Astronomy. — *Egyptian "Eternal tables"*. II. By B. L. VAN DER WAERDEN. (Communicated by Prof. A. PANNEKOEK.)

(Communicated at the meeting of May 31, 1947.)

In the preceding paper I have discussed the dates of entrance of planets into the signs of the ecliptic, contained in 3 Egyptian texts, published by O. Neugebauer:

P: Berlin Papyrus P 8279
S: Stobart tablets A, $C_1 + C_2$ and E
T: Papyrus Teptunis II 274

and I have shown that the dates for Venus, Mars and Jupiter are calculated by means of Babylonian methods.

In this paper I shall compare the motion of Saturn and Mercury in these texts with Babylonian ideas, and I shall discuss the reduction of Babylonian dates to the Alexandrian calendar in the texts S and T.

Saturn.

According to the Babylonian procedure text AO 6477, analyzed by KUGLER (Sternkunde II, p. 578) the velocities of Saturn are as follows:

Daily velocity of Saturn	"slow motion" 10° ♌ to 30° ♒	"fast motion" 30° ♒ to 10° ♌
Near the sun	5′	6′
After heliacal rising 30^D	5′	6′
Until 1st station 90^D	3′ 20″	4′
Until opposition $52\frac{1}{2}^D$	— 4′ 13″ 40‴	— 5′ 4″ 24‴
Until 2nd station $69\frac{2}{6}\frac{1}{0}^D$	— 3′ 20″	4′
After 2nd station 90^D	3′ 35″ 30‴	4′ 18″ 40‴
Until heliacal setting 30^D	5′	6′
Total retrograde course	7° 33′ 7″ 30‴	9° 3′ 45″
Total synodic course	11° 43′ 7″ 30‴	14° 3′ 45″

The text does not tell us, how long the time "near the sun" lasts. In order to obtain the prescribed synodic arcs (11°43′7″30‴ or 14°3′45″) the time ought to be $46\frac{1}{2}^D$, but in order to obtain the right synodic period it ought to be only 24^D. Probably the time interval was intentionally not prescribed, in order to avoid errors in either date or position, which would sum up to large errors after many synodic periods. I suppose that at the beginning of a new synodic period the position and date were determined anew from tables of well-known type giving date and position at heliacal rising [1]). This would explain also the irregular date differences which we found in the case of Mars in the neighbourhood of the con-

[1]) See B. L. VAN DER WAERDEN, Babylonische Planetenrechnung, Eudemus I (1941).

junction. Possibly such corrections were also applied at the stationary points; this would explain certain irregularities for Jupiter in P and S.

Our text S is not calculated according to the procedure text AO 6477, but the division of the ecliptic into a slow and a fast region is the same. In the fast region the time needed for traversing a sign is always less than in the slow region, as is seen from the following table:

Slow region: ♍ ♎ ♏ ♐ ♑ ♒				Fast region: ♓ ♈ ♉ ♊ ♋			
Year	Date	Sign	Difference	Year	Date	Sign	Difference
Vespasian 6	2 7	♐	802^d	Trajan 13	7 24	♓	771
Vespasian 8	4 18	♑		Trajan 15	[9] 4	♈	790
				Trajan 17	11 4	♉	
Trajan 9	3 5	♑	800				
Trajan 11	5 14	♒	800	Trajan 16	6 7	♈	783
Trajan 13	7 24	♓		Trajan 18	7 30	♉	774
Hadrian 11	2 1	♎	801	Hadrian 1	9 13	♊	778
Hadrian 13	[4] 11	♏		Hadrian 3	11 1	♋	
Hadrian 14	2 1	♏	811				
Hadrian 16	4 22	♐					

The normal, (i.e. minimal) difference in the slow region is apparently $800^d = 27^M 3^D$, in the fast region $771^d = 26^M 4^D$. This means: The time necessary for traversing 2 complete synodic arcs, that is 23°26′15″ or 28°7′30″, and the additional 6°3′45″ or 1°52′30″ necessary to make up 30°, is $27^M 3^D$ in the slow region, and $26^M 4^D$ in the fast region. (The larger differences 811, 790, 783, 774 and 778 are apparently due to the fact that in these cases the additional arc does not entirely belong to the "linear part", where the velocity is highest).

