lished by the reviewer), and learn from them, before proceeding with the publication of her own book.

Gothenburg. Jöran Friberg.

P. J. Huber and **S. De Meis**, Babylonian Eclipse Observations from 750 BC to 1 BC. VI + 291 pp. Milano, Mimesis – Rome, IsIAO, 2004. € 30,–. ISBN 8884832136.

This volume contains transliterations, translations and commentaries of approximately 359 Neo- and Late Babylonian records of lunar and solar eclipses, an astronomical and statistical investigation of these records, and several tables and maps. It is the fruit of a truly interdisciplinary enterprise by authors who are known experts of Babylonian astronomy and utilise their assyriological, astronomical, statistical, and geophysical skills in order to produce results that are relevant for each of these disciplines. This review begins with a table of contents, which is lacking in the book.

A full-blown study of Babylonian eclipse observations dealing with all the philological, contextual and history-of-science aspects of the subject is not provided. Instead, the book aims to make available the records and provide an astronomical and statistical evaluation of the data, as stated in the preface. Material not related to eclipses is omitted from the transliterations and translations (§ 4.2), and critical and philological notes are kept to a minimum. The reports originate from 5 groups of texts (§ 1.1):[1] (A) lists arranged in 18-year cycles, (B) other lists, (C) individual records, (D) Astronomical Diaries, (E) Goal-Year Texts. Only A-C, also known as Eclipse Texts, deal exclusively with eclipses. Eclipse lists (A-B) are partly predictive, since they contain reports arranged on a grid of eclipse possibilities which are predicted using a Saros scheme (Steele 2000b). Purely predictive texts (Almanacs, Normal-Star Almanacs and Saros texts),[2] reports which could not be dated[3] and Assyrian astrological reports[4] are excluded. Complete editions of the sources can be found elsewhere.[5] In general both editions are equivalent, but here and there the method of transliteration (§ 1.6) differs from the conventional one.[6]

Given their technical nature, it is hardly avoidable that even in translated form the reports can be cryptic at first sight. Their abbreviated terminology (§ 1.7) is also known from the Astronomical Diaries (ADRT I, pp. 11-38). Unlike what is suggested in § 1.6, the

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[1]) It requires some effort to find out from what type of text a particular record was extracted. The list of texts mentioned on p. 1 is incomplete since it includes only LBAT numbers. A full list is provided in § 4.1, but here A-C are lumped together as Eclipse Texts.

[2]) (Normal-Star) Almanacs are to appear in a future volume of ADRT. For Saros texts cf. Aaboe, A. – Britton, J. P. – Henderson, J. A. – Neugebauer, O. – Sachs, A. J. 1991: "Saros Cycle Dates and Related Babylonian Astronomical Texts", *Transactions of the American Philosophical Society* 81, 6; Steele (2000b).

[3]) E.g. ADRT V, nr. 33.

[4]) De Meis, S. – Hunger, H. 1998: *Astronomical Dating of Assyrian and Babylonian Reports* (= *Serie Orientale* Roma LXXXI).

[5]) Eclipse Texts (A-C): ADRT V; cf. the Appendix by J. Steele. In terms of his classification, A roughly corresponds to ii, B to i, and C to iv. Diaries (D): ADRT I-III; Goal-Year Texts (E): ADRT VI.

[6]) For instance, the sign **mul** or **mul**$_2$ preceding a star name is apparently not regarded as a determinative (e.g. p. 13).

abbreviations are not always made on a phonetic level (e.g. *e* for *eli*, 'above', and **e** for $\mathbf{e}_3$ = *aṣu*, 'to rise'), since some have an orthographic origin (e.g. AN for A.AN = *zunnu*, 'rain'). Some aspects of the terminology have been discussed elsewhere. The phrases 'it/which passed' [(*ša*$_2$) **dib**] and **bar dib** accompany predicted eclipses that did not materialize (Steele 2001/2). In the case of a lunar eclipse this happens when the Moon is below the horizon or when the eclipse occurs during daylight, as is sometimes indicated by a predicted time (e.g. in the reports for -685 Oct 15; -667 May 2; -667 Oct 25). Consequently not only dates of eclipse possibilities but also eclipse times were being predicted when the reports were written, perhaps as early as the 8th c.[7] For the meaning of *iṭṭarridu* in date formulas (p. 12), cf. Boiy (2004), pp. 181-182. For ḪAB-*rat*, 'disk' (p. 13) cf. ACT I, pp. 197-198.

