition (whether father-son or not) was disregarded in the search for matching eclipses (but it turned out to match surprisingly well).

The Guti eclipse 21-IV, discussed in the preceding subsection, presents an intriguing dilemma also with regard to the chronology of the Akkad dynasty. According to Sollberger's ladder, Utuhegal preceded Ur-Nammu and reigned 10 years. Presumably, he would have vanquished the Guti near the beginning of his reign. But in our chronology -2159 corresponds not to Utuhegal's, but to Ur-Nammu's first year. The nearest preceding eclipse more or less matching the description is much too early, it falls in -2188. Thus, as already pointed out, either the identification of the eclipse is incorrect, or there must be a considerable overlap between Utuhegal and Ur-Nammu. The historical evidence strongly favors the second alternative, cf. the comments on eclipses (4), (5) and (7).

But if the overlap between Utuhegal and Ur-Nammu is real, it shortens the segment of Sollberger's ladder from Akkad to Ur III: the kings of Akkad would have to be moved down ten years, and this would destroy the perfect match between Sollberger's relative chronology (i. e. Sargon year 1 = -2380) and the Akkad eclipses. In view of the synchronism between Ur-Nammu and Nammahani (cf. Appendix A), the shift also affects the Ensis of Lagaš and moves them forward by the same number of years, since, presumably, the synchronism between Nammahani and Ur-Nammu is with Ur-Nammu the king, not with Ur-Nammu the

governor.

In order to restore the match with the Akkad eclipses we might try to lengthen Sollberger's ladder by re-inserting those 10 years (i. e. by lengthening the Uruk period, or by inserting a brief Guti reign). But this appears to be out of the question: the historical evidence on the contrary argues in favor of shortening the ladder. I quote from a letter of Claus Wilcke (18.12.1997): "Urnammu im Verhältnis zur Akkadzeit: Er ist Zeitgenosse Kutik-Inšušinaks (hat ihn besiegt: Wilcke, in: Isin III). Dessen Verwandte sind noch zu Šulgis Zeiten in Lagaš nachweisbar (Steinkeller). Sonstige, vor allem archäologische Datierung des K. sieht ihn etwa zeitgleich mit Šarkališarri. Die alte vertraute Sollbergersche Chronologie haut hinten und vorne nicht mehr hin. Gudea ist zeitgleich mit der Ur III Dynastie Kurzum, der Abstand Šarkališarri – Urnammu (nicht etwa Ende Akkad – Urnammu!) ist äusserst gering." The consensus (Hallo – Steinkeller – Wilcke) points to a gap Šarkališarri – Urnammu of about one generation.

In fact, it is also possible to re-synchronize the dynasty of Akkad with the eclipses by moving it forward 54 years (to Sargon year 1 = -2326). Lunar phenomena very nearly repeat themselves after 669 months, which is about 54 years and 1 month, and we get a comparably good agreement between eclipses and changes of reigns. Actually, this is the only other chronology in a 300-year range that gives similarly good, multiple matches between omens and eclipses. This shift shortens the distance between Šarkališarri and Ur-Nammu to about 25 years. The Uruk dynasty is squeezed out: Šu-DURUL (-2160 to -2146), the last king of Akkad; Utuhegal (ca. -2159 to -2150), the only king of the fifth dynasty of Uruk; and Ur-Nammu (-2159 to -2142), initially governor and then king of Ur, would hold office simultaneously. See the modified table in Appendix A.

Below, after the relevant parts of the omen texts, again excerpted from Rochberg-Halton's translation, we list the eclipses matching the two proposed chronologies. By (S -2380) we denote a chronology for Akkad with Sargon's reign beginning in -2380 (this corresponds to Amar-Sin year 1 = -2093, extended backward through Sollberger's relative chronology); the chronology (S -2326) is 54 years later. Minor mismatches between description and calculation are explicitly listed. In the case of entry and exit angles I indicate by how much the cut-off point is exceeded. Mismatches of the day shall be recorded, but for reasons already mentioned they seem to be meaningless (with one possible exception: 21-VI). For further details on the calculated eclipses see Appendix B.

Tablet 20, Month I.

- (8) If an eclipse occurs on the 14th day of Nisannu, the god in his eclipse becomes dark on the side south above, and clears on the side north below,, [in the last watch the eclipse end]s¹. If in his *šurinnu* Venus [enters within him], the son of the king will enter the throne (var.: house) of his father. The king of Agade will die The god who in his eclipse began the last watch, delayed 1/3 (variant: 2/3) of the watch, and set while eclipsed

Matching eclipses:

- 2301MAR9: mismatch day. Venus rises at beginning of eclipse.
(S -2380): transition Maništusu - Naramsin
-2264MAR19: mismatch day, exit (5°). Venus rises 0.5h before beginning of eclipse.
(S -2380): transition Naramsin - Šarkališarri
-2236MAR10: all items match. Venus invisible.
(S -2380): transition 4K - Dudu
-2247APR10: mismatch day, end (0.1 watches), entry (6°). Venus invisible.
(S -2326): transition Maništusu - Naramsin
-2210APR21: mismatch day. Venus rises 0.4h after beginning of totality.
(S -2326): transition Naramsin - Šarkališarri
-2182APR12: all items match. Venus invisible.
(S -2326): transition 4K - Dudu

With the earlier chronology (S -2380), the year begins very early for all three eclipses (about 1.5 months before the vernal equinox), with the later (S -2326), it begins about on target.

This is the omen that had struck me in 1987, because with Sollberger's relative chronology, no fewer than three eclipses matching the description coincided with transitions of reign. Two of them (-2301, -2264) are two consecutive father-son transitions, and I then had speculated that such a pair of very similar eclipses, preceding the deaths of two consecutive kings, might have been the sequence of events giving birth to omen astrology. In 1987, I had conjectured that the passage about the *šurinnu* perhaps referred to an occultation of Venus near the beginning or end of the month (occultations of Venus cannot occur near the middle of a lunar month). In view of the use of the term in the eclipse (6), I now believe that the passage must refer to a Venus event taking place in connection with the lunar eclipse itself. The most plausible such event would be a rising of Venus. The three eclipses where Venus became

¹) Literally: "ends the last watch", i. e. sets while eclipsed.

visible correspond to father-son transitions.

Tablet 21, Month I.

- (9) If an eclipse occurs on the 14th day of Nisannu, and it begins in the south and [clears in]; it begins in the evening watch and clears in the middle watch. You observe his eclipse and [bear in mind the south]. The prediction is given for the king of Akkad. The king of Akkad will die. If the eclipse does not affect the king: There will be destruction and famine. The people will send their children out to the market (to be sold). The great country will go to the small country for food.

This clearly refers to at least two eclipses; with one, the king dies.

Matching eclipses:

- 2200MAR31: all items match
(S -2380): end of dynasty of Akkad
-2146MAY 3: mismatch day
(S -2326): end of dynasty of Akkad

Tablet 21, Month VI.

- (10) If an eclipse occurs on the 14th day of Ulūlu, and it begins in the north and clears in the south, variant: east; it begins in the evening watch and clears in the middle watch. You observe his eclipse and bear in mind the north. The prediction is given for the king of Akkad: Revolt for the king. If the eclipse does not affect the king: Rains in the sky, floods in the source will cease. There will famine in the land. The people will sell their children for money.

If an eclipse occurs on the 15th day: the son of the king will kill his father and take the throne, variant: the enemy will attack and ravage the land.

This clearly refers to several eclipses, but not all of them are connected with a change of reign.

- 2301SEP 2: all items match (day 15!)
(S -2380): transition Manišusu - Naramsin
-2239NOV 4: all items match (day 14!)
(S -2380): transition Šarkališarri - 4K
-2236SEP 2: all items match (day 14!)
(S -2380): transition 4K - Dudu
-2247OCT 4: all items match (day 15!)
(S -2326): transition Manišusu - Naramsin
-2182OCT 5: all items match (day 14!)
(S -2326): transition 4K - Dudu

Notes: Two consecutive eclipses ought to be at least 6 months apart. In order to reconcile the eclipse dates of 20-I and 21-VI with eclipses occurring in the same year one would have to assume an intercalary month I2. The presence of such an intercalation would agree well with an early beginning of the year, as commented on in the notes to 20-I above. For the eclipse of -2239NOV4 on the other hand the year begins very late (therefore the eclipse has no admissible counterpart 54 years later). There are only 35 lunar months between -2239NOV4 and -2236SEP2, so not both eclipses can have occurred in month VI. I am inclined to reject the identification with the eclipse of -2239.

7 A solar eclipse.

The astrological reports from Assyria (Hunger 1992) contain a number of interesting quotes from omen texts, together with revealing discussions and interpretations of contemporary observations. Unfortunately, most of them are of little direct help with regard to chronology, because if they offer promisingly precise protases, their apodoses will match too many historical events, and vice versa. For example, Reports No. 101 and 452 indicate that if Mars becomes stationary in Cancer, then the ruler will die – which ruler? The most promising among them may be No. 104, which reports a partial solar eclipse. Apparently, this is the eclipse of -656APR15, beginning 9.9h local time, ending 12.4h, and reaching magnitude 0.85, at a solar longitude of 18°. Among possible consequences of such an eclipse the text quotes: “If there is an eclipse in Nisan (I) on the 28th day: the king of that land will fall ill but recover; in his stead, a daughter of the king, an *entu*-priestess, will die.”

If this is to be taken literally, and if this reflects actual events that took place in Akkad or Ur III times – two very big IFs! – the only two high priestesses that died during the reign of their own father appear to be the unnamed predecessor of Enheduanna, who according to Sollberger must have died around year 50 of Sargon, and Ennirzianna, who was succeeded in year 43 of Šulgi, cf. Sollberger (1954-56).

Chance has it that there are matching solar eclipses for Sargon year 50, both in the original Sollberger chronology and 54 years later (do not pay attention to the calculated solar eclipse magnitudes, they are sensitive to errors in ΔT):

-2331APR23, beginning 15.4h local time, ending 17.7h, and reaching magnitude 0.53, at a solar

longitude of 13°; -2277MAY26, beginning 10.0h local time, ending 12.7h, and reaching magnitude 0.51, at a solar longitude of 44°.

Is this a fortuitous coincidence or is there more to it?

8 Alternative chronologies?

At present, most historians would prefer to lower the date of the Hammurapi dynasty considerably below that of the Long Venus chronology.

Given that the Long chronology and the associated dates for the earlier dynasties (Ammissaduqa year 1 = -1701, Amar-Sin year 1 = -2093, Sargon year 1 = -2380 or -2326) are the only ones compatible with all five parts of the astronomical evidence (see Section 1), it is not possible to get rid of the Long chronology without ignoring or doing violence to some parts of the astronomical evidence. I shall now sketch what happens if we selectively omit some pieces of the astronomical evidence.

8.1 Alternative Ur III chronologies?

First, we disregard the Akkad dynasty and concentrate on three central, independent, but interconnected pieces of evidence for the absolute chronology of Ur III: the Venus Tablet, the Ur III month-lengths, and the Simanu eclipse presaging the death of Šulgi (EAE 20-III). The three, taken together, are compatible with only one chronology: Amar-Sin 1 = -2093. What happens if we ignore one of the three?

