On the Astronomical Records and Babylonian Chronology

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METHODOLOGY

This paper, which covers some aspects of the astronomical background of the chronology proposed by Gasche *et al.* (1998), is offered here for two reasons. That brief volume was intended to present a new approach and was not regarded as a comprehensive treatment of chronological issues in the ancient Near East, and certainly not as the final word on the role astronomy can play in solving chronological problems. It was to be hoped that polemical debate could be avoided and the ensuing critical discussion would be based on the data and methodology presented. The drawbacks of the approach are now apparent, however. On the one hand, there appears to be a real need (e.g., Huber 1999/2000b) for some additional general explanation of the astronomical conclusions published in that volume. On the other hand, it is increasingly evident that the work of colleagues (particularly Huber) who have employed astronomical methods requires a more direct kind of attention. The little attention payed to Huber and the lack of astronomical detail in Gasche *et al.* (1998) can be attributed to the fact that the book's origins lay in the study of the archaeological material and the Middle Chronology, and thus neither astronomy nor the High Chronology were at the center of the project. A discussion of the archaeology must be left to my colleagues, but papers by Huber (1999/2000a, 1999/2000b, and Huber, this volume) — and criticism because we did not discuss his work exhaustively — demand that the astronomical issues be raised again.

The archaeological material was abundant, but could not provide precise dates. Astronomical data are one of the few means of securing potentially relevant and precise dates; astronomical sources are rare in the ancient Near East. Huber (1999/2000a: 55) described the very Ur III omens we selected as being "so detailed and unsystematic that they appear to contain actual records of observations." This statement includes two separate judgments about the material. One is that the data are detailed and the other that the organization of the material implied that actual observations were recorded.

The primary evaluation of the information in the omens depends upon their reliability. This means that the more reliable sources must be selected, and that preference be given to the most important parameters. For me, "reliable sources" include

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astronomical data that can be extracted and which are unambiguous in character; it does not mean that the sources are "reliable informants." An astronomer can recognize whether the data recorded reflect unique phenomena which can be isolated. An astronomer cannot judge the level of confidence which can be assigned to any given text: only colleagues from the relevant field are qualified to translate the texts, thus allowing others to make and debate judgments of this kind.

Some omens seem to meet these sets of standards. We exploited the above-mentioned methodology for the analysis of the records with astronomical content in the EAE series, essentially that discussed by Brinkman (2000), with the goal of securing information which may be limited in quantity, but of potentially high quality. Even if the conclusions are indecisive from the standpoint of the questions originally posed, they may still allow certain conclusions to be excluded by demonstrating discrepancies between the alleged records and the actual events.

EAE 20 and 21 describe eclipses which have been linked to the Ur III period. They have been regarded as being more reliable than the Venus Tablet. By their very nature records of eclipses differ significantly from the records of the visibility of the planet Venus. The omina that were interpreted as recording an eclipse are regarded as reliable precisely because the description should allow the eclipses to be identified, if the description preserved is correct. By contrast, it is a well-known fact that the Venus Tablet dataset contains numerous errors. Separating the parameters from the background noise must be accomplished by a statistical evaluation to secure the non-corrupted information. The problem is not new, since statistical methods inevitably face two fundamental obstacles:[1]

(a) the arbitrary character of the choice of the sample parameters to be statistically weighed;
(b) the arbitrary character of the normalization of probabilities.

Each of these factors is crucial and a slight variation of the arbitrary parameters can suffice to distort the data to such an extent that the conclusions are completely unreliable.

There are, however, also purely astronomical reasons which render the alleged records of eclipses more valuable than the Venus Tablet. Doubt can be cast upon the records of the Venus Tablet concerning issues ranging from their apparent regularity to local conditions influencing visibility. This means that even if the data preserved were completely uncorrupted, the interpretation of the Venus Tablet would still be far from straightforward.

UR III ECLIPSES

The informative data recorded for the two lunar eclipses of EAE 20 and 21 can be reduced to 4 parameters:

(a) the entering and

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[1] For modern methods of the study of non-linear astrophysical problems, from planetary dynamics to data analysis, see e.g. Gurzadyan and Kocharyan 1994, and Gurzadyan and Ruffini 2000.

(b) exit positions of the darkening of the lunar disk;
(c) the watch-times of the beginning and
(d) the end of the eclipse.

Some data recorded, namely the day of the eclipses (EAE 20 is dated to 14 Simanu and EAE 21 to 14 Addaru) and the direction of the wind are not informative for our purpose.