Now 2 synodical periods are $25^M 16^D$ or $25^M 21^D$, for this is the time which the sun needs to traverse 720° + 23°26′15″ or + 28°7′30″; hence the time necessary to traverse the remaining 6°3′45″ or 1°52′30″ at maximum speed is

$$27^M 3^D - 25^M 16^D = 47^D$$

or

$$26^M 4^D - 25^M 21^D = 13^D$$

So the maximum velocity of Saturn is approximately

$$364' : 47^D = 7\tfrac{3}{4} \ (' \text{ per } ^D)$$

in the slow region, and

$$112\tfrac{1}{2} : 13 = 8\tfrac{1}{3} \ (' \text{ per } ^D)$$

in the fast region. These figures are only approximate, especially the last one. Most probably the exact velocities are 7′30″ in the slow region and 9′ in the fast region. In any case they are higher than those of the procedure text, just as in the case of Jupiter.

Mercury.

For Mercury the date differences are, if we restrict ourselves to the main part of text S and to non-retrograde motion

(~ means: retrogradation in this sign).

Text $C_1 + C_2$		♍	♎	♏	♐	♑	♒	♓	♈	♉	♊	♋	♌
Trajan	8				20	16	17	~	17	16	19	~	18
	9	19	20	~	17	18	~	16	14	18	~	28	18
	10	18	~	17	19	18	~	17	16	19	~	18	16
	11	23	~	19	18	~	13	20	44	~	23	15	18
	12	~	19	19	16	~	17	16	24	~	15	15	~
	13	19	20	19	~	18	17	17	~			20	~
	14	18	20	20	~	17	17	~	19	15	17	~	18
	15	21	20	~	34	17	18	~	17	16	22	~	21
	16	17	~	20	17	18	~	16	16	17	~	19	15
	17	20	~	17	19	19	~	16	17	23	~	16	16
	18	~	18	19	20	~	18	16	28	~	14	15	20
	19	~	19	20	~	21	16	17	~	25	13	15	~
Hadrian	1	21	19	19	~	17	16	18	~		15	23	~
	2	19	20	~	19	18	15	~	16	16	18	~	20
	3	20	13	~	20	18	20						

In some synodic periods we have 2, in most cases 3 successive date differences, of which the middle one is generally smallest. This could be expected, because for all planets the motion is fastest in the middle part of the direct course. Now if we want to single out this maximum speed, we have to restrict ourselves to those cases where the middle number is really the smallest of the three, or where there are only two nearly equal numbers. We also exclude the cases in which the middle number seems too small. The remaining middle numbers are, if the method is applied to the whole text S:

	Text A	Text $C_1 + C_2$	Text E
♍	19	19, 19, 20	20, 17
♎	19, 19, 19	19, 19, 20	19
♏	20	19, 19, 20	20
♐	17	17, 18, 17	18
♑	17	16, 18, 17, 17, 18	17
♒	16, 15	17, 17, 16, 16	
♓	15	16, 16	17
♈		14, 16, 16, 17	16
♉	16	16, 15, 16, 16	16, 16
♊		15, 13, 15	14, 15
♋		15, 15, 16, 15	15, 15
♌		18, 16, 15, 16	17, 18

It appears from this list, that the ecliptic was divided into a *slow region*

(containing the signs ♍ ♎ ♏), where the time for traversing a sign lies between 19 and 20^d, one or two *middle regions*, where the time lies between 16 and $17\frac{1}{2}^d$, and a *fast region* (containing ♉ ♊ ♋), where the time is about 15^d. In Babylonian units, the speeds might be 1°30′, 1°48′(?) and 2° per 1^D.

Now in Babylonian texts, the ecliptic is also divided into 3 parts. For instance, in Sp II 57 + 59 (KUGLER, Sternkunde I, p. 188) the synodic arc from one heliacal rising of Mercury in the morning to the next one is:

106° between 1° ♌ and 16° ♑
141°20′ between 16° ♑ and 30° ♉
94°13′20″ between 30° ♑ and 1° ♌

Similarly, the synodic arc from one heliacal rising of Mercury in the evening to the next one is

160° between 6° ♋ and 26° ♎
106°40′ between 26° ♎ and 10° ♓
96° between 10° ♓ and 6° ♋

I do not, however, see any direct connection between these synodic arcs and the maximum velocities of Mercury previously found. In order to establish such a connection, it would be necessary to study the retrograde motion as well.