With regard to the **Venus data**, we shall assume that Year 1 of Amar-Sin falls 400 years before Year 1 of Ammissaduqa, plus/minus 15 years, and we shall consider only the five main Venus chronologies mentioned above: Ammissaduqa year 1 = -1701, -1645, -1637, -1581 or -1517, see Table 2.1.

The **month-lengths** have been discussed in Section 3, see in particular Table 3.1.

The **eclipses** have been discussed in Section 6; see list (1) in Appendix C.

When taken separately, each of the three pieces of evidence agrees with at least 3 to 5 chronologies per century; with the exception of the Venus solutions, these tend to be very irregularly spaced. But, with the exception of the Long Chronology, it is difficult to find a chronology matching any two of the three sources simultaneously. The following is an abbreviated account of a search for solutions satisfying at least two sources of evidence.

First pairing: Venus chronologies and Ur III

month-lengths. Because of uncertainties in the back-reckoning, each Venus chronology fixes the date of Amar-Sin only to within plus/minus 15 years or so. The Long chronology gives that Amar-Sin Year 1 begins -2093APR3, with 83 misses for the month-lengths, as already mentioned. The Middle chronologies give four possible beginnings for Amar-Sin Year 1 (-2042, -2040, -2039 and -2037, with 91, 89, 92 and 90 misses for the corresponding alignments of month-lengths). The Short chronology gives two fits (-1983MAY16, 89 misses, and -1981FEB25, 91 misses). The Supershort chronology gives -1907FEB16, with 88 misses, and an excessively early beginning of the year.

Second pairing: Venus chronologies and Simanu eclipse (EAE 20-III). For the Long chronology, the only feasible match is the eclipse of -2094JUL25 (unique between -2139 and -2063, in which years there are two poorly matching eclipses); for the Middle chronologies there are no matching eclipses between -2063 and -2018 (also poorly matching), for the Short none between -2001 and -1936; for the Supershort, there is a match with the eclipse of -1907JUN28, but there are no matches for the Addaru eclipse (EAE 21-XII), approximately 42 years later.

Third pairing: Simanu eclipse and Ur III months. The eclipse ought to fall into a 12-month span before the beginning of Amar-Sin's reign, and the latter should align exactly with the month-lengths. In a 300-year range of years between -2154 and -1854, there is only one such eclipse compatible with the month-lengths: -2094JUL25 (83 misses for the month-lengths); it corresponds to the Long chronology.

The most noteworthy result is that of the third pairing: *If we throw out the Venus data, the Long Chronology is the only one compatible with the remaining evidence.*

8.2 Alternative chronologies matching the Akkad eclipses?

I searched for chronologies such that each of the three Akkad omens should match up with at least one eclipse immediately preceding one of the eight changes of reign in the dynasty of Akkad. The search was made for Sargon year 1 beginning anywhere between -2380 and -2080. By far the most impressive matches, 6 or more eclipses, were obtained with the two chronologies discussed above: (S -2380) and (S -2326). All other choices gave at most 3 or 4 matching eclipses. The following lists the chronologies and the matching eclipses obtained for the three omens 20-I; 21-I; 21-VI; eclipses matching the same omen are joined together with &.

- (S -2380): -2301MAR9 & -2264MAR19 & -2236MAR10; -2200MAR31; -2301SEP2 & -2239NOV4 & -2236SEP2
 (S -2377): -2236MAR10; -2322APR29; -2236SEP2
 (S -2374): -2258MAY12; -2209APR10; -2258NOV4
 (S -2365): -2301MAR 9; -2200MAR31; -2301SEP2
 (S -2347): -2182APR12; -2268MAY31 & -2203JUN1; -2182OCT5
 (S -2337): -2258MAY12; -2282MAR8; -2258NOV4
 (S -2326): -2247APR10 & -2210APR21 & -2182APR12; -2146MAY3; -2247OCT4 & -2182OCT5
 (S -2323): -2182APR12; -2268MAY31; -2182OCT5
 (S -2322): -2258MAY12; -2181APR1; -2258NOV4
 (S -2311): -2247APR10; -2146MAY3; -2247OCT4
 (S -2279): -2163APR12; -2200MAR31; -2099OCT17
 (S -2250): -2171MAR12; -2134MAR22; -2134SEP15
 (S -2102): -1958MAR27; -1961MAY27; -1986SEP28

Note that the chronologies are quite unevenly distributed: 10 in the 24th century, 2 in the 23rd and 1 in the 22nd. If we should want not only to shorten the distance between Šarkališarri and Ur-Nammu, but also to lower the date of the Hammurapi dynasty, we end up in the sparsely populated last part of the list: (S -2279), (S -2250) or (S -2102).

9 Discussion of the conclusions.

A consistent fit of all parts of the astronomical evidence is obtained with the chronologies: Ammišaduqa Year 1 = -1701; Amar-Sin Year 1 = -2093; Sargon Year 1 = -2380 (using Sollberger's original relative chronology as is), or alternatively, Sargon Year 1 = -2326 (this shortens Sollberger's ladder by 54 years). We end up with these *chronologies even if we ignore the Venus data*. For the Akkad dynasty both choices of chronology produce an almost identical, amazingly "ominous" picture, with the same omen corresponding to several similar eclipses preceding changes of reign within a year.

The criticism of the historians has two unrelated components, both directed towards shortening a particular historical segment. First, with the Long Venus chronology, there is an irritating blackout period in the middle of the second millennium which ought to be closed. Second, the gap between Šarkališarri's death and Ur-Nammu (which is 80 years in Sollberger's relative chronology) ought to be narrowed to about one generation, and Gudea should be moved closer to Ur III. According to Steinkeller (1988), the reign of Gudea overlapped with that of Ur-Nammu.

The first goal requires lowering the date of the Hammurapi dynasty by some 60-150 years (i. e. replacing the so-called Long by a Middle or Short chronology; a more drastic shortening to the Super-short chronology and beyond appears to be unrealistic,

it would seem to create conflicts with Amarna-period synchronisms). The second can be accommodated by overlaying the Guti and Uruk kings with the later part of the Akkad dynasty. To get Wilcke's "very short distance" between Šarkališarri and Ur-Nammu, one would have to shift the Akkad dynasty by about 40-70 years, resulting in a gap of 40 to 10 years between Šarkališarri and Ur-Nammu. In Sollberger's chronology, the distance from Amar-Sin 1 to Sargon 1 is 287 years; this distance thus should be shortened to a target range of 217-247 years.

If one considers both criticisms and tries to meet one, or the other, or both, with one of the alternative chronologies for Amar-Sin found in Section 7.1, by extending those chronologies forward to Babylon I and backward to Akkad, one ends up with the following chronological proposals. For each of them, the OB, Ur III and Akkad parts need to be discussed separately. They are conveniently grouped as "Long", "Middle", etc., even though only the OB part is directly related to the Venus chronologies.

"Long":

Ammišaduqa year 1 = -1701. Long Venus Chronology, confirmed by OB month-lengths.

Amar-Sin year 1 = -2093. Unique match with both Ur III month-lengths and Ur III eclipses.

Sargon year 1 = -2380 or -2326. Excellent matches with the Akkad eclipses. The first corresponds to the original Sollberger chronology, the second is 54 years later.

"Middle":

Ammišaduqa year 1 = -1645 or -1637. Middle Venus chronologies. Agrees poorly with the Venus Tablet and is not supported by the OB month-lengths.

Amar-Sin year 1 = -2042, -2040, -2039 or -2037. Based on the Ur III month-lengths, but agrees poorly. Disagrees with Ur III eclipses.

Sargon year 1 = -2326, -2279, -2250. Based on the

Akkad eclipses. These years correspond roughly to the original Sollberger relative chronology and to shifts of approximately 47 or 76 years, respectively.

“Short”:

Ammišaduqa year 1 = -1581. Based on the Short Venus chronology, but not supported by the OB month-lengths.

Amar-Sin year 1 = -1983 or -1981. Based on Ur III month-lengths, but agrees poorly. Disagrees with Ur III eclipses.

Sargon: no good agreement with Akkad eclipses. Sollberger's relative chronology gives Sargon 1 = -2270 or -2268. (S -2279) lengthens this by 9 years. The shifted target range is -2230 to -2198. The best date from Akkad eclipses is (S -2250), which shifts too little (20 years).

“Supershort”:

Ammišaduqa year 1 = -1517. Supershort Venus chronology.

Amar-Sin year 1 = -1913 or -1906. Based on Simanu eclipse (EAE 20-III). Incompatible with Ur III month-lengths, no counterparts for the Addaru eclipse. Alternatively, Amar-Sin year 1 = -1907, based on Ur III month-lengths; disagrees with Ur III eclipses.

Sargon: no good agreement with Akkad eclipses. Sollberger date for Sargon year 1: -2200 or -2193. Shifted target range: -2160 to -2123. Best date from Akkad eclipses: (S -2102). This shifts too much (91 years).

We can summarize: the “Long” solution satisfies all five independent sources of astronomical evidence and can provide the desired compression of Akkad - Ur III, but of course it fails to lower the Hammurapi date. The “Middle” solution disagrees with two of the five sources (OB month-lengths, Ur III eclipses) and agrees poorly with another two (Venus Tablet, Ur III month-lengths); that is, despite an acceptable agreement with the Akkad eclipses, it is incompatible with the combined astronomical evidence. The “Short” disagrees with the OB month-lengths and the Ur III eclipses, while the “Supershort” agrees very poorly with all of the Ur III data, and both give an unsatisfactory compression of Akkad - Ur III; so they are neither astronomically nor historically convincing.

At present, I see no way how one could accommodate simultaneously a compression of Akkad - Ur III and a lowering of the date of the Hammurapi dynasty without doing severe violence to the currently available astronomical evidence. In other words, if the Long Chronology should ever be proven impossible by harder evidence than the astronomical, the

case would be thrown wide open. The only other independent hard piece of absolute chronological evidence available at present, namely the tree-ring date for the Sarıkaya Palace at Acemhöyük (Kuniholm *et al.* 1996), admittedly argues for a lowering of the Šamši-Adad date and hence of the chronology of the Hammurapi dynasty. But in my opinion the astronomical case for the Long Chronology and the associated interlinking mesh now is sufficiently strong that it cannot be overthrown by dendrochronological evidence from a single site.

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APPENDIX A: Sollberger's relative chronology.

Extracted from Sollberger (1954-56) and anchored at Amar-Sin year 1 = -2093. The synchronisms between Uruk and Lagaš are soft: they are based on back-reckoning from Ur-Nammu 2 = Nammahani 3.

	AKKAD:	ENSIS OF LAGAŠ	EN-PRIESTESSES
-2380	Sargon 1 50→ 56	Enheduanna
-2324	Rimuš 1 9	Ki-KU-id	
-2315	Maništusu 1 15	Engilsa	
-2300	Naramsin 1 6→ 37	Ur'a	Enmenanna
-2263	Šarkališarri 1 5→ 25	Lugalušumgal	X1
-2238	Igigi etc. 1	Puzurmama	
-2235	Dudu 1 13→ 21	Urutu Urmama	X2
-2214	Šu-DURUL 1 15	Lubau Lugula Kakug	
	URUK:		
-2199	Urnigin 1 2 7	Urbau	1 6 7
-2192	Urgigir 1 6		12→ 13
-2186	Kudda 1 2 3 6	Gudea	14 1 4
-2180	Puzurili 1 5		5 9
-2175	Urutu 1 6		10 15
-2169	Utuhegal 1 2 6 7 8 9 10	Urningirsu Pirigme Ur-GAR Nammahani	16 1 5 1 2 1 1
	UR III:		
-2159	Ur-Nammu 1 2→ 3 5→ 18	Nammahani Uraba Lugalbur (etc.)	2 ←3 Ennirgalanna
-2141	Šulgi 1 15→ 43→ 48	Ennirzianna Enuburzianna
-2093	Amar-Sin 1 9		
-2084	Šu-Sin 1 9		
-2075	Ibbi-Sin 1 10→	Ennirsianna
-2052	24		

Transition Akkad - Uruk - Ur (modified).