In Gasche *et al.* (1998) we proposed the eclipse of 27 June 1954 BC as a candidate for the EAE 20 description. In his critical analysis of our conclusions, Koch (1998) concluded that "the eclipse of June 27, 1954 BC would appear to fit the omen EAE 20 IIIB exactly." He based this on the fact that the correlation fits the exit position ("lower west"). Since the eclipse began below or close to the horizon in the twilight, "the beginning of the darkening was nothing more than the assumed position of the lunar disk and therefore not binding for the examination of the Ur III Simanu eclipse." In contrast to the precise relationship between our candidate and interpretation, Koch concluded that the eclipse proposed by Huber (1987a; 25 July 2095 BC) contradicted the textual evidence referring to the "lower west" although the exit of the actual eclipse must have been the "upper west."

The crucial role of the end of the darkening results from the simple fact that the end of a sequence is always more reliably recorded than its beginning. The observer must adjust his position or instruments (in later periods) and thus the description of the close of the sequence is always more accurate. Regardless of all other errors — including scribal errors — the exit information has to be considered more reliable for an eclipse identification that the entry information. Huber (1987a) overlooked this basic astronomical reality and assumed the contrary, with the unfortunate result that his proposed eclipse of 2095 BC fails to fulfil this significant criterion. The record of the beginning of the event will also be even more defective if the eclipse began below the horizon, so that the beginning was in fact never observed, but merely reconstructed.

In these cases, the duration and time may also be relevant. The crucial criterion of EAE 20 IIIA that "the evening watch passes and the middle watch is touched" or of EAE 20 IIIB, that "the evening watch is half over," is more suitable for the eclipse of 1954 BC than the eclipse of 2095 BC (Koch 1998).

The eclipse of EAE 20 IIIB also meets an additional condition, namely that "the lunar eclipse must end at the time when the weakly shining stars become visible" (Donbaz and Koch 1995, 71; Koch 1998), which is again suitable for the eclipse of 1954 BC, but not that of 2095 BC.

The situation with the EAE 21 XII eclipse is more or less identical, but with one critical difference, the possible presence of a scribal error or misinterpretation. The crucial parameter of the textual evidence concerning the exit position of the darkening ("north") matches the eclipse of 17 March 1912 BC precisely, but not that of 13 April 2053 BC (Huber 1987a) ("west"). The only ambiguity in the eclipse of 1912 BC is the duration of the watch-times. The omen records an impossibly long eclipse far exceeding any possible eclipse, as Koch (1998) has pointed out.

In the final analysis, however, the eclipses of 1954 BC and 1912 BC (proposed in Gasche *et al.* 1998) fit the most significant information in EAE 20 and 21 while the eclipses of 2095 BC and 2053 BC (proposed by Huber *et al.* 1982, Huber 1987a, 1987b, 1999/2000b, and Huber, this volume) fail to meet the criteria, and actually contradict the conditions of the omina. On this basis, at least, they should be excluded, regardless of any statistical evaluations.

This illustrates one of the dangers of conclusions based on statistical evaluations. Neglecting the basic astronomical information, Huber (1987b) found that eclipses — which were ruled out for astronomical reasons — reflected a state where "the probability of error is below 1%." Statistics cannot usefully be employed to determine the probability of something which is excluded in advance. Similar difficulties lie behind other statements such : "even if the chronology is wrong, we will find a matching eclipse in a 20-year window" (1999/2000a : 56), if the proper input information is wrong.

Huber (1999/2000a : 61) remarked that he had excluded the pair of eclipses proposed by us because he assumed that one of them began "too early." As we saw above, this is not the case : the eclipses correspond to the crucial factor of the exit and are otherwise largely compatible with the givens (Koch 1998), Huber had subjectively reduced the size of his sample before commencing his statistical project, and thereby endangered any potential reliability his methods and conclusions could have had.

THE VENUS TABLET

As mentioned by Huber and others, the data from the Venus Tablet has been thrown into doubt due to the numerous errors which have corrupted the text. It is therefore useful to examine the reliability of the presence of the 56/64 year Venus cycle preserved in the text, and whether this can be used.

The Old Babylonian calendar was not continually modified, but was altered only when the discrepancy between the seasons and the calendar forced the issue (Neugebauer 1975). One cannot expect that if certain Venus visibility data fit one given 8-year-period, that they would therefore necessarily fit the period of 56 or 64 years before/after with the same (a) probability and (b) accuracy.

The probability implies that if a primary period is found to fit the data with a certain probability, then the 56/64 year earlier or later periods cannot have the same probability. The accuracy of any given record indicates the time separating the record from the last revision of the lunar calendar. This means that, for example, 6 or 9 Venus cycles, i.e. 48 or 72 years respectively, may happen to fit the primary period that would be required by the lunar calendar, since the scribe was obviously recording the official date recognized in the kingdom and not intent on making precise astronomical measurements.