The reports are ordered strictly chronologically (§ 4.2).[8] Each text is provided with a header containing the date established for the eclipse and other relevant astronomical data obtained from a modern computation.[9] The eclipse contacts are expressed in *true local time* (TLT, called LT in the book), which is defined such that the midpoint between sunset and sunrise is 24:00 TLT.[10]

Chapter 2 explains the astronomical and statistical analysis of the records and is not for the faint-hearted. Any effort to date and analyse ancient eclipse records requires that one deals with 3 kinds of uncertainties: (1) differences between ancient and modern observational practices and astronomical definitions, (2) past variations in the length of day (LOD), and (3) ill-known and fluctuating observational circumstances. In order to achieve optimal agreement between modern computations and Babylonian data, selected empirical parameters are derived from the eclipse data. The computations were performed using well-tested ephemeris programs. While some of the parameters are individually tuned if the effects cannot be readily separated, others are determined from a least-square fit of the eclipse timings. The involved steps are often based on intricate statistical arguments which tend to be phrased in a condensed manner, and it is taken for granted that the reader knows what a least-square fit is. Hence it takes some effort to understand the fitting procedure from § 2.3 and the highly technical supplement § 2.11. The free parameters which are determined by the fitting procedure are the 4 additional shadow factors (p. 23) and the 3 polynomial coefficients describing the curve for ΔT (ST82f), to be discussed below. Solar eclipses are excluded from the fit because they are too few (§ 2.8, 12). There is a degree of arbitrariness in the adopted approach, but, as will be argued, this need not be a problem as long as one is aware that the deviations between the modern computations and the Babylonian data could also be disentangled in a different way.

For instance, Babylonian astronomers used sunset and sunrise as reference points for expressing the time of an eclipse (§ 2.2). Compared to modern computations for an observer in Babylon and assuming that risings and settings are defined in terms of the upper limb as in modern usage, recorded risings of the Sun and the Moon are systematically delayed by about 2 min, while settings are advanced by the same amount (Huber 2000; Steele 2000a, pp. 47-51). A possible explanation proposed by the authors is that the observations were made from a height of 108 m with respect to the horizon, so that the apparent altitude of celestial objects is uniformly increased with respect to that for an observer at zero elevation (p. 21).[11] However, it cannot be taken for granted that the modern definition of risings and setting coincides with Babylonian practice. Evidence from procedure texts with instructions for computing moonrise and moonset by means of mathematical ('ACT-type') schemes and other arguments suggest that risings and settings were sometimes defined by the *preceding* limb of the Moon and the *trailing* limb of the Sun with respect to the daily rotation of the sky, either of which can coincide with the upper or the lower limb.[12] If this is true, the shifts of the recorded risings and settings of Sun and Moon with respect to modern computations are no longer a uniform 2 min, and the assumption of an

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7) Steele (2000a), pp. 69-70. For a possible method which might also explain the mysterious numbers mentioned e.g. in LBAT 1413 Obv 1,3 and LBAT 1414 Obv 1 cf. Brack-Bernsen – Steele (2005).

8) There is no index to the tablets, so that it is a tedious job to find a particular text if one does not know the date of the eclipse, even more so since most tablets from the British Museum are not identified by the familiar BM number, which must be retrieved from the concordance in LBAT, pp. X-XXXVIII or ADRT V, pp. XI-XII.

9) Except that for unexplained reasons the data in the headers and in § 2.7 are based on formula ST82i for ΔT versus ST82f elsewhere. As a result, the times can deviate from those in § 5 by several min.

10) In TLT, sunset and the following sunrise always add up to 24 hrs. TLT has the disadvantage of being non-uniform since TLT-UT varies from day to day, unlike the more common definition LT = UT +λ/15, where λ is geographical longitude measured positively eastwards (for Babylon LT - UT = 2.96 hrs).

11) The formula describing this effect can be found in Seidelmann, P. K. (ed.) 1992: *Explanatory Supplement to the Astronomical Almanac* (Sausalito, University Science Books), pp. 488-489. It assumes that the horizon is perfectly circular and not blocked by elevations, which might be a good approximation in the plains of southern Mesopotamia.

12) Cf. Ossendrijver, M., *Babylonian Mathematical Astronomy: Procedure Texts*, to appear.

elevated observer no longer suffices to explain all of them simultaneously.[13]