This is a tentative year-by-year alignment of the transition period from the late dynasty of Akkad to the early Third dynasty of Ur. Against Sollberger, the Akkad dates are lowered 54 years, and it is assumed that the year counts of Utuhegal (as king in Uruk) and of Ur-Nammu (as governor in Ur) start in -2159, and that Ur-Nammu became king ca. -2149. This would seem to give the best alignment with the eclipses. It also satisfies Steinkeller's (1988) claim for an overlap between the reigns of Gudea and Ur-Nammu (although just barely).

YEAR	OMEN	AKKAD:	URUK:	UR:	LAGAŠ:
-2189			Urgin 1		
-2188					Urbau 1
-2187					
-2186					
-2185	(5)	Šarkališari 25			
-2184		Igigi etc. 1			
-2183				7	
-2182	(8,10)		Urgigir 3	1	
-2181		Dudu 1			
-2180					
-2179					
-2178					
-2177				6	
-2176			Kudda 1		
-2175					14
-2174					1
-2173					
-2172					
-2171				6	
-2170			Puzurili 1		
-2169					
-2168					
-2167					
-2166				5	
-2165			Urutu 1		
-2164					
-2163					
-2162					
-2161		Dudu 21			
-2160	(6)	Šu-DURUL 1		6	
-2159	(7)		Utuhegal 1	Ur-Nammu 1	Gudea 16
-2158				(governor)	Urningirsu 1
-2157					
-2156					
-2155					
-2154					5
-2153					Pirigme 1
-2152					2
-2151					Ur-Gar 1
-2150			Utuhegal 10	10	Nammahani 1
-2149	(4,5)			Ur-Nammu 2	
-2148				(king)	3
-2147					Uraba 1
-2146	(9)	Šu-DURUL 15			
-2145		End of dynasty			
-2144					
-2143					
-2142					
-2141				Šulgi 18	
-2140				1	

APPENDIX B: List of Lunar Eclipses.

The list of eclipses was calculated for the coordinates of Babylon. The exact location of Agade is not known, but it seems to have been nearby, and the values of this crude table are good enough also for Ur. The table uses a lunar orbital acceleration of $-26''/\text{cy}^2$ and

$$\Delta T = ET - UT = 32.5 t^2 \text{ sec,}$$

where t is the time since 1800 AD, measured in centuries.

Explanations:

- DATE** Date in the Julian Calendar (for moment of mid-eclipse, in UT).
- M** Approximate Babylonian month, calculated from the solar/lunar longitude λ at the conjunction of sun and moon immediately preceding the beginning of the month, according to the formula $M = \lambda/30 + 1.5$. Thus, if this longitude is between -15° and 15° , then M is between 1.0 and 2.0, etc. Deviations of up to plus/minus 1.5 months can be expected.
- D** Day of the eclipse in the Babylonian month.
- Beg** Begin of the eclipse, expressed in watches of the night (1.0 = beginning of the first watch, 3.5 = midpoint of the third watch, etc.). Values less than 1 indicate that the eclipse began before sunset.
- End** End of the eclipse, expressed in watches of the night. Values greater than 4 indicate that the eclipse ended after sunrise.
- Angles** Entrance and exit angles of the shadow. Note the overlapping classification:
 North: 0° - 90° and 270° - 360°
 East: 45° - 135°
 South: 90° - 270°
 West: 225° - 315°
- Magn** Magnitude, in fractions of the diameter of the moon (values of 1 and greater indicate a total eclipse).

DATE	M	D	Beg	End	Angles	Magn	DATE	M	D	Beg	End	Angles	Magn
-2350MAY 8	1.9	14	1.9	2.4	59 355	0.20	-2323MAY10	1.9	14	3.9	4.9	82 309	1.10
-2349MAR30	12.6	15	4.1	4.6	174 245	0.27	-2323NOV 3	7.7	13	2.9	3.8	83 244	1.51
-2348MAR18	12.2	15	0.4	1.4	125 291	1.61	-2322APR29	1.6	15	1.8	2.7	124 270	1.30
-2348SEP10	5.9	13	2.0	3.0	55 252	1.57	-2322OCT23	7.4	13	3.9	4.7	42 282	0.88
-2347MAR 7	11.9	15	1.2	1.9	78 334	0.65	-2320MAR 8	12.0	14	1.8	2.3	43 347	0.13
-2347AUG31	5.6	14	-0.2	0.7	95 217	0.94	-2320SEP 1	5.6	14	2.2	2.8	129 205	0.33
-2345JAN15	10.2	13	0.0	0.6	141 236	0.53	-2319FEB25	11.6	13	1.9	2.8	93 292	1.53
-2345JUL11	3.9	15	2.6	3.5	39 311	0.44	-2318FEB15	11.3	13	3.8	4.5	132 247	0.80
-2344JAN 5	9.8	13	3.0	3.8	94 274	1.86	-2318AUG11	4.9	15	0.8	1.8	49 298	0.73
-2344JUN29	3.6	14	2.6	3.9	89 270	1.80	-2317DEC27	9.5	14	3.1	3.7	37 300	0.56
-2344DEC24	9.5	14	1.4	2.0	51 308	0.65	-2316DEC15	9.1	15	0.1	0.9	73 256	1.80
-2343JUN19	3.2	13	3.6	4.5	139 230	0.49	-2315JUN 9	2.9	14	1.1	2.3	107 291	1.81
-2342NOV 3	7.7	14	1.3	1.9	127 199	0.27	-2315DEC 4	8.8	14	0.9	1.5	112 209	0.55
-2341APR29	1.6	14	1.8	2.8	88 307	1.23	-2313OCT14	7.0	13	3.4	3.9	2 299	0.19
-2341OCT23	7.4	14	0.8	1.8	81 243	1.51	-2312APR 9	12.9	15	3.9	4.8	135 284	1.34
-2340APR18	1.2	15	-0.1	0.8	129 267	1.17	-2312OCT 2	6.7	14	0.3	1.3	50 251	1.52
-2340OCT11	7.0	13	1.8	2.6	43 282	0.88	-2311MAR29	12.6	14	4.4	5.3	91 327	0.92
-2338FEB26	11.6	15	0.2	0.8	47 338	0.25	-2309FEB 6	10.9	13	3.6	4.1	155 241	0.43
-2337FEB15	11.3	14	0.3	1.2	93 286	1.63	-2308JAN26	10.6	14	1.5	2.3	107 281	1.77
-2337AUG12	4.9	15	3.5	4.7	90 257	1.64	-2308JUL21	4.3	14	-0.6	0.7	72 269	1.55
-2336FEB 4	10.9	13	2.1	2.7	131 241	0.72	-2307JUL10	3.9	14	0.4	1.5	120 231	0.76
-2335DEC15	9.1	15	1.2	1.8	33 295	0.59	-2304MAY10	1.9	15	3.8	4.8	118 273	1.44
-2334JUN 9	2.9	13	2.8	3.7	149 249	0.60	-2304NOV 2	7.7	13	0.2	1.0	44 283	0.89
-2334DEC 5	8.8	14	3.5	4.3	69 251	1.81	-2302MAR20	12.3	14	3.5	3.8	35 359	0.00
-2333NOV24	8.4	14	4.4	5.1	109 205	0.54	-2301MAR 9	12.0	13	3.6	4.5	93 298	1.42
-2332MAY19	2.2	14	4.0	4.6	64 346	0.34	-2301SEP 2	5.6	15	1.2	2.3	87 247	1.52
-2331OCT 2	6.7	13	1.2	1.7	2 299	0.19	-2300FEB26	11.6	14	0.1	0.9	132 253	0.90
-2330MAR29	12.6	15	2.1	3.1	130 288	1.48	-2300AUG22	5.3	14	3.0	4.0	48 292	0.80
-2330SEP22	6.3	13	4.3	5.3	52 251	1.54	-2298JUL 1	3.6	14	-0.2	0.6	151 230	0.35
-2329MAR19	12.3	14	2.7	3.5	85 331	0.78	-2298DEC26	9.5	15	1.9	2.7	77 261	1.78
-2329SEP11	5.9	14	2.2	3.1	91 216	0.97	-2297JUN21	3.3	13	3.4	4.5	107 283	1.82
-2327JAN25	10.6	13	1.8	2.4	148 239	0.49	-2297DEC15	9.2	14	2.6	3.3	115 213	0.56
-2325JAN 5	9.8	14	3.2	3.9	57 312	0.68	-2296JUN 9	2.9	14	1.3	2.2	69 329	0.61
-2324NOV14	8.1	14	3.3	3.8	130 201	0.27	-2294OCT13	7.0	13	2.7	3.6	50 251	1.51