Changes in the calendar appear inexplicable without specific information, and such changes are very remarkable when all other data appears to be absolutely constant. For example, a historian studying modern records based on a small data sample and only the knowledge of the Julian and Gregorian calendars, would be perplexed by the apparent

mismatch of events in England in the 18th century or in Russia in the early 20th, unless a sudden 13-day shift might be recognized.

The meaning of such difficulties is overlapped with the intrinsic noise in the Venus Tablet, compounded by visibility aspects, e.g. when the first/last visibility records might actually be made later/earlier than it is required by the limiting stellar magnitude (Reiner and Pingree 1975), and potential scribal errors, quite aside from unconscious restorations in antiquity. Altogether, this means that the visibility records could actually be assigned completely different positions in the cycle. This demonstrates that the 20 chronologies proposed by Huber *et al.* (1982; Huber 1987a) cannot be used in astronomical historical arguments.

The reliability of the lunar calendar in the Venus Tablet is further undermined by the nature of certain errors. For example, the text of Omen 11 mentions the last visibility date III 11 and an interval of 9 months 4 days. For the same period, Omens 21 and 59 record XII 11 an interval of 4 days (Reiner and Pingree 1975), thus indicating the adjustment between the date and the interval made by the copyist. This reflected the tradition of inserting "appropriate data" rather than actual data drawn from observations, in order to secure regularity (Neugebauer 1983; see also Fatoohi *et al.* 1999, 51).

What can, therefore, be extracted from the Venus Tablet with a high degree of confidence ? In Gasche *et al.* (1998), we advocated the use of the least noisy signature, namely, the use of the basic 8-year cycle to the exclusion of all others, i.e., any trace of the 584 day Venus synodic period (roughly 5 synodic Venus periods = 8 sidereal years minus 4 days). Only the relative sequence of the inferior and superior conjunctions is reflected in the tablet and not the absolute lunar calendar. In stating that the recorded observations were not visible for the proposed inferior conjunctions compatible for our proposed year for Ammisaduqa 1, Huber (1999/2000a: 53) shows that he has failed to appreciate the significance of our method. Since our system does not recognize the validity of Huber's calendar for 20 chronologies, our 8-year Venus cycles are not anchored as Huber's are. The result is that the 8-year Venus cycle data are compatible with the data drawn from the lunar eclipses, because they do not rely on Huber's 20 chronologies, which are based on the rejected 56/64 year cycles. The background noise in the Venus Tablet makes this virtually the only logical approach: recognize the 8-year cycles.

Later, I became aware that Hunger (2000a) has also recognized only the 8-year cycle.

The relative sequence of the inferior and superior conjunctions and not the lunar calendar lie at the base of our approach to the 8-year Venus cycles. This sequence was unique and its signature would have been the last to have been effaced and lost as a result of careless copying and inattentive observation. The date for Ammisaduqa 1 = 1550 BC is thus anchored by the lunar eclipses but not by the lunar calendar.

To illustrate the significance and value of the method, the Venus data for Ammisaduqa 1 are calculated for 1702, 1646, 1582 and 1550 BC, corresponding to the traditional High, Middle, Low Chronologies, and Ultra-Low Chronology (Gasche *et al.* 1998). In order to avoid the possible impact of local visibility conditions and other uncertainties, the elongation alone is presented. The data thus relies on the angular

separation of Venus from the Sun, by means of which Venus becomes invisible from a specific critical angle θ_{cr}. The glare critical angle for average vision is given by the formula (Schaefer 1991):

$$\log \theta_{cr} = 0.2 (9.28 + m_v)$$

where m_v is the visual stellar magnitude. The table below includes the dates of Venus's passage according to the angle $\theta_{cr} = 11°$. The relative magnitudes for each chronology are