Issues of definition and observational circumstances also affect the timing of the 4 phases of a lunar eclipse as reported by the Babylonians, B1 ... B4 (§ 2.3). If the modern designations for the eclipse contacts are C1 = first contact of the Moon with the Earth's shadow, C2 = beginning of totality, C3 = end of totality, and C4 = last contact, then it cannot be taken for granted that B1 = C1 etc. In modern computations of C1 ... C4 the diameter of the Earth's shadow is conventionally multiplied by an empirical factor 1.02 which accounts for atmospheric effects. As shown in Table 1 (p. 23) this prescription does not produce complete agreement with the Babylonian measurements, since B2-B1, B3-B2 and B4-B3 deviate by about +6, -3 and +13 min, respectively. These deviations are remarkably small, and one wonders whether they are really significant as claimed, given that the time measurements exhibit random errors of about 7 min (§ 2.5). Since the responsible effects cannot be readily separated, the authors proceed by adopting the 108 m elevation and the upper rim convention for risings and settings, after which they deduce from the least-square fit that agreement with the Babylonian timings is optimal if the diameter of the Earth's shadow is enhanced by 6 % for C1 and C4 and reduced by 3 % for C2 and C3, on top of the conventional increase of 2 %.[14] The authors see confirmation of the 3 %-reduction for C2 and C3 in the fact that the lunar eclipse of 1 June -119 is reported as partial whereas it should be total (eclipse magnitude 1.02) according to a modern computation if the 3 %-reduction is omitted. It is nevertheless difficult to imagine how the shadow diameter can have been systematically different from the modern value, and different for different contacts. Moreover, the additional reduction by 3 % for C2 and C3 would imply that the effect of the atmosphere is a net decrease of the shadow diameter, which seems unlikely on physical grounds. The shadow factors as well as the adopted definition of risings and settings and the elevated position of the observer are convenient parametrizations which optimize agreement between the modern computations and the Babylonian data, but their true origin may be different from what is suggested. More detailed investigations of Babylonian observational practices might be able to correctly disentangle and explain the individual effects that really cause the deviations.

Changes in the LOD are quantified by their cumulative effect ΔT = ET - UT, which is the difference between Ephemeris Time (ET), the uniform time frame of astronomical computation, and Universal Time (UT), our civil time frame which is linked to the Earth's rotation (§ 2.4). If the LOD changes by as little as a fraction of a second the effect on ΔT will accumulate to hours in the course of centuries. If at a given date ΔT is increased, all astronomical events are uniformly advanced by this amount. Hence the time of an eclipse and the visibility of a total solar eclipse on a given location are highly sensitive to changes in the LOD, so that ancient eclipse records are valuable to geophysicists wishing to reconstruct the history of the Earth's rotation (Stephenson 1997; Steele 2000a). Since ΔT exhibits irregular fluctuations on a timescale of decades[15] the value derived from a single eclipse can deviate by several minutes from the long-term trend, which can be established only by analysing many eclipses. The authors discuss various alternative expressions for the long-term trend, and they present their own version which is derived from their least-square fit. The resulting formula (ST82f; p. 25) has an accuracy of a few minutes (Table 3, last column), but it is correct only when used in conjunction with the other assumptions (p. 27). This is because for many eclipses only 1 contact (B1) is timed with respect to sunset while the others are relative to B1, so that there is no way to separate the effect of a change in ΔT from that of a change in the shadow diameter or, I would add, from that of a different definition of sunset.

§ 2.5-7 contain a discussion of the residuals of the eclipse timings resulting from the least-square fit. It appears that eclipse timings were measured much less accurately than moonrise and moonset (as quantified by the Lunar Six intervals), which may reflect different ways of measuring time. Some eclipses are timed with respect to the culmination of a *ziqpu*-star (Hunger – Pingree 1999, pp. 84-90). These data are consistent with ST82f.[16]

In § 2.9-10 the empirical expressions for ΔT are compared with theoretical ones based on geophysical models (Stephenson 1997). In Fig. 6 the differences between them are rendered more obvious to the eye by subtracting a reference model ('tidal + rebound'), which removes most of the long-term trend. Curve ST82f, the result of the authors' least square fit, is positioned in the middle of its 1σ error band shown in gray. For the period spanned by the Babylonian records ST82f is

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[13] The inferred height cannot be brought into connection with the ziqqurrat in Babylon because it was probably dilapidated during the Achaemenid period, and Alexander had it completely removed (Boiy 2004, pp. 66-67, 110-111).

[14] A different definition of sunset would uniformly modify C1 ... C4 so that the differences between them would not change.

[15] Even if these fluctuations might be considered stochastic (e.g. p. 24) on a purely descriptive level they are not truly stochastic because they are caused by geophysical processes.

[16] The caption to Table 7 suggests that the stellar positions (α) were obtained by correcting those in Table 6 for precession, but the numbers imply that they have also been corrected for proper motion, as they should.

effectively equivalent with nearly all the other expressions included in the graph since the differences between them are comparable to the accuracy to which the long-term trend can be determined. Hence it is not clear in what sense, if any, ST82f represents an improvement. The figures in § 2.9 clarify why this is the case. Due to the mentioned decadal fluctuations, values for ΔT derived from individual eclipses (shown in Fig. 6 as vertical bars) can deviate significantly from the curves, which model only the long-term trend. As illustrated in Fig. 7, this means that the trend can be determined only to within about 10 min even if there were many more eclipse records. The dangers of extrapolating any of the curves beyond the interval of the corresponding data are illustrated in Fig. 11.