DATE	M	D	Beg	End	Angles	Magn	DATE	M	D	Beg	End	Angles	Magn
-2293APR 9	1.0	15	0.0	1.0	97 323	1.08	-2236MAR10	12.0	14	3.4	4.3	130 284	1.45
-2293OCT 3	6.7	14	0.6	1.4	87 215	1.01	-2236SEP 2	5.7	14	1.2	2.3	46 264	1.21
-2291FEB16	11.3	14	0.0	0.6	161 241	0.36	-2235FEB27	11.7	15	1.7	2.4	87 322	0.98
-2291AUG12	5.0	15	2.0	2.5	9 315	0.12	-2235AUG22	5.3	13	2.3	3.3	90 226	1.13
-2290FEB 6	10.9	14	3.3	4.1	113 283	1.71	-2233JAN 7	10.0	14	1.5	1.9	155 216	0.17
-2290AUG 1	4.6	14	1.6	2.8	65 267	1.44	-2233JUL 3	3.7	15	1.1	1.9	42 315	0.44
-2289JAN26	10.6	15	1.7	2.4	69 319	0.76	-2233DEC27	9.6	14	1.3	2.2	101 261	1.48
-2289JUL21	4.3	13	2.7	3.7	111 230	0.87	-2232DEC15	9.2	13	2.7	3.4	57 295	0.91
-2288DEC 5	8.8	14	1.5	2.0	137 207	0.25	-2231JUN11	3.0	15	0.9	1.8	141 232	0.49
-2287MAY31	2.6	14	1.4	2.4	68 313	0.82	-2230OCT26	7.5	14	1.3	1.8	129 195	0.22
-2287NOV24	8.5	14	1.2	2.1	87 249	1.51	-2229OCT16	7.1	14	3.8	4.7	85 239	1.42
-2286NOV13	8.1	13	2.3	3.1	46 285	0.89	-2228APR 9	1.0	13	1.4	2.3	123 274	1.38
-2285MAY10	1.9	15	2.2	2.7	173 219	0.06	-2226FEB18	11.3	15	1.6	2.1	47 334	0.29
-2284SEP23	6.3	15	0.4	1.0	128 198	0.26	-2225FEB 8	11.0	15	3.5	4.4	89 285	1.58
-2283SEP13	6.0	14	3.5	4.6	86 243	1.48	-2224JAN28	10.6	14	4.0	4.8	128 239	0.73
-2282MAR 8	12.0	13	1.8	2.6	131 259	1.00	-2224JUL23	4.3	14	3.3	4.4	66 296	1.05
-2280JAN17	10.3	15	1.5	2.1	44 313	0.49	-2223DEC 6	8.9	13	2.4	2.8	14 308	0.22
-2280JUL11	4.0	13	2.1	2.8	152 220	0.24	-2222JUN 2	2.7	15	0.0	0.8	154 249	0.54
-2279JAN 6	9.9	14	3.6	4.5	81 267	1.75	-2222NOV26	8.5	14	0.0	0.8	57 258	1.52
-2279DEC26	9.5	14	4.3	5.0	119 219	0.58	-2221MAY22	2.4	14	0.2	1.3	111 297	1.73
-2278JUN21	3.3	14	3.6	4.5	69 320	0.73	-2221NOV16	8.1	14	3.5	4.3	91 219	1.01
-2277NOV 4	7.8	13	1.8	2.3	4 301	0.20	-2220MAY10	2.0	14	1.1	1.8	66 347	0.35
-2276APR30	1.6	15	1.2	2.2	143 273	1.02	-2218SEP14	6.1	13	3.3	4.4	43 263	1.16
-2275APR19	1.3	14	1.6	2.6	101 317	1.23	-2217MAR11	12.0	15	3.5	4.3	93 321	1.07
-2275OCT14	7.0	14	2.9	3.7	86 215	1.02	-2215JAN18	10.3	14	3.1	3.5	163 218	0.13
-2273FEB27	11.7	13	1.8	2.3	168 240	0.28	-2215JUL14	4.0	14	3.5	4.3	32 316	0.33
-2273AUG24	5.3	14	4.2	4.6	359 317	0.04	-2214JAN 7	10.0	13	3.0	3.8	107 264	1.45
-2272AUG12	5.0	13	3.8	5.0	58 266	1.35	-2214JUL 3	3.7	15	0.3	1.5	82 275	1.64
-2271FEB 6	10.9	14	3.5	4.2	75 321	0.82	-2213JUN22	3.3	15	2.9	3.9	132 233	0.62
-2270DEC17	9.2	14	3.3	3.8	142 210	0.23	-2212NOV 6	7.8	14	3.4	3.9	131 197	0.22
-2269JUN12	3.0	14	3.7	4.6	60 314	0.69	-2211MAY 1	1.7	14	0.4	1.3	73 321	0.77
-2269DEC 6	8.9	13	3.0	3.9	91 253	1.51	-2211OCT26	7.5	15	0.0	0.9	85 240	1.41
-2268MAY31	2.6	15	1.1	2.2	105 275	1.72	-2210APR21	1.4	13	3.3	4.3	119 277	1.52
-2268NOV24	8.5	13	4.2	5.0	49 288	0.89	-2210OCT15	7.1	15	0.8	1.7	45 279	0.95
-2267MAY21	2.3	15	4.1	4.7	161 225	0.20	-2209APR10	1.0	14	1.5	2.0	167 230	0.20
-2266OCT 4	6.7	14	2.8	3.3	128 196	0.24	-2208MAR 1	11.7	15	3.4	3.9	45 342	0.20
-2265MAR30	12.7	14	1.3	2.2	88 308	1.18	-2207FEB18	11.4	15	0.1	0.7	90 291	1.49
-2264MAR19	12.3	13	3.6	4.5	129 265	1.12	-2207AUG13	5.0	14	0.7	1.8	99 246	1.33
-2264SEP12	6.0	15	0.6	1.6	46 283	0.90	-2206FEB 7	11.0	15	0.4	1.2	129 245	0.81
-2262JAN28	10.6	15	3.3	3.9	46 320	0.44	-2205DEC18	9.3	13	4.2	4.7	18 313	0.22
-2262JUL23	4.3	13	4.5	5.0	153 210	0.14	-2204JUN12	3.0	15	1.9	2.7	157 239	0.38
-2261JAN17	10.3	15	0.2	1.0	84 273	1.71	-2204DEC 6	8.9	14	2.0	2.8	61 262	1.52
-2261JUL12	4.0	14	0.7	1.8	105 267	1.59	-2203JUN 1	2.7	14	2.0	3.2	113 289	1.77
-2260JAN 6	9.9	15	0.8	1.5	123 225	0.62	-2203NOV26	8.5	15	0.1	0.9	94 222	1.01
-2259NOV15	8.2	13	3.9	4.3	7 302	0.21	-2202MAY22	2.4	13	3.0	3.8	71 338	0.51
-2258MAY12	2.0	15	3.0	4.0	147 266	0.86	-2200MAR31	12.7	14	1.4	2.3	139 280	1.23
-2258NOV 4	7.8	14	1.2	2.1	52 253	1.51	-2199SEP13	6.1	13	0.1	1.1	81 224	1.23
-2257MAY 1	1.7	14	3.3	4.4	105 311	1.40	-2198SEP 3	5.7	13	3.7	4.1	136 174	0.01
-2256APR19	1.3	13	4.1	4.4	50 9	0.03	-2196JUL13	4.0	15	2.6	3.8	74 273	1.52
-2255MAR10	12.0	13	3.6	4.1	176 238	0.19	-2195JAN 6	10.0	13	1.1	1.9	68 303	0.96
-2254FEB27	11.7	14	1.6	2.4	124 285	1.55	-2193MAY12	2.1	13	2.3	3.1	66 324	0.62
-2253FEB17	11.3	15	0.1	0.7	81 322	0.89	-2193NOV 6	7.8	15	2.1	3.0	87 241	1.41
-2253AUG12	5.0	13	0.1	1.0	96 228	1.06	-2192OCT26	7.5	14	2.8	3.7	46 279	0.96
-2250JUN12	3.0	15	3.2	4.4	98 276	1.85	-2191APR21	1.4	14	3.5	4.1	160 236	0.33
-2250DEC 5	8.9	13	0.8	1.6	52 292	0.89	-2189MAR 1	11.7	15	1.5	2.4	90 297	1.39
-2247APR10	1.0	13	3.0	3.9	84 313	1.05	-2189AUG25	5.4	13	3.2	4.2	97 241	1.27
-2247OCT 4	6.7	15	1.6	2.6	84 239	1.43	-2188FEB18	11.4	14	1.9	2.8	130 252	0.90
-2246SEP24	6.4	14	2.8	3.7	45 281	0.93	-2188AUG13	5.0	14	1.0	2.0	63 282	1.21
-2243JAN27	10.6	15	1.9	2.7	87 279	1.65	-2187DEC28	9.7	14	0.9	1.4	22 318	0.21
-2243JUL23	4.3	13	3.1	4.3	103 260	1.50	-2186JUN24	3.4	14	4.0	4.7	160 227	0.23
-2242JAN16	10.3	14	2.4	3.2	126 232	0.67	-2186DEC18	9.3	13	3.9	4.7	65 267	1.51
-2242JUL12	4.0	14	0.9	1.9	68 303	0.96	-2185JUN13	3.1	14	3.9	5.2	114 281	1.61
-2241NOV26	8.5	13	0.4	0.9	10 305	0.21	-2185DEC 7	8.9	14	2.1	2.9	97 226	1.01
-2240NOV15	8.2	13	3.4	4.2	54 255	1.52	-2182APR12	1.1	14	3.4	4.3	143 276	1.10
-2239NOV 4	7.8	14	1.4	2.2	88 217	1.01	-2182OCT 5	6.8	14	1.2	2.2	38 262	1.10