Calendar reduction.

The dates given in T are in close agreement with those of text S. NEUGEBAUER writes: "Comparisons between the positions given in T and S show a slight tendency to place the entrance of a planet into a sign earlier than T, but this might be purely accidental in our little fragments (in 10 instances it is earlier, averaging one day; in 3 instances later; in 12 there is exact agreement)" [2]).

The most natural explanation of this agreement and of these divergences seems to be, that S and T used the same Babylonian planetary text, but that the reduction to the Alexandrian calendar was made by a different scheme. The means to perform this reduction are given by the text T itself, for it contains the following dates of New Moons and subsequent crescents:

(Trajan) year 11 VIII 4
X 3 6
XII 2 5

The New Moons of months IX and XI are left indetermined. I suppose that they were tacitly assumed to take place either 30 days after the

[2]) O. NEUGEBAUER, Egyptian Planetary Texts p. 242 (Trans. Amer. Philos. Soc. 32, 1942).

preceding New Moon, or 30 days before the next one. Adopting the first supposition, we get the complete scheme used for date reduction:

	New Moon	Crescent	Carlsberg crescent
Year 11	VIII 4	VIII 7	VIII 7
Trajan	IX 4	IX 7	IX 6
	X 3	X 6	X 6
	XI 3	XI 6	XI 5
	XII 2	XII 5	XII 5
	epag 2	epag 5	epag 4

The last column "Carlsberg crescent" is obtained as follows: In Pap. Carlsberg 9 a periodical scheme for calculating new moons is exposed. NEUGEBAUER and VOLTEN, who have published this papyrus [3]) suppose that the dates given in Carlsberg 9 mean crescent, i.e. first visibility of the moon, instead of new moon. This supposition is confirmed by their calculations for the first year of the last cycle (AD 144/145), but in most other years the dates given by the Papyrus are nearer to the new moon than to the crescent, and quite near to the mean new moon. Two instances will illustrate this:

Year AD	Cycle year	Carlsberg date	Mean New Moon	New Moon	Crescent
108	14	X 6 = April 28	April 28, 12^h	April 28, 23^h	April 29 or 30
146	3	VI 7 = Dec. 21	Dec. 21, 6^h	Dec. 21, 2^h	Dec. 23

For the year Trajan 11 the Carlsberg text gives the following dates:

(Egyptian) VIII 7 (= Alexandrian VII 4)
X 6 (= IX 3)
XII 5 (= XI 2)

Adding (as in T) 3 days to get the crescent, although this would seem a little bit too much [4]), and interpolating the Alexandrian months VIII, X and XII as before by the addition of 30 days, I obtained the dates given in the last column "Carlsberg crescent".

The near agreement of this column with the preceding one derived from text T is another strong argument in favour of our interpretation of the dates in Carlsberg 9 as new moon dates. It is seen that in half of the cases Carlsberg leads to the same crescent as T, in the other half to a crescent 1 day earlier. Hence in applying these or similar schemes to the reduction of Babylonian dates, half of the dates will result 1 day earlier

[3]) Quellen u. Studien, Gesch. Math. B 4, p. 383.

[4]) According to SCHOCH (in Langdon–Fotheringham, Ammizaduga) the lapse of time between New Moon and the noon of the day after crescent in Babylon (day 1 of the Babylonian Month) varies between $1\frac{1}{2}$ and 3 days.

according to the second scheme, which is just what NEUGEBAUER found in comparing the dates of S and T.

