The Babylonian Theory of the Planets. By N. M. SWERDLOW. Princeton, NJ: Princeton University Press, 1998. Pp. xv + 246. $39.50.

It is around one hundred years since Epping, Strassmaier and Kugler made the discovery that the Babylonians not only watched the skies, but also computed a whole host of celestial events, ranging from the first visibility of the lunar crescent, to the dates of the appearances and disappearances of the five planets. Through the extensive labors of these and later scholars most aspects of the operation of the Babylonian mathematical astronomy are now well understood. However, the question of how the various Babylonian theories were formulated has only recently begun to be addressed.

In The Babylonian Theory of the Planets, Noel Swerdlow has attempted to show how the fundamental parameters of the Babylonian planetary theory could have been derived from the observations that were available to the Babylonian astronomers as represented by the records in the astronomical diaries. Swerdlow claims that his method, based upon manipulating observations of the length of time between two successive rising or setting phenomena - known as synodic time - "was the way the Babylonians derived the parameters of their mathematical astronomy," or that he "at any rate, can see no plausible alternative." (p. xiii)

Swerdlow begins his book with a discussion of the background to the various cuneiform astronomical texts. He is of the opinion that divination provided the primary motivation for astronomy in Babylon, although he does suggest that eventually the study of astronomy may have come to take on a life of its own through a purely scientific interest on the part of the Babylonian astronomers, writing that "the complexity and diversity of the ephemerides goes far beyond what is necessary to predict ominous phenomena ... and suggests nothing less than a rigorously scientific interest in the mathematical description of periodic phenomena." (p. 174) On the whole, this is a highly interesting and informative discussion, although at times slightly over-simplified in its interpretation of the omen literature and containing a few inaccurate statements in the description of the technical framework of Babylonian astronomy. For example, Swerdlow writes that, "the UŠ of time is principally a unit of computation, although indirectly it can also be measured." (p. 36) However, the UŠ, which corresponds to four of our minutes, is used extensively as the unit when quoting measured times of observations from at least the eighth century BC. It is also equal to a thirtieth of a bēru, which itself seems to have been originally defined as the time it takes to walk a fixed distance of about seven miles.

After this gentle introduction, Swerdlow leads us into a technical discussion of the methods he believes were used to derive the parameters of the various theories for calculating what have become known as the "Greek-letter phenomena" (the dates of the appearances, disappearances and stationary points) of the five planets. The analysis itself is not for the faint-hearted. It is based upon a clever manipulation of observed synodic times, or, where there are no observations preserved, modern data used to mimic the observations that it is assumed were available to the ancient astronomers. These times are taken to be an excess number of days over an integer number of years. Since the Babylonian calendar was governed by the visibility of the moon, the month could contain either twenty-nine or thirty days, and so for convenience the Babylonian astronomers used a unit defined as being exactly one thirtieth of a lunar month in their mathematical astronomy. This unit has become known as a "tithi" after the corresponding unit used in Indian astronomy. Swerdlow therefore converts his synodic times into tithis and compares them with the approximate position in the zodiac at which the synodic event took place. From this he is able to determine the maximum and minimum synodic times and therefore, using previously established period relations - and sometimes a little force - the final parameters for the various theories.

In formulating the method outlined above, Swerdlow has come up with an ingenious way in which the parameters might have been derived for some of the planetary theories. However, to my mind, the question as to whether Swerdlow is correct in his belief that he has found the one and only method by which the Babylonian astronomers derived these parameters still remains open. In an appendix he outlines his reasons for rejecting two other possible methods, one based upon counting the number of phenomena within zones of the zodiac, and the other by direct measurement of longitudes. Swerdlow's reasons for dismissing these methods, at least as detailed here, do not seem to be fully convincing. For instance, we do know that the Babylonian astronomers were capable of measuring longitudes if they wished; the existence of a fragmentary star catalogue proves this. Furthermore, he notes that the preserved diaries do not contain as many reports of the distance of a rising or setting planet to a normal star (from which the longitude could be obtained using something like the star catalogue mentioned above) as one would need to derive the planetary parameters. However, this does not necessarily imply that such measurements were not available, or could not have been made, by the astronomers who formulated the planetary theories. In truth, neither Swerdlow's method nor the methods he dismisses work perfectly for every planet, and it seems much more likely that the Babylonian astronomers chose whichever worked best, or rather whichever was the most convenient, for each individual case.