DATE	M	D	Beg	End	Angles	Magn	DATE	M	D	Beg	End	Angles	Magn
-2181APR 1	12.7	15	1.3	2.2	102 316	1.30	-2121DEC20	9.3	14	4.2	5.1	101 255	1.39
-2181SEP24	6.4	13	2.4	3.4	79 224	1.26	-2120JUN13	3.1	14	0.1	1.3	87 285	1.56
-2179AUG 4	4.7	15	1.1	1.6	13 317	0.14	-2117APR13	1.1	15	2.4	3.4	78 318	0.87
-2178JAN28	10.7	14	1.1	2.0	119 271	1.35	-2117OCT 7	6.8	14	-0.3	0.6	93 230	1.15
-2177JAN18	10.3	13	2.9	3.6	74 307	1.00	-2116APR 1	12.8	14	2.7	3.7	121 275	1.40
-2177JUL14	4.0	15	-0.3	0.8	114 233	0.87	-2116SEP26	6.5	14	3.8	4.7	57 267	1.37
-2176NOV27	8.6	14	2.0	2.4	137 202	0.22	-2115MAR22	12.4	13	3.4	3.7	175 220	0.06
-2175MAY23	2.4	13	4.3	5.1	58 328	0.48	-2115SEP15	6.1	15	1.1	1.5	2 325	0.01
-2175NOV17	8.2	14	4.1	4.9	89 244	1.41	-2114FEB 9	11.1	13	2.9	3.3	31 346	0.06
-2174MAY12	2.1	14	0.8	1.8	108 282	1.80	-2113JAN30	10.8	14	0.9	1.7	79 289	1.38
-2171MAR12	12.1	15	3.2	4.1	89 303	1.28	-2110NOV18	8.3	13	3.5	4.3	42 268	1.08
-2170MAR 1	11.7	14	3.5	4.4	129 259	1.01	-2109MAY14	2.1	15	2.7	3.8	115 296	1.85
-2170AUG25	5.4	14	3.4	4.4	61 277	1.27	-2108OCT26	7.5	13	2.5	2.9	124 179	0.12
-2168JAN 8	10.0	13	2.7	3.2	26 324	0.19	-2106MAR12	12.2	13	2.4	3.2	143 272	1.00
-2168DEC28	9.6	14	0.6	1.4	69 272	1.49	-2106SEP 6	5.8	15	0.1	1.1	42 266	1.11
-2167DEC18	9.3	14	4.0	4.8	101 230	1.01	-2105AUG26	5.4	15	1.2	2.3	85 229	1.23
-2166JUN12	3.1	14	-0.2	0.8	76 320	0.82	-2104FEB20	11.4	14	3.0	3.3	44 1 0.04	
-2164OCT16	7.2	13	3.3	4.3	38 263	1.09	-2103JAN10	10.1	14	4.3	4.6	159 216	0.14
-2163APR12	1.1	15	3.2	4.2	107 313	1.43	-2103DEC30	9.7	15	0.8	1.7	106 259	1.37
-2162SEP24	6.4	13	1.8	2.2	127 176	0.08	-2102JUN24	3.5	14	2.4	3.5	79 284	1.44
-2161AUG16	5.1	14	3.6	4.0	3 318	0.06	-2102DEC19	9.3	14	1.2	2.0	62 294	0.99
-2160FEB 9	11.1	13	2.8	3.6	126 273	1.28	-2101JUN14	3.1	15	0.4	1.4	122 248	0.99
-2160AUG 4	4.7	15	-0.1	1.1	59 270	1.32	-2099APR24	1.5	14	4.3	5.1	72 323	0.72
-2159JUL24	4.4	15	1.8	3.0	105 232	0.98	-2099OCT17	7.2	13	2.0	2.9	94 230	1.15
-2158DEC 9	8.9	14	3.9	4.3	141 206	0.21	-2098APR13	1.1	14	4.4	5.4	116 280	1.56
-2157NOV28	8.6	15	0.6	1.4	92 247	1.41	-2098OCT 7	6.8	15	-0.2	0.8	57 266	1.38
-2156MAY23	2.4	13	2.9	3.9	101 284	1.83	-2097SEP27	6.5	15	3.4	3.7	2 322	0.03
-2156NOV16	8.2	14	1.1	1.9	50 283	0.96	-2095FEB10	11.1	14	2.7	3.5	82 295	1.32
-2155MAY12	2.1	14	1.0	1.8	146 244	0.60	-2095AUG 5	4.8	14	-0.3	0.8	112 239	0.97
-2153SEP15	6.1	14	1.3	2.2	94 233	1.19	-2094JAN30	10.7	15	0.9	1.7	116 253	1.14
-2149JAN 8	10.0	14	2.5	3.2	73 277	1.47	-2094JUL25	4.5	13	1.1	2.3	74 285	1.32
-2149JUL 4	3.7	14	0.6	1.9	115 263	1.32	-2092JUN 4	2.8	15	0.6	1.4	158 242	0.41
-2149DEC29	9.6	15	0.7	1.4	106 235	1.03	-2092NOV28	8.7	14	-0.1	0.8	45 272	1.08
-2148JUN22	3.4	13	1.9	3.0	76 311	0.96	-2091NOV17	8.3	13	1.3	2.2	82 229	1.30
-2146MAY 3	1.8	15	1.1	2.0	150 265	0.83	-2090MAY14	2.1	15	0.5	1.3	71 340	0.49
-2145OCT16	7.2	13	0.7	1.6	77 224	1.29	-2088MAR23	12.5	13	4.2	5.0	149 269	0.89
-2144APR11	1.1	15	1.7	2.1	52 7 0.05		-2088SEP16	6.2	15	2.3	3.3	38 266	1.06
-2144OCT 5	6.8	13	4.1	4.5	124 177	0.10	-2087MAR12	12.2	14	0.9	1.8	104 311	1.42
-2142AUG15	5.1	15	2.3	3.4	52 269	1.23	-2087SEP 6	5.8	14	3.4	4.5	80 228	1.29
-2141FEB 8	11.1	13	1.2	1.9	87 311	1.13	-2085JAN21	10.4	15	0.9	1.3	167 217	0.10
-2141AUG 5	4.7	14	4.0	5.1	98 231	1.08	-2084JAN10	10.1	15	2.5	3.4	112 263	1.33
-2140DEC19	9.3	15	0.6	1.0	146 209	0.20	-2084DEC30	9.7	14	2.9	3.7	68 298	1.02
-2139JUN13	3.1	13	1.5	2.1	39 333	0.21	-2083JUN24	3.4	14	2.7	3.7	114 248	1.12
-2139DEC 8	9.0	15	2.4	3.3	96 251	1.40	-2081OCT29	7.6	13	4.2	5.0	94 231	1.15
-2138NOV28	8.6	14	2.9	3.8	53 286	0.96	-2080APR23	1.5	14	-0.2	0.9	111 284	1.71
-2137MAY24	2.4	14	3.1	3.9	138 246	0.73	-2080OCT17	7.2	14	2.1	3.0	57 266	1.38
-2135APR 2	12.8	15	0.7	1.6	83 313	1.02	-2079APR12	1.2	14	0.7	1.4	159 237	0.34
-2135SEP26	6.5	13	3.6	4.5	94 231	1.17	-2077AUG16	5.2	14	2.0	3.0	111 232	0.89
-2134MAR22	12.4	14	1.1	2.0	125 270	1.26	-2076FEB11	11.1	15	2.7	3.5	118 259	1.20
-2134SEP15	6.1	14	1.4	2.4	58 269	1.35	-2076AUG 5	4.8	13	3.4	4.6	72 278	1.41
-2132JAN30	10.8	14	1.1	1.5	31 338	0.11	-2075JUL25	4.5	14	0.1	0.6	27 331	0.14
-2131JAN19	10.4	14	4.3	5.1	76 283	1.43	-2074JUN15	3.2	14	2.9	3.6	161 232	0.27
-2131JUL14	4.1	14	2.7	3.9	114 255	1.19	-2074DEC 9	9.0	13	1.8	2.6	49 276	1.08
-2130JAN 8	10.0	14	2.5	3.3	110 241	1.05	-2073JUN 5	2.8	15	-0.2	1.0	118 282	1.61
-2130JUL 4	3.8	13	4.0	5.2	76 302	1.09	-2073NOV29	8.7	13	3.3	4.1	85 232	1.30
-2128MAY14	2.1	14	3.2	4.0	153 258	0.69	-2072MAY24	2.5	15	2.3	3.2	75 331	0.64
-2128NOV 6	7.9	13	1.5	2.4	40 266	1.08	-2072NOV17	8.3	14	1.1	1.5	128 183	0.13
-2127MAY 3	1.8	15	0.7	1.8	113 303	1.71	-2070APR 3	12.9	14	0.0	0.8	154 265	0.76
-2127OCT27	7.5	13	2.9	3.8	78 225	1.30	-2069MAR24	12.5	13	2.7	3.6	109 309	1.54
-2126APR23	1.4	15	3.5	4.0	60 357	0.19	-2068MAR12	12.1	14	1.1	1.5	61 354	0.23
-2126OCT16	7.2	14	0.3	0.7	124 177	0.12	-2067JAN31	10.8	15	2.7	3.0	175 217	0.04
-2124MAR 1	11.8	14	0.7	1.6	138 273	1.11	-2066JAN21	10.4	14	4.2	5.1	119 266	1.28
-2123FEB19	11.4	13	2.9	3.7	93 312	1.21	-2066JUL16	4.2	14	-0.2	0.8	63 282	1.22
-2122DEC30	9.7	15	2.4	2.9	152 213	0.18	-2063MAY15	2.2	15	1.4	2.2	56 333	0.39
-2121JUN25	3.5	13	3.7	4.2	27 337	0.09	-2063NOV 8	8.0	14	0.7	1.5	96 233	1.15

DATE	M	D	Beg	End	Angles	Magn	DATE	M	D	Beg	End	Angles	Magn
-2062MAY 4	1.8	14	1.5	2.6	105 287	1.78	-2003MAR14	12.2	15	1.2	1.6	171 222	0.09
-2062OCT29	7.6	14	4.3	5.2	58 268	1.38	-2003SEP 6	5.9	13	2.7	3.4	27 303	0.41
-2061APR23	1.5	13	2.4	3.2	152 243	0.49	-2001JAN22	10.5	13	3.5	4.3	65 298	0.98
-2061OCT18	7.2	15	1.6	1.9	2 321	0.03	-2001JUL18	4.2	15	1.3	2.4	116 249	1.08
-2059MAR 3	11.8	14	1.0	1.8	83 306	1.16	-2000JAN11	10.2	14	0.3	1.1	101 253	1.38
-2059AUG27	5.5	13	4.1	5.1	110 226	0.82	-2000JUL 7	3.9	14	3.0	4.2	78 296	1.21
-2057AUG 5	4.8	13	2.5	3.1	28 322	0.22	-2000DEC31	9.8	13	3.6	4.0	142 202	0.17
-2056DEC20	9.4	13	3.6	4.4	53 280	1.07	-1998MAY16	2.3	13	1.0	1.6	173 238	0.21
-2055JUN15	3.2	15	2.0	3.1	118 274	1.46	-1998NOV10	8.0	15	1.0	1.8	37 270	0.98
-2055DEC 9	9.0	12	-0.1	0.8	89 236	1.31	-1997MAY 6	1.9	13	4.4	5.5	123 292	1.70
-2054JUN 5	2.8	14	4.2	5.3	77 323	0.79	-1997OCT30	7.7	14	1.3	2.3	74 229	1.40
-2054NOV29	8.7	13	3.1	3.5	131 186	0.13	-1996APR24	1.5	14	2.6	3.4	83 335	0.72
-2052APR13	1.2	13	1.8	2.6	159 260	0.63	-1996OCT18	7.3	13	1.3	1.8	120 182	0.18
-2052OCT 8	6.9	15	0.5	1.4	35 266	1.01	-1994MAR 5	11.9	15	0.2	1.0	144 269	0.94
-2051SEP27	6.5	14	1.1	2.2	75 227	1.36	-1994AUG28	5.6	14	2.4	3.3	37 276	0.90
-2050MAR24	12.5	14	2.9	3.5	68 350	0.34	-1993FEB22	11.5	14	0.4	1.3	100 308	1.36
-2050SEP16	6.2	14	1.2	1.7	126 178	0.10	-1993AUG18	5.2	15	0.1	1.2	78 240	1.58
-2048FEB 1	10.8	15	0.7	1.5	125 268	1.22	-1992FEB11	11.2	14	1.0	1.3	44 358	0.06
-2048JUL26	4.5	14	2.2	3.3	55 280	1.12	-1992AUG 7	4.8	14	4.4	5.0	132 194	0.18
-2047JAN20	10.5	14	1.0	1.8	80 304	1.11	-1991DEC22	9.5	14	3.3	4.1	111 248	1.15
-2047JUL16	4.1	15	0.0	1.1	98 246	1.34	-1990JUN16	3.2	14	2.0	3.2	74 295	1.15
-2045MAY27	2.5	14	3.3	4.0	45 338	0.23	-1990DEC11	9.1	15	1.4	2.2	70 280	1.37
-2045NOV19	8.3	13	2.8	3.5	99 236	1.15	-1989JUN 6	2.9	13	3.4	4.5	121 255	1.11
-2044MAY15	2.2	14	3.3	4.4	98 290	1.62	-1987APR15	1.2	14	2.7	3.5	71 325	0.70
-2044NOV 8	8.0	15	0.7	1.6	60 270	1.37	-1987OCT 9	7.0	14	-0.1	0.7	108 215	0.68
-2043MAY 4	1.9	13	4.3	5.1	144 248	0.65	-1986APR 5	12.9	15	0.4	1.3	113 283	1.71
-2043OCT29	7.6	14	3.7	4.0	3 323	0.02	-1986SEP28	6.6	13	1.3	2.3	67 258	1.67
-2041MAR15	12.2	14	2.8	3.6	81 311	1.05	-1985MAR25	12.5	15	2.8	3.3	165 231	0.21
-2041SEP 7	5.9	14	-0.4	0.5	109 222	0.76	-1983FEB 1	10.9	14	0.0	0.8	67 304	0.92
-2040MAR 3	11.8	15	0.8	1.7	119 270	1.37	-1983JUL29	4.5	15	3.6	4.7	115 241	0.97
-2040AUG26	5.5	13	0.9	2.1	69 267	1.56	-1982JAN21	10.5	13	2.1	2.9	104 259	1.42
-2038JUL 7	3.8	15	0.3	0.7	167 208	0.03	-1981JAN11	10.1	14	0.3	0.7	145 209	0.20
-2038DEC31	9.8	14	0.1	0.9	57 286	1.05	-1980MAY26	2.6	13	3.1	3.6	178 226	0.08
-2037JUN27	3.5	15	4.2	5.4	118 266	1.33	-1980NOV21	8.4	14	3.0	3.8	40 273	0.98
-2037DEC20	9.4	13	1.8	2.6	93 241	1.32	-1979MAY16	2.2	14	-0.2	0.9	125 285	1.56
-2034APR25	1.6	13	3.7	4.4	163 254	0.49	-1979NOV10	8.0	14	3.2	4.2	76 232	1.41
-2034OCT19	7.3	15	2.6	3.5	35 267	0.99	-1978OCT30	7.7	13	3.3	3.8	120 183	0.19
-2033APR14	1.2	14	0.5	1.4	117 302	1.80	-1976MAR15	12.2	15	1.8	2.7	150 267	0.82
-2033OCT 9	6.9	14	3.2	4.2	73 227	1.38	-1975MAR 4	11.9	14	2.0	2.9	106 307	1.47
-2032SEP27	6.6	13	3.3	3.8	123 179	0.14	-1975AUG28	5.6	14	2.5	3.6	73 239	1.64
-2030FEB11	11.2	15	2.3	3.2	131 270	1.14	-1974FEB21	11.6	13	2.6	3.0	53 354	0.16
-2029JAN31	10.8	14	2.6	3.4	87 306	1.18	-1972JAN 2	9.8	14	0.1	0.8	116 252	1.13
-2029JUL27	4.5	14	2.4	3.5	91 244	1.43	-1972JUN27	3.6	13	4.0	5.2	65 295	1.00
-2026NOV20	8.3	14	2.8	3.6	63 272	1.37	-1972DEC22	9.4	14	3.3	4.1	75 284	1.37
-2023SEP17	6.2	13	1.8	2.7	109 218	0.72	-1969OCT20	7.4	13	2.0	2.8	109 215	0.67
-2022MAR14	12.2	15	2.6	3.5	118 275	1.47	-1968APR15	1.2	15	2.2	3.2	109 287	1.84
-2022SEP 7	5.9	13	3.3	4.3	68 262	1.61	-1968OCT 9	7.0	13	3.5	4.5	67 257	1.68
-2021AUG27	5.5	14	0.3	0.9	28 308	0.36	-1967SEP28	6.6	14	0.9	1.6	27 297	0.47
-2019JAN10	10.2	13	1.8	2.6	61 292	1.02	-1965FEB12	11.3	13	1.7	2.4	69 310	0.86
-2019DEC31	9.8	13	3.6	4.4	97 247	1.34	-1964FEB 2	10.9	13	3.8	4.7	107 265	1.48
-2018JUN26	3.5	15	1.0	2.1	79 305	1.07	-1964JUL28	4.6	15	-0.1	1.1	76 279	1.44
-2018DEC20	9.4	14	1.8	2.1	139 196	0.15	-1963JAN21	10.5	14	2.1	2.6	148 216	0.24
-2015APR24	1.6	13	2.4	3.4	120 297	1.84	-1963JUL17	4.2	14	0.3	0.8	27 338	0.08
-2014APR14	1.2	14	0.7	1.4	79 340	0.59	-1961MAY27	2.6	14	1.9	3.0	126 279	1.43
-2012FEB23	11.5	14	4.0	4.9	138 270	1.05	-1960MAY16	2.2	15	0.1	1.0	88 322	1.00
-2012AUG17	5.2	14	-0.1	0.9	42 277	0.96	-1958MAR27	12.6	14	3.5	4.3	156 263	0.69
-2011FEB11	11.2	14	4.2	5.1	93 308	1.26	-1958SEP19	6.3	14	0.6	1.4	29 274	0.82
-2010JUL27	4.5	15	2.1	2.6	141 193	0.10	-1957MAR16	12.3	14	3.6	4.6	111 305	1.60
-2009DEC11	9.1	14	1.4	2.2	106 243	1.15	-1956MAR 4	11.9	13	4.2	4.8	62 351	0.27
-2008JUN 5	2.9	14	0.0	1.2	82 294	1.30	-1956AUG28	5.6	15	1.9	2.6	119 193	0.30
-2007MAY25	2.5	13	1.3	2.4	129 254	0.96	-1954JAN12	10.2	14	1.9	2.6	122 256	1.10
-2007NOV19	8.3	15	2.1	2.4	6 329	0.00	-1953JAN 2	9.8	15	0.0	0.8	80 289	1.39
-2005APR 5	12.9	15	0.7	1.5	76 321	0.82	-1953JUN27	3.6	14	0.3	1.5	104 256	1.39
-2005SEP29	6.6	13	3.9	4.8	108 216	0.69	-1953DEC22	9.5	15	2.4	2.7	17 342	0.00
-2004MAR25	12.5	14	4.5	5.4	116 279	1.58	-1952JUN16	3.2	13	4.5	4.9	160 208	0.07