Still, I am not quite sure that the reduction of dates in S was performed exactly by means of the scheme "Carlsberg Crescent". The only date for which this hypothesis can be directly checked is the entrance of Mercury into Leo in the year 11 of Trajan, for which S and T give the dates

T: XI 21 ♌ S: [XI] 20 ♌

If the original Babylonian date is supposed to be Duzu 16, the dates in T and S would be obtained by assuming Duzu 1 = XI 6 and = XI 5 respectively, as in our columns "Crescent" and "Carlsberg Crescent". However, in the beginning of the same year 11, months 2—3, the dates of T coincide exactly with those of S for 2 months in succession, which would mean that here the reduction schemes of S and T coincide. In the years 14 and 15 we find again a regular alternation of months in which S and T give the same data, and months in which the difference is 1^d, e.g.:

Planet	Year	Month	Text T	Text S
Mars	14	8	3	3 ♒
Mars	14	9	13	12 [5]) [♓]
Jupiter	15	8	6 ♓	5 ♓
Saturn	15	9	4 ♈	4 ♈

A closer examination shows that in these years the "Carlsberg crescent" scheme does not give a satisfactory explanation of the text dates, unless the new moons not mentioned in Carlsberg are chosen 30 days before the next ones instead of 30 days after the preceding ones. This point requires further investigation.

Program for further investigation.

By lack of time, I am not able to carry the investigation beyond this point, but I hope that others will continue it. It seems desirable

1) to reduce all dates of text S to the Babylonian calendar with the aid of Carlsberg 9 or a similar scheme, and to see whether the regularity of the differences (e.g. for Venus) is increased by this reduction,

2) to investigate whether P is calculated by the same rules as S,

3) to establish conclusively the law of motion of Venus in P and S,

4) to determine the stationary points, especially of Jupiter, and to compare their positions with those given by Babylonian Jupiter tables,

[5]) NEUGEBAUER writes: Traces only compatible with 12 or 17. But only 12 gives the correct difference 39 (see our table of differences of Mars).

5) to see whether the Babylonian planetary ephemerides, published by KUGLER (see my paper I, footnote [13]), follow the same rules as our texts P and S.

6) to give a more complete description of the motion of Jupiter, Mars, Mercury and, if possible, also of Saturn.

I hope that this investigation will lead to a better understanding of Babylonian astronomy in its highest development, and of its influence on Hellenistic astronomy and astrology.

Zoology. — *Viscosity changes during cleavage in the eggs of Limnaea stagnalis.* By MIEKE C. HEIKENS. (From the Zoological Laboratory, University of Utrecht.) (Communicated by Prof. CHR. P. RAVEN.)

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Introduction.

The observations of FRY & PARKS (1934) show that in eggs of *Nereis, Cumingia* and *Arbacia* the viscosity changes in cycles during the first period of development. These cyclical variations in viscosity correspond to the mitotic cycles. The following cycle has been observed: prophase: viscosity low; metaphase: viscosity low or rising; anaphase and telophase: viscosity high. Viscosity is low when the structures concerned are being organised, rising when the cell processes are in action and remains high at the conclusion of the cycle, until the next cycle makes its appearance.

Similar viscosity changes have been observed by LEHMANN (1938) in the eggs of *Tubifex.*

The same investigations were carried out by RAVEN (1945) in eggs of *Limnaea stagnalis.* He also observed viscosity changes during the period of the uncleaved egg, but, whereas FRY & PARKS found a high viscosity at the formation of the first polar body, the formation of the second polar body, the fusion of the pronuclei and the first cleavage, RAVEN observed an increased viscosity at the fusion of the pronuclei and the first cleavage only. During the maturation divisions viscosity shows no significant cyclic changes in *Limnaea.* There is an increase in viscosity, beginning shortly before the extrusion of the second polar body and reaching its maximum when the sperm-aster is at its height, a rapid drop to a minimum at the prophase of the first cleavage and a rise during cleavage mitosis.

The purpose of this investigation was to determine whether cyclic changes in viscosity can also be observed during the next cleavages.

Methods.

By means of centrifugation a stratification is brought about in the egg consisting of a fat zone, hyaloplasm zone, zone of granules, zone of proteid yolk. The degree of stratification is used as a means of estimating the relative viscosity changes. The viscosity is low if the egg is fully stratified, and relatively high if stratification is less distinct. Comparing the stratification of eggs centrifuged at different successive stages, one gets an impression of viscosity changes occurring in the egg.