Table 1

Venus	Date	m_v	θ_{cr}	Venus	Date	m_v	θ_{cr}
	1703 BC				1647 BC		
Southern	14.08	-4.1	11°51'	Southern	28.07	-4.1	11°11'
Southern	15.08	-4.1	10°55'	Southern	29.07	-4.0	10°13'
Southern	23.08	-4.2	10°42'	Southern	06.08	-4.1	10°14'
Southern	24.08	-4.2	11°36'	Southern	07.08	-4.1	11°12'
	1702 BC				1646 BC		
Southern	29.04	-3.9	11°14'	Southern	14.04	-3.9	11°02'
Southern	30.04	-3.9	10°58'	Southern	15.04	-3.9	10°46'
Northern	17.07	-3.9	10°43'	Northern	02.07	-3.9	10°53'
Northern	18.07	-3.9	11°00'	Northern	03.07	-3.9	11°10'
	1701 BC				1645 BC		
Northern	22.03	-4.0	12°03'	Northern	07.03	-4.0	11°16'
Northern	23.03	-4.0	10°50'	Northern	08.03	-4.0	10°14'
Northern	03.04	-4.0	10°59'	Northern	17.03	-4.1	10°54'
Northern	04.04	-4.1	12°12'	Northern	18.03	-4.1	12°00'
Northern	01.12	-3.9	11°13'	Northern	13.11	-3.9	11°11'
Northern	02.12	-3.9	10°58'	Northern	14.11	-3.9	10°56'

Venus	Date	m_v	θ_{cr}	Venus	Date	m_v	θ_{cr}
	1583 BC				1551 BC		
Southern	08.07	-4.0	11°03'	Southern	28.06	-4.0	11°12'
Southern	09.07	-4.0	9°53'	Southern	29.06	-4.0	9°56'
Southern	19.07	-4.1	10°24'	Southern	10.07	-4.1	10°24'
Southern	20.07	-4.1	11°37'	Southern	11.07	-4.1	11°42'
	1582 BC				1550 BC		
Southern	26.03	-3.9	11°14'	Southern	17.03	-3.9	11°10'
Southern	27.03	-3.9	10°59'	Southern	18.03	-3.9	10°54'
Northern	14.06	-3.9	10°47'	Northern	05.06	-3.9	10°44'
Northern	15.06	-3.9	11°04'	Northern	06.06	-3.9	11°00'
	1581 BC				1549 BC		
Northern	17.02	-4.1	11°55'	Northern	08.02	-4.1	11°25'
Northern	18.02	-4.1	10°54'	Northern	09.02	-4.1	10°28'
Northern	26.02	-4.1	10°16'	Northern	17.02	-4.1	10°44'
Northern	27.02	-4.1	11°12'	Northern	18.02	-4.1	11°43'
Northern	24.10	-3.9	11°04'	Northern	14.10	-3.9	11°03'
Northern	25.10	-3.9	10°49'	Northern	15.10	-3.9	10°48'

calculated and Universal Time is set at 00:41. The calculations were performed with the Ephemeris — Tool 4.1 Version 4.1003, 2000 software, elaborated by M. Dings based on Newcomb theories, which is quite sufficient for this purpose. The sequence of the conjunctions can be clearly followed for each chronology. The data in the Venus Tablet can only be linked to any given chronology if anchored by an alternative link. Without any reliable data (such as the Ur III eclipses), the signal cannot be anchored with confidence.

MONTH LENGTHS

The principal of the method is to fit the distribution of 29 and 30 day months to any given chronology. With this goal, Huber (1987b) relied upon assumptions which could possibly distort the conclusions, e.g.

(a) assuming that data from incompatible collections, e.g. Late and Neo-Babylonian, share the same month-length distribution and data quality, which is certainly not fulfilled;
(b) the distribution of month lengths for his datasets cannot be given binomial or Poissonian distribution, due to potential inhomogeneities in the frequencies;
(c) the use of sample-depended parameters.

Let us illustrate the situation with his analysis of Ur III month lengths where an explicit plot is available (Huber 1987b; Exhibit 4). The data have $K_0 = 83$ discrepancies from $N = 228$ month lengths. He concludes that the result favours the High Chronology while conceding "that the statistical significance is not quite reached." This does not quite compare with the confidence he has since expressed on the very same results in his later papers.

The situation is, however, more complicated, as it revolves around the issue of the choice of the correctness of one of the two distributions. A proper evaluation of *A* (correct chronology) and *B* (best of wrong chronologies) must also include the null hypothesis. Then, at $K>K_0$, the area between the distribution curve of *A* and the abscissa (discrepancy) axis will correspond to the significance level of the hypothesis "*A* is correct" but the criterion is excluding it. *A* $K<K_0$, the area below the distribution curve corresponding to the hypothesis *B* indicates the probability of the error of the second category, i.e., when hypothesis *B* is correct but the criterion accepts the hypothesis *A*. Since K_0 is sample dependent and non-homogeneous and is hence unstable, no conclusion can be drawn on the correctness of either of the hypotheses (e.g., Prokhorov and Statulevicuius 2000). As Schaefer (1999) noted, "without a disproof of the null hypothesis, Occam's Razor would imply that the claimed discovery is false."