DATE	M	D	Beg	End	Angles	Magn	DATE	M	D	Beg	End	Angles	Magn
-1951MAY 7	1.9	15	0.3	1.0	58 333	0.42	-1900FEB14	11.3	14	2.1	2.9	140 263	0.94
-1951OCT31	7.7	13	4.0	4.7	110 216	0.67	-1899FEB 3	10.9	15	0.1	1.0	97 299	1.52
-1950APR27	1.6	15	4.1	5.2	104 290	1.77	-1899JUL29	4.6	14	-0.3	0.9	80 252	1.74
-1950OCT20	7.4	13	-0.2	0.7	67 257	1.69	-1898JAN23	10.6	15	2.4	2.8	39 349	0.09
-1949APR16	1.3	15	0.1	0.9	153 243	0.48	-1898JUL19	4.3	13	4.0	4.8	128 213	0.43
-1949OCT10	7.0	13	3.2	3.9	29 296	0.49	-1897DEC 3	8.8	13	4.1	4.8	118 225	0.68
-1947FEB23	11.6	13	3.4	4.1	69 316	0.78	-1896MAY29	2.6	15	3.6	4.7	84 296	1.33
-1947AUG19	5.3	15	1.0	2.0	113 227	0.80	-1896NOV21	8.5	13	0.5	1.4	73 263	1.69
-1946FEB12	11.3	14	0.3	1.2	109 270	1.55	-1895NOV11	8.1	13	3.8	4.4	31 300	0.50
-1946AUG 8	4.9	14	2.1	3.3	75 272	1.53	-1893MAR28	12.7	13	3.1	3.7	63 333	0.47
-1945FEB 2	10.9	14	3.9	4.4	150 223	0.29	-1893SEP21	6.3	15	1.2	2.0	112 214	0.63
-1945JUL28	4.6	14	2.4	3.0	30 326	0.19	-1892MAR16	12.3	14	0.1	1.0	108 286	1.83
-1944DEC12	9.1	15	1.4	2.1	47 281	0.96	-1892SEP 9	6.0	14	1.6	2.8	72 257	1.74
-1943JUN 7	2.9	13	4.2	5.2	127 271	1.29	-1891MAR 6	12.0	14	4.1	4.7	149 242	0.53
-1943DEC 1	8.8	14	1.5	2.4	82 238	1.42	-1891AUG29	5.6	14	1.6	2.5	31 302	0.46
-1942MAY27	2.6	14	2.2	3.2	90 314	1.13	-1889JAN14	10.3	15	1.4	2.2	58 298	0.87
-1942NOV20	8.4	13	1.6	2.0	124 189	0.21	-1889JUL10	4.0	13	3.9	4.9	125 247	0.92
-1940SEP30	6.7	14	2.9	3.8	28 274	0.80	-1888JAN 3	9.9	14	1.5	2.3	93 254	1.49
-1939SEP19	6.3	15	0.7	1.7	66 237	1.72	-1888JUN28	3.6	15	1.7	2.8	90 291	1.52
-1938MAR15	12.3	14	0.2	0.8	69 347	0.39	-1888DEC22	9.5	13	1.7	2.2	134 204	0.25
-1938SEP 9	5.9	14	4.1	4.8	114 192	0.34	-1886NOV 2	7.8	13	3.6	4.3	28 276	0.78
-1936JAN24	10.6	14	3.7	4.5	128 259	1.06	-1885APR28	1.7	13	4.4	5.5	129 287	1.47
-1936JUL18	4.3	14	0.9	1.9	47 295	0.75	-1885OCT22	7.4	14	1.4	2.3	64 238	1.75
-1935JAN12	10.2	15	1.8	2.6	86 293	1.42	-1884OCT11	7.0	14	4.2	4.9	109 192	0.40
-1935JUL 7	3.9	13	2.5	3.7	95 255	1.52	-1882FEB25	11.7	14	4.0	4.7	146 263	0.86
-1934JAN 2	9.8	14	4.2	4.5	24 345	0.02	-1882AUG20	5.3	14	0.3	1.2	23 294	0.46
-1933MAY18	2.3	15	2.5	3.1	50 337	0.28	-1881FEB14	11.3	15	1.9	2.7	103 300	1.58
-1933NOV11	8.1	13	0.3	1.1	112 218	0.67	-1881AUG 9	5.0	13	2.1	3.2	73 251	1.83
-1932MAY 7	1.9	15	-0.4	0.6	98 293	1.62	-1880FEB 4	10.9	14	4.1	4.5	47 350	0.14
-1932OCT30	7.7	13	1.9	2.8	69 258	1.69	-1879DEC13	9.2	13	0.7	1.4	122 229	0.68
-1931APR26	1.6	15	1.8	2.7	146 248	0.62	-1878DEC 2	8.8	13	2.5	3.3	77 267	1.69
-1929AUG31	5.6	15	3.3	4.2	112 222	0.73	-1877MAY29	2.6	15	0.4	1.5	123 257	1.08
-1928FEB23	11.6	13	2.1	2.9	110 276	1.63	-1877NOV22	8.5	14	0.4	1.0	34 303	0.50
-1928AUG19	5.3	14	4.2	5.4	74 266	1.62	-1875OCT 2	6.7	14	3.3	4.1	112 212	0.60
-1927FEB12	11.2	14	0.4	1.0	150 230	0.36	-1874MAR27	12.7	14	1.9	2.8	106 290	1.82
-1927AUG 8	4.9	13	4.4	5.2	31 316	0.30	-1874SEP21	6.4	14	3.7	4.8	72 254	1.78
-1926DEC24	9.5	14	3.1	3.9	51 286	0.94	-1873MAR17	12.3	14	0.3	0.9	147 248	0.63
-1925DEC13	9.1	14	3.3	4.1	85 243	1.43	-1873SEP10	6.0	13	3.8	4.6	31 297	0.51
-1924JUN 7	2.9	14	4.4	5.5	90 307	1.27	-1871JAN25	10.6	15	3.1	3.8	61 305	0.82
-1924DEC 1	8.8	13	3.4	3.9	127 193	0.21	-1870JAN14	10.3	14	3.1	4.0	97 260	1.53
-1922APR17	1.3	15	1.0	1.7	168 251	0.39	-1870JUL10	4.0	14	4.1	5.2	88 283	1.63
-1921APR 6	1.0	14	1.0	2.0	121 298	1.77	-1869JAN 3	9.9	13	3.4	3.9	137 210	0.28
-1921OCT 1	6.7	14	3.0	3.9	65 237	1.74	-1869JUN29	3.6	15	1.3	1.9	41 338	0.19
-1920MAR25	12.6	13	1.9	2.6	76 343	0.52	-1868NOV12	8.1	14	0.1	0.8	31 279	0.78
-1920SEP19	6.3	15	-0.2	0.5	111 192	0.37	-1867MAY 8	2.0	14	-0.4	0.8	133 281	1.30
-1918FEB 3	10.9	15	0.3	1.1	134 262	1.00	-1867NOV 2	7.8	14	3.5	4.4	66 239	1.75
-1918JUL30	4.6	13	3.1	4.0	38 294	0.64	-1866APR27	1.7	14	0.9	1.9	91 326	0.96
-1917JAN24	10.6	14	3.6	4.4	92 296	1.46	-1866OCT22	7.4	15	0.4	1.0	109 193	0.40
-1916JAN13	10.2	15	0.7	1.1	31 348	0.05	-1864MAR 7	12.0	15	0.3	1.0	151 262	0.76
-1916JUL 7	3.9	14	1.6	2.4	137 213	0.32	-1864AUG30	5.7	13	2.6	3.3	17 293	0.40
-1915NOV21	8.5	13	2.3	3.0	115 221	0.68	-1863FEB25	11.6	15	3.7	4.5	109 301	1.67
-1914MAY18	2.3	15	1.5	2.6	92 295	1.47	-1863AUG20	5.3	13	4.4	5.5	67 249	1.82
-1914NOV11	8.1	13	4.0	4.9	70 260	1.69	-1862FEB14	11.3	15	0.4	0.9	54 349	0.21
-1913MAY 8	2.0	15	3.6	4.5	139 252	0.77	-1862AUG 9	5.0	14	1.5	2.3	112 212	0.62
-1913OCT31	7.7	14	1.7	2.3	29 298	0.50	-1861DEC24	9.6	13	2.5	3.2	127 233	0.67
-1911MAR16	12.3	13	1.3	2.0	66 328	0.58	-1860JUN19	3.3	15	0.6	1.7	68 297	1.04
-1910MAR 6	12.0	13	3.9	4.8	109 281	1.73	-1859JUN 8	3.0	15	2.3	3.5	115 258	1.23
-1910AUG30	5.6	15	-0.6	0.6	73 261	1.68	-1859DEC 2	8.8	14	2.4	3.0	37 307	0.50
-1909FEB23	11.6	14	2.2	2.8	150 236	0.44	-1857APR18	1.4	14	0.7	1.2	51 345	0.23
-1907JUN28	3.6	14	1.5	2.5	126 255	1.04	-1856APR 7	1.0	13	3.8	4.8	103 294	1.70
-1904APR27	1.7	15	2.7	3.4	175 242	0.23	-1856OCT 1	6.7	14	-0.5	0.6	72 252	1.81
-1904OCT21	7.4	14	1.4	2.2	27 275	0.78	-1855MAR27	12.7	14	2.1	2.8	143 253	0.74
-1903APR16	1.3	14	2.7	3.7	126 293	1.62	-1853JUL31	4.7	14	1.4	2.3	123 231	0.73
-1902APR 6	1.0	13	3.6	4.4	82 337	0.66	-1851JUL10	4.0	15	3.5	4.2	42 328	0.30
-1902SEP30	6.7	15	2.1	2.8	109 192	0.39	-1850NOV23	8.5	14	2.2	2.9	33 282	0.78