Given the highly technical nature of the book, it is unfortunate that the exposition of the main arguments is somewhat hampered by the layout. Since the tables and figures are collected at the end of the book, rather than in the main body of the text, the reader is often trying to look at three pages at once to try to follow Swerdlow's arguments. Furthermore, the quality of the reproduction of the figures is poor, and when, for example, one is invited to look at figure 2.3 which shows different sets of data as open circles, filled circles, and open squares, it is not always easy to distinguish which ones are which.

In conclusion, The Babylonian Theory of the Planets is an interesting and provocative book. The inclusion of the introductory chapter on the place of astronomy in Babylonian society is particularly welcome since this is an aspect all too often neglected in technical works on the history of science. Although some of the analysis requires more than one reading to fully understand, it is certainly worth the effort, even if some readers will not agree with all of the author's conclusions.

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Noel M. Swerdlow. *The Babylonian Theory of the Planets.* xviii + 246 pp., figs., tables, bibl., index. Princeton: Princeton University Press, 1998. $39.50, £27.50 (cloth).

The different aspects of Babylonian astronomy and the relations between astronomy and omen astrology have so far mostly been studied separately. One chief point of research was the techniques used by the Babylonians for computing special lunar and planetary phases. The cuneiform texts witnessing this mathematical astronomy are published and explained in Otto Neugebauer (ACT, Lund Humphries, London, 1955). Since then we have a good understanding of how the highly technical and elegant Babylonian methods for computing these events worked. Another chief point was working on the non mathematical astronomical texts. They exist in four different types of collections of observed or predicted celestial phenomena. Only recently (1988 -1996), the so-called Diaries have been published in an English translation. Except for a description and survey of content, the other three types are still only available in cuneiform transcription. Still another field is the connection between divination and celestial observation and the social position and institutional background of the Babylonian scholars.

The book of Noel Swerdlow combines all three aspects. It starts with the presentation and analysis of a selection of planetary omina. The author points out that the celestial phenomena which were regarded as ominous are exactly those which were collected or computed in the different types of astronomical texts. He stresses that it were the same persons who performed all types of astronomy and astrology, that they did not distinguish between these subjects, and he concludes that the interest in observing, predicting and interpreting celestial events was the primus motor for the development of the mathematical astronomy. Another motivation being the pure scientific interest in the mathematical description of periodic natural phenomena. The main purpose of the book is, however, to demonstrate how all parameters underlying the Babylonian ephemerides can be derived from the data recorded in the Diaries.

There have been attempts to construct the Babylonian calculation methods from observations. Asger Aaboe (1958) controlled the precision of the Babylonian planetary theories through comparison against modern calculations. He proposed that some might have been constructed from the positions of consecutive phenomena, others by the times of their occurrences. Later (1964) he showed that the Babylonian step function for calculating consecutive positions of one synodic phenomenon results in an uneven distribution in the ecliptic of the events. This corresponds to reality: Aaboe therefore proposed that a simple counting of the number of events taking place within different zones of the ecliptic could lead to the Babylonian step function - eventually by choosing or changing numbers slightly in order to get easy to handle numbers.

Swerdlow, having all the Diaries at his disposal, remarked that generally the *times* of planetary phenomena were given much more accurate than the *positions* where they occurred. He therefore undertook a great effort to demonstrate that it is possible to derive the parameters of all the planetary models from the dates of phenomena and from locations by zodiacal sign as recorded in the Diaries.

The period relations, upon which the planetary calculation schemes were based, are found from shorter periods. Such shorter periods (specific for each planet and known by the Babylonians) were used by Swerdlow also to check the accuracy of data recorded in the Diaries. The appropriate period relation serves then as a starting point for the reconstruction of each single arithmetical function.