The amount of hard philological and analytical work that has been carried out in order to produce this book cannot be overestimated. By tuning various empirical parameters or determining them from a least-square fit the authors have succeeded in optimizing agreement between their computations and the Babylonian eclipse data. In the process they have obtained secure dates for hundreds of reported eclipses, and a new expression for the quantity ΔT, which is consistent with previous expressions for the period spanned by the records. As argued, it remains to be seen whether the interpretation of the empirical corrections is final. There is a somewhat unfinished, stenographic touch to the book, so that the results are not as accessible as one might hope for, especially given the complexity of the subject. The latter has understandably also led to a narrow focus on the statistical and astronomical interpretation, at the cost of other aspects of the Babylonian eclipse observations. However, the authors are to be congratulated for setting high statistical standards for the investigation of ancient eclipse observations. Moreover, such investigations are perhaps the only means by which we can hope to learn something about the observational practice of the Babylonian astronomers, since the cuneiform texts are very silent about this issue.

References

ACT = Neugebauer, O. 1983: *Astronomical Cuneiform Texts* (= *Sources in the History of Mathematics and Physical Sciences* 5) (New York – Heidelberg – Berlin, Springer-Verlag).

ADRT = *Astronomical Diaries and Related Texts.* Sachs, A. J. – Hunger, H. 1988: ADRT I; 1989: ADRT II; 1996: ADRT III; Hunger, H. 2001: ADRT V; 2006: ADRT VI (Wien, Verlag der Österreichischen Akademie der Wissenschaften).

LBAT = Sachs, A. J. 1955: *Late Babylonian Astronomical and Related Texts* (Providence, Brown University Press).

Boiy, T. 2004: *Late Achaemenid and Hellenistic Babylon* (= *Orientalia Lovaniensia Analecta* 136) (Leuven, Peeters).

Brack-Bernsen, L. – Steele, J. M. 2005: "Eclipse Prediction and the Length of the Saros in Babylonian Astronomy", *Centaurus* 47, 181-206.

Huber, P. J. 2000: "Babylonian Sort-Time Measurements: Lunar Sixes", *Centaurus* 42, 223-234.

Hunger, H. – Pingree, D. 1999, *Astral Sciences in Mesopotamia* (= *Handbuch der Orientalistik* I.XLIV) (Leiden, Brill).

Steele, J. M. 2000a: *Observations and Predictions of Eclipse Times by Early Astronomers* (Dordrecht, Kluwer).

Steele, J. M. 2000b: "Eclipse Prediction in Mesopotamia", *Archive for the History of Exact Science* 54, 421-454.

Steele, J. M. 2001/2: "The Meaning of BAR DIB in Late Babylonian Astronomical Texts", *AfO* 48/49, 107-112.

Stephenson, F. R. 1997: *Historical Eclipses and Earth's Rotation* (Cambridge University Press).

Tübingen. M. Ossendrijver.

F. Rochberg, The Heavenly Writing. Divination, Horoscopy, and Astronomy in Mesopotamian Culture. xxvi + 331 pp. Cambridge, Cambridge University Press, 2004. £ 45. ISBN 0-521-83010-9.

The traditional view of Babylonian science is that of a static system of data collection, without much in the way of recorded theory or hypotheses which explain the information being gathered.

In terms of mathematics, for instance, Babylonians are usually thought to solve mathematical problems ad hoc without developing general rules; hence Babylonians used and understood the geometric principles which became known as Euclidian geometry but without formulating any actual theorem, or at least one which is preserved in Akkadian. Similar opinions have been expressed about Babylonian astronomy, which made the first great advances in assembling data and performing calculations, but it was the Greeks rather than the Babylonians who systematised astronomy (see O. Neugebauer, *The Exact Sciences in Antiquity*, [1969], 156ff., and Lewis Wolpert, *The Unnatural Nature of Science*, [1992], 35ff.)

This widely held view of Babylonian science does not take into account certain innovations, such as astral medicine, which combines medical recipes with the invention of the horoscope, in trying to determine which days of the year are most propitious or unlucky for medical treatment. Although lucky and unlucky days already existed within hemerologies (see R. Labat, *Hémérologies et Ménologies d'Assur* [1939], 190 et passim) new ideas of astral medicine focussed more on the individual patient than upon portentous phenomena affecting either the king or the population as a whole. Moreover, advances in astronomy are reflected in being able to fix the 19-year cycle of the luni-