The situation is similar or even worse for his other samples: 6-13 discrepancies in 21 month lengths (Ammisaduqa) and 20 discrepancies in 57 (Hammurabi-Samsuiluna) (Huber 1987b).

Besides this, there are also crucial astronomical-observational effects which were neglected by Huber. First, the lunar synodic period is not 29.53, but can vary from 29.27

to 29.83 days (see Schaefer 1992). Second, as is noted in Schaefer (1992), Huber had not taken into account the seasonal variations of the extinction coefficients, while there are numerous effects to be taken into account, i.e. the lunar albedo, the relative positions of the moon with respect to the sun and the horizon, the dependence of the extinction coefficient on the date, latitude, humidity, on the optical pathlength in the atmosphere, the atmospheric refraction, the brightness of the twilight sky, the detection probability of the human eye, etc.

Such statistical approaches cannot, therefore, be used for any far-reaching conclusions concerning any chronologies. The month-lengths, however, may serve as a useful complementary tool for more complete and reliable datasets.

CONCLUSION

We have, therefore, observed that Huber (1987a; 1987b) arrived at erroneous eclipse identifications while failing to consider others which were potentially valid. This was at least partially due to his neglect of important bits of astronomical information recorded in the omens. The same neglect also accounts for his claims for the potential eclipses proposed for the Akkadian period (Huber 1999/2000a).[2] Huber's interpretation of the Venus Tablet is at least partially illusory since (a) the estimations of confidence levels are biased, (b) the 56/64 year cycles cannot be traced through and linked with a moving lunar calendar, and (c) his month-length assumptions are not statistically significant enough to match his chronological aims.

Without these supports, the High Chronology lacks any astronomical basis. Nor does any actual alternative support exist for the High Chronology (Hunger, personal communication). Huber (1999/2000b) himself concedes that the High Chronology is not supported by other alternative data. He nevertheless continues to claim that his astronomical arguments remain valid, even though — as we saw above — there are reasonable grounds for disputing them.

The analysis of astronomical records by distinguishing the reliability of their information as well as their possible chronological significance promises to produce results. Isolating the eclipse parameters of EAE 20 and 21 and extracting the limited data from the Venus Tablet allow a high degree of confidence in employing these as the astronomical anchor for the Ultra-Low Chronology proposed in Gasche *et al.* (1998).[3]

As stated at the outset, the astronomical and historical sources were sought to buttress an argument which was primarily based on archaeological evidence. The typological and stratigraphical evidence originally presented has not been thrown into

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[2] There are many cases which demonstrate that the purely statistical-probability approach is insufficient and misleading. Nobel laureate Piotr Kapitza drew attention to the fact that "numerous mistakes and false discoveries [are] obtained via statistical analysis, when the scientist aims to obtain the desirable result" (Kapitza 1981).

[3] Due to technical reasons I had no possibility to see the final galley proofs of Gasche *et al.* (1998), as well as the artwork in Gurzadyan (2000) prepared by the editors, and therefore here I tried to maximally clarify the points which might be misinterpreted from there.

doubt. Scholars not associated with the development of this hypothesis studying seals (e.g., Gualandi 1998), Egyptian materials (Krauss 1998 and personal communication), and Anatolian dendrochronological evidence (Kuniholm *et al.* 1996) have all provided additional interpretations of evidence compatible with the Ultra-Low Chronology. Other contributors present at the Ghent Colloquium (e.g. the contributions of Gates, van Soldt and Warburton in this volume) likewise presented interpretations compatible with the Ultra-Low Chronology.

While no compelling arguments have been brought against any elements of the astronomical or archaeological evidence, Hunger (2000a) has likewise come to share the opinion of the Venus data, suggesting that only the 8-year cycles can be taken as reliable markers.

The recent conclusion drawn by Spence on the shortening of the Egyptian chronology of the IIIrd millennium BC by means of her remarkable idea on the alignment of the pyramids at Giza (Spence 2000, Gingerich 2000) is also compatible (Warburton, in this volume) with the Ultra-Low Chronology.

Our work was built on that of previous generations of scholars and has been achieved through intensive co-operation between the representatives of each discipline. We believe that such collaboration can lead to a deeper insight into analogous multi-scale problems, and believe that it will become a common practice in the future.[4]

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[4] The news that a record of another solar eclipse linked to the life of the Assyrian King Šamši-Adad has been discovered suggests such further co-operation. Particularly, the eclipses of 8 October -1763 and 28 July -1732 would have been visible at Mari, but only with a co-operation that the potential chronological significance of these and other eclipses can be established.

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