A relation of synodic arc and time is also used heavily: with a few exceptions, the numerical difference between synodic arc in degrees and synodic time in "tithis" is a constant. Swerdlow emphasizes that this arithmetic rule, used by the Scribes for calculating the ephemerides, also can be utilized to derive synodic arcs from observed synodic times and vise versa.

Until now the Babylonian functions have been controlled only for those phases which are easy to calculate or to find from ephemerides. Swerdlow, being convinced that the functions were constructed from first or last visibility, undertakes the very cumbersome task to calculate the positions and times of first and last visibility over long periods of time for all the planets. The calculated data, approximating the functions quite well, are also used to guide for the appropriate selection of Babylonian observed data.

In case of the zigzag functions of System B one only has to select the right maximum and minimum value of the synodic time and the function is determined.

In System A the synodic arc is given as a function of the position in the ecliptic. Swerdlow utilizes the relation between synodic time and arc to obtain synodic arcs from observed times. He then starts from the right number and approximate size of ecliptic zones, and a rough (but well chosen) estimate of the synodic arc on two zones. Solving simultaneous equations and the requirement of nice numbers lead to the Babylonian step function. All arithmetic manipulations which could be handled by the Babylonians.

In order to calculate a series of consecutive phenomena by Babylonian methods, one only has to know the precise position and date of the first occurrence. All the following times and positions are determined by means of the step or zigzag functions. For the first time, Swerdlow demonstrates how it is possible to derive such initial positions from observations. Hereby he uses his interpretation of the relation between synodic time and arc, as resting upon two more fundamental principles: 1) the sun is taken to move uniformly and 2) a given phase always takes place at at fixed elongation from the sun, and that. I cannot share this point of view and will discuss it at another place.

A strength of Swerdlow's approach is the consequence with which he uses the same basic idea and methods for deriving all functions and parameters of the Babylonian planetary theory. But maybe it is also a weakness, or at least something worth discussing. How were these two types of functions developed?

To me it seems probable that not all the functions were constructed as proposed by Swerdlow. One step function may at the first place have been found empirically from uneven distributions of phenomena in the ecliptic. In case of lunar texts it is evident that the functions were deduced from positions. Was the first step function developed in this way? The experience from one working step function would furnish the scribe with a know-how allowing him to construct further functions in the way proposed by Swerdlow. I am convinced by his reconstruction of Mercury's functions.

Swerdlow controls the dates of phenomena recorded in the Diaries and other collections. They turn out to be quite inaccurate. As a consequence, there is a great spreading amongst the observed data. Therefore he has to select the observed input carefully in order to derive the Babylonian parameters. As he puts it: "what comes out had to go in" (pp. 73, 109, 125). Aaboe could have used the same argument. Swerdlow's choice of longest and shortest synodic time in his reconstruction of Mars' step function seems to me as probable as a hypothetical change by Aaboe from 32 and 14 events within the fastest and slowest zone to 36 and 12 events within these zones. But this rises in each single case the question of how to decide between the two possible ways of constructing the function.

Another point worth discussing is how precisely did the Babylonians knew the position of the planets. The Diaries record the day of first visibility plus position through zodiacal signs. But this does not imply that the Babylonians did not know the position of a planet more precisely: the Diaries record also the dates when a planet enters a new sign, the date of other phases and the position by zodiacal signs of all planets visible in the beginning of each month. At least for the slow planets Jupiter and Saturn, this information is sufficient to survey the movement much more closely than by zodiacal signs only.

The book is well written and structured. It presents for the first time a complete and consistent reconstruction of all the planetary models. The reconstructions are based on synodic times derived from the diaries and on the relation between synodic time and arc. A huge amount of Babylonian data are extracted from the Diaries or other collections and presented in tables. Synodic times have been calculated from these data, and in figures compared to the Babylonian functions al well as to synodic times found by modern calculations. Figures and tables are very informative and of good layout.

Maybe this is not the last word on the topic. But it is a very challenging, inspiring and useful book. It serves as a solid basis for further research and discussions. To read this book is a must for everybody severely interested in ancient astronomy.

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