APPENDIX C: List of Candidate Eclipses

The following 10 lists were extracted from Appendix B. Each of them contains candidate eclipses for one of the 10 numbered omens of Table 6.1. The extraction criteria are given at the beginning of each list. Note that for the timings, 0.4 watches were added at each end, in order to account for modern clocktime and ancient timing errors. Also the entrance and exit angles were slightly extended.

(1) 20-III

-2200 ≤ DATE ≤ -1850
 2 ≤ M ≤ 5
 0.6 ≤ Beg
 1.6 ≤ End ≤ 2.6
 40 ≤ Entry ≤ 140
 220 ≤ Exit ≤ 320

DATE	M	D	Beg	End	Angles	Magn
-2188AUG13	5.0	14	1.0	2.0	63 282	1.21
-2174MAY12	2.1	14	0.8	1.8	108 282	1.80
-2149JUL 4	3.7	14	0.6	1.9	115 263	1.32
-2094JUL25	4.5	13	1.1	2.3	74 285	1.32
-2018JUN26	3.5	15	1.0	2.1	79 305	1.07
-2007MAY25	2.5	13	1.3	2.4	129 254	0.96
-2001JUL18	4.2	15	1.3	2.4	116 249	1.08
-1936JUL18	4.3	14	0.9	1.9	47 295	0.75
-1914MAY18	2.3	15	1.5	2.6	92 295	1.47
-1907JUN28	3.6	14	1.5	2.5	126 255	1.04
-1860JUN19	3.3	15	0.6	1.7	68 297	1.04
-1853JUL31	4.7	14	1.4	2.3	123 231	0.73

(2) 21-XII

-2200 ≤ DATE ≤ -1850
 11 ≤ M or M ≤ 2
 0.6 ≤ Beg ≤ 2.4
 2.6 ≤ End ≤ 4.4
 80 ≤ Entry
 260 ≤ Exit

DATE	M	D	Beg	End	Angles	Magn
-2106MAR12	12.2	13	2.4	3.2	143 272	1.00
-2062MAY 4	1.8	14	1.5	2.6	105 287	1.78
-2052APR13	1.2	13	1.8	2.6	159 260	0.63
-2030FEB11	11.2	15	2.3	3.2	131 270	1.14
-2015APR24	1.6	13	2.4	3.4	120 297	1.84
-1976MAR15	12.2	15	1.8	2.7	150 267	0.82
-1975MAR 4	11.9	14	2.0	2.9	106 307	1.47
-1968APR15	1.2	15	2.2	3.2	109 287	1.84
-1928FEB23	11.6	13	2.1	2.9	110 276	1.63
-1900FEB14	11.3	14	2.1	2.9	140 263	0.94
-1881FEB14	11.3	15	1.9	2.7	103 300	1.58
-1874MAR27	12.7	14	1.9	2.8	106 290	1.82

(3) 20-II

-2200 ≤ DATE ≤ -1850
 1 ≤ M ≤ 4
 0.6 ≤ Beg ≤ 2.4
 Entry ≤ 100
 Exit ≤ 280

NO ECLIPSE FOUND!

(4) 20-IV

-2200 ≤ DATE ≤ -1850
 3 ≤ M ≤ 6
 0.6 ≤ Beg ≤ 2
 40 ≤ Entry ≤ 140
 Exit ≤ 280

DATE	M	D	Beg	End	Angles	Magn
-2159JUL24	4.4	15	1.8	3.0	105 232	0.98
-2149JUL 4	3.7	14	0.6	1.9	115 263	1.32
-2105AUG26	5.4	15	1.2	2.3	85 229	1.23
-2077AUG16	5.2	14	2.0	3.0	111 232	0.89
-2055JUN15	3.2	15	2.0	3.1	118 274	1.46
-2040AUG26	5.5	13	0.9	2.1	69 267	1.56
-2001JUL18	4.2	15	1.3	2.4	116 249	1.08
-1956AUG28	5.6	15	1.9	2.6	119 193	0.30
-1947AUG19	5.3	15	1.0	2.0	113 227	0.80
-1916JUL 7	3.9	14	1.6	2.4	137 213	0.32
-1907JUN28	3.6	14	1.5	2.5	126 255	1.04
-1892SEP 9	6.0	14	1.6	2.8	72 257	1.74
-1862AUG 9	5.0	14	1.5	2.3	112 212	0.62
-1853JUL31	4.7	14	1.4	2.3	123 231	0.73

(5) 21-VIII

-2200 ≤ DATE ≤ -1850
 7 ≤ M ≤ 10
 1.6 ≤ Beg ≤ 3.4
 2.6 ≤ End ≤ 4.4
 Entry ≤ 100
 Exit ≤ 280

DATE	M	D	Beg	End	Angles	Magn
-2193NOV 6	7.8	15	2.1	3.0	87 241	1.41
-2192OCT26	7.5	14	2.8	3.7	46 279	0.96
-2185DEC 7	8.9	14	2.1	2.9	97 226	1.01
-2164OCT16	7.2	13	3.3	4.3	38 263	1.09
-2149JAN 8	10.0	14	2.5	3.2	73 277	1.47
-2139DEC 8	9.0	15	2.4	3.3	96 251	1.40
-2127OCT27	7.5	13	2.9	3.8	78 225	1.30
-2099OCT17	7.2	13	2.0	2.9	94 230	1.15
-2080OCT17	7.2	14	2.1	3.0	57 266	1.38
-2074DEC 9	9.0	13	1.8	2.6	49 276	1.08
-2073NOV29	8.7	13	3.3	4.1	85 232	1.30
-2045NOV19	8.3	13	2.8	3.5	99 236	1.15
-2037DEC20	9.4	13	1.8	2.6	93 241	1.32
-2034OCT19	7.3	15	2.6	3.5	35 267	0.99
-2026NOV20	8.3	14	2.8	3.6	63 272	1.37
-1980NOV21	8.4	14	3.0	3.8	40 273	0.98
-1979NOV10	8.0	14	3.2	4.2	76 232	1.41
-1932OCT30	7.7	13	1.9	2.8	69 258	1.69
-1925DEC13	9.1	14	3.3	4.1	85 243	1.43
-1878DEC 2	8.8	13	2.5	3.3	77 267	1.69

(6) 20-XI

-2200 ≤ DATE ≤ -1450
 10 ≤ M
 2.6 ≤ Beg ≤ 4.4
 3.5 ≤ End ≤ 4.5
 80 ≤ Entry

DATE	M	D	Beg	End	Angles	Magn
-2171MAR12	12.1	15	3.2	4.1	89 303	1.28
-2170MAR 1	11.7	14	3.5	4.4	129 259	1.01
-2160FEB 9	11.1	13	2.8	3.6	126 273	1.28
-2123FEB19	11.4	13	2.9	3.7	93 312	1.21
-2116APR 1	12.8	14	2.7	3.7	121 275	1.40
-2115MAR22	12.4	13	3.4	3.7	175 220	0.06
-2095FEB10	11.1	14	2.7	3.5	82 295	1.32
-2076FEB11	11.1	15	2.7	3.5	118 259	1.20
-2069MAR24	12.5	13	2.7	3.6	109 309	1.54
-2041MAR15	12.2	14	2.8	3.6	81 311	1.05
-2022MAR14	12.2	15	2.6	3.5	118 275	1.47
-1958MAR27	12.6	14	3.5	4.3	156 263	0.69
-1945FEB 2	10.9	14	3.9	4.4	150 223	0.29
-1936JAN24	10.6	14	3.7	4.5	128 259	1.06
-1917JAN24	10.6	14	3.6	4.4	92 296	1.46
-1870JAN14	10.3	14	3.1	4.0	97 260	1.53
-1863FEB25	11.6	15	3.7	4.5	109 301	1.67
-1823JAN 4	10.0	13	2.9	3.7	91 280	1.73
-1816FEB16	11.4	14	2.7	3.6	103 279	1.74
-1815FEB 4	11.0	13	3.2	3.8	143 231	0.45
-1809MAR30	12.7	15	3.5	4.5	123 296	1.75
-1769FEB 6	11.1	13	3.1	3.9	109 289	1.87
-1761MAR 9	12.1	13	2.9	3.6	141 251	0.73
-1739JAN 6	10.0	15	2.9	3.5	132 219	0.42
-1722JAN28	10.7	15	2.8	3.6	94 275	1.86
-1715MAR10	12.1	13	3.2	4.0	125 290	1.64
-1712JAN 8	10.1	14	3.7	4.3	142 233	0.47
-1696MAR10	12.1	14	3.4	4.1	88 327	0.91
-1668MAR 1	11.8	15	2.8	3.6	98 291	1.65
-1658FEB 9	11.2	14	3.5	4.1	163 238	0.30
-1657JAN29	10.8	14	3.3	4.2	113 280	1.59
-1603MAR 2	11.9	14	2.9	3.8	131 282	1.34
-1602FEB19	11.6	13	3.7	4.5	87 321	0.97
-1563JAN10	10.2	14	3.5	4.4	108 270	1.55
-1548MAR23	12.6	13	3.4	4.3	102 316	1.29
-1509FEB12	11.3	15	3.7	4.5	125 278	1.39
-1501MAR14	12.3	14	2.6	3.5	124 270	1.31
-1472FEB23	11.7	14	3.0	3.9	92 318	1.08
-1461JAN22	10.6	13	2.7	3.5	112 254	1.21
-1455MAR16	12.4	15	3.5	4.4	141 276	1.12

(7) 21-IV

-2200 ≤ DATE ≤ -1850
 3 ≤ M ≤ 6
 0.6 ≤ Beg ≤ 2.4
 1.6 ≤ End ≤ 3.4
 Exit ≤ 280

DATE	M	D	Beg	End	Angles	Magn
-2159JUL24	4.4	15	1.8	3.0	105 232	0.98
-2149JUL 4	3.7	14	0.6	1.9	115 263	1.32
-2142AUG15	5.1	15	2.3	3.4	52 269	1.23
-2105AUG26	5.4	15	1.2	2.3	85 229	1.23
-2077AUG16	5.2	14	2.0	3.0	111 232	0.89

DATE	M	D	Beg	End	Angles	Magn
-2055JUN15	3.2	15	2.0	3.1	118 274	1.46
-2048JUL26	4.5	14	2.2	3.3	55 280	1.12
-2040AUG26	5.5	13	0.9	2.1	69 267	1.56
-2010JUL27	4.5	15	2.1	2.6	141 193	0.10
-2001JUL18	4.2	15	1.3	2.4	116 249	1.08
-1994AUG28	5.6	14	2.4	3.3	37 276	0.90
-1956AUG28	5.6	15	1.9	2.6	119 193	0.30
-1947AUG19	5.3	15	1.0	2.0	113 227	0.80
-1946AUG 8	4.9	14	2.1	3.3	75 272	1.53
-1916JUL 7	3.9	14	1.6	2.4	137 213	0.32
-1907JUN28	3.6	14	1.5	2.5	126 255	1.04
-1892SEP 9	6.0	14	1.6	2.8	72 257	1.74
-1881AUG 9	5.0	13	2.1	3.2	73 251	1.83
-1862AUG 9	5.0	14	1.5	2.3	112 212	0.62
-1853JUL31	4.7	14	1.4	2.3	123 231	0.73

(8) 20-I

-2400 ≤ DATE ≤ -1950
 12 ≤ M or M ≤ 3
 2.9 ≤ Beg ≤ 4.0
 3.6 ≤ End ≤ 5.0
 80 ≤ Entry
 260 ≤ Exit

DATE	M	D	Beg	End	Angles	Magn
-2388MAY 8	1.9	13	3.6	4.6	142 273	1.04
-2351MAY19	2.2	13	3.8	4.9	105 305	1.53
-2323MAY10	1.9	14	3.9	4.9	82 309	1.10
-2312APR 9	12.9	15	3.9	4.8	135 284	1.34
-2304MAY10	1.9	15	3.8	4.8	118 273	1.44
-2301MAR 9	12.0	13	3.6	4.5	93 298	1.42
-2264MAR19	12.3	13	3.6	4.5	129 265	1.12
-2258MAY12	2.0	15	3.0	4.0	147 266	0.86
-2257MAY 1	1.7	14	3.3	4.4	105 311	1.40
-2250JUN12	3.0	15	3.2	4.4	98 276	1.85
-2247APR10	1.0	13	3.0	3.9	84 313	1.05
-2236MAR10	12.0	14	3.4	4.3	130 284	1.45
-2217MAR11	12.0	15	3.5	4.3	93 321	1.07
-2210APR21	1.4	13	3.3	4.3	119 277	1.52
-2182APR12	1.1	14	3.4	4.3	143 276	1.10
-2171MAR12	12.1	15	3.2	4.1	89 303	1.28
-2163APR12	1.1	15	3.2	4.2	107 313	1.43
-2156MAY23	2.4	13	2.9	3.9	101 284	1.83
-2044MAY15	2.2	14	3.3	4.4	98 290	1.62
-1958MAR27	12.6	14	3.5	4.3	156 263	0.69
-1957MAR16	12.3	14	3.6	4.6	111 305	1.60

(9) 21-I

-2400 ≤ DATE ≤ -1950
 12 ≤ M or M ≤ 3
 0.6 ≤ Beg ≤ 2.4
 1.6 ≤ End ≤ 3.4
 80 ≤ Entry

DATE	M	D	Beg	End	Angles	Magn
-2395MAR27	12.5	14	2.1	3.0	100 296	1.62
-2376MAR27	12.5	15	2.2	3.0	137 259	0.92
-2369MAY 8	1.9	13	1.8	2.8	103 312	1.39
-2367MAR18	12.2	15	2.2	2.8	166 250	0.40
-2361JUN 8	2.9	14	1.6	2.3	149 227	0.35

DATE	M	D	Beg	End	Angles	Magn	(10)	21-VI
-2352MAY29	2.6	14	0.7	1.7	147	258	0.74	
-2341APR29	1.6	14	1.8	2.8	88	307	1.23	-2400 ≤ DATE ≤ -1950
-2330MAR29	12.6	15	2.1	3.1	130	288	1.48	5 ≤ M ≤ 8
-2322APR29	1.6	15	1.8	2.7	124	270	1.30	0.6 ≤ Beg ≤ 2.4
-2315JUN 9	2.9	14	1.1	2.3	107	291	1.81	1.6 ≤ End ≤ 3.4
-2285MAY10	1.9	15	2.2	2.7	173	219	0.06	Entry ≤ 100
-2282MAR 8	12.0	13	1.8	2.6	131	259	1.00	Exit ≤ 280
-2276APR30	1.6	15	1.2	2.2	143	273	1.02	
-2275APR19	1.3	14	1.6	2.6	101	317	1.23	
-2268MAY31	2.6	15	1.1	2.2	105	275	1.72	DATE
-2265MAR30	12.7	14	1.3	2.2	88	308	1.18	M
-2231JUN11	3.0	15	0.9	1.8	141	232	0.49	D
-2228APR 9	1.0	13	1.4	2.3	123	274	1.38	Beg
-2209APR10	1.0	14	1.5	2.0	167	230	0.20	End
-2204JUN12	3.0	15	1.9	2.7	157	239	0.38	Angles
-2203JUN 1	2.7	14	2.0	3.2	113	289	1.77	Magn
-2200MAR31	12.7	14	1.4	2.3	139	280	1.23	
-2181APR 1	12.7	15	1.3	2.2	102	316	1.30	-2395SEP20
-2174MAY12	2.1	14	0.8	1.8	108	282	1.80	6.2 14 0.6 1.7 81 246 1.56
-2155MAY12	2.1	14	1.0	1.8	146	244	0.60	-2348SEP10
-2146MAY 3	1.8	15	1.1	2.0	150	265	0.83	5.9 13 2.0 3.0 55 252 1.57
-2135APR 2	12.8	15	0.7	1.6	83	313	1.02	-2341OCT23
-2134MAR22	12.4	14	1.1	2.0	125	270	1.26	7.4 14 0.8 1.8 81 243 1.51
-2127MAY 3	1.8	15	0.7	1.8	113	303	1.71	-2329SEP11
-2106MAR12	12.2	13	2.4	3.2	143	272	1.00	5.9 14 2.2 3.1 91 216 0.97
-2087MAR12	12.2	14	0.9	1.8	104	311	1.42	-2301SEP 2
-2062MAY 4	1.8	14	1.5	2.6	105	287	1.78	5.6 15 1.2 2.3 87 247 1.52
-2061APR23	1.5	13	2.4	3.2	152	243	0.49	-2258NOV 4
-2052APR13	1.2	13	1.8	2.6	159	260	0.63	7.8 14 1.2 2.1 52 253 1.51
-2015APR24	1.6	13	2.4	3.4	120	297	1.84	-2247OCT 4
-2007MAY25	2.5	13	1.3	2.4	129	254	0.96	6.7 15 1.6 2.6 84 239 1.43
-2003MAR14	12.2	15	1.2	1.6	171	222	0.09	-2239NOV 4
-1998MAY16	2.3	13	1.0	1.6	173	238	0.21	7.8 14 1.4 2.2 88 217 1.01
-1976MAR15	12.2	15	1.8	2.7	150	267	0.82	-2236SEP 2
-1968APR15	1.2	15	2.2	3.2	109	287	1.84	5.7 14 1.2 2.3 46 264 1.21
-1961MAY27	2.6	14	1.9	3.0	126	279	1.43	-2235AUG22
								5.3 13 2.3 3.3 90 226 1.13
								-2210OCT15
								7.1 15 0.8 1.7 45 279 0.95
								-2207AUG13
								5.0 14 0.7 1.8 99 246 1.33
								-2193NOV 6
								7.8 15 2.1 3.0 87 241 1.41
								-2182OCT 5
								6.8 14 1.2 2.2 38 262 1.10
								-2181SEP24
								6.4 13 2.4 3.4 79 224 1.26
								-2153SEP15
								6.1 14 1.3 2.2 94 233 1.19
								-2145OCT16
								7.2 13 0.7 1.6 77 224 1.29
								-2142AUG15
								5.1 15 2.3 3.4 52 269 1.23
								-2134SEP15
								6.1 14 1.4 2.4 58 269 1.35
								-2128NOV 6
								7.9 13 1.5 2.4 40 266 1.08
								-2105AUG26
								5.4 15 1.2 2.3 85 229 1.23
								-2099OCT17
								7.2 13 2.0 2.9 94 230 1.15
								-2088SEP16
								6.2 15 2.3 3.3 38 266 1.06
								-2080OCT17
								7.2 14 2.1 3.0 57 266 1.38
								-2051SEP27
								6.5 14 1.1 2.2 75 227 1.36
								-2044NOV 8
								8.0 15 0.7 1.6 60 270 1.37
								-2040AUG26
								5.5 13 0.9 2.1 69 267 1.56
								-1998NOV10
								8.0 15 1.0 1.8 37 270 0.98
								-1997OCT30
								7.7 14 1.3 2.3 74 229 1.40
								-1994AUG28
								5.6 14 2.4 3.3 37 276 0.90
								-1986SEP28
								6.6 13 1.3 2.3 67 258 1.67

Correction: in the header of the Venus column of Table 2.1, read "31 obs.", and similarly in the legend below.