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Astronomy. — *"The Origin of the Saros"*. By Dr. A. PANNEKOEK. (Communicated by Prof. W. DE SITTER).

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The forecast of eclipses, which to the uneducated is such a convincing proof of the power and accuracy of astronomical science, is not the fruit of the highly developed modern theory, but belongs to the oldest products of human science. Greek writers tell us that the Babylonians were already able to predict the eclipses by means of a period of 18 years, which they called "saros", and which rested on the fact that 223 synodic lunar periods and 242 draconic revolutions are practically equal (both $6585^1/_3$ days), that after this period, therefore, full and new moon return to the same position relatively to the nodes.

When at a later period this meaning of the saros as common multiple of two lunar periods was once grasped, the saros itself was no longer necessary, and the eclipses could be calculated directly from the knowledge of the orbits of sun and moon. But this scientific height was reached in Seleucidic Babylon and in Greece only in the last centuries B. C. The origin of the use of the saros falls in earlier times; and the first question is, what times?

According to the theory of HUGO WINCKLER's school, Babylonian astronomy had reached its highest perfection as early as 2000—3000 B. C, and therefore the origin of the saros lay in such a far-off time that there is no possibility of following the road to the discovery. But KUGLER's researches have proved this theory to be to a large extent ungrounded romance. Afterwards, the last champion of the great antiquity of Babylonian astronomy, ERNST WEIDNER, tried to prove that the saros must have been known at least 1000 B. C., but in this he was not successful [1]). KUGLER's argument for the opposite opinion is undoubtedly sound:

"The most ancient Babylonian observations of lunar eclipses which are in any way serviceable, date according to Ptolemy from the years 721 and 720 B. C. The accuracy found therein in no way exceeds

[1]) E. WEIDNER, "Alter u. Bedeutung der babylonischen Astronomie u. Astrallehre" (1914) p. 16. See also F X KUGLER, "Sternkunde u. Sterndienst in Babel. Ergänzungen" p. 241.

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that which we find in some of the later Assyrian texts. Of a knowledge of the saros there is not the least indication in these texts; everything indicates on the contrary that the astrologers of that period were not acquainted with the saros so as to be able to forecast a lunar eclipse with certainty some time beforehand"[1]) and he concludes from this: "Before the 8th century the eclipses of the moon (and sun) were not observed with that care which is necessary for establishing their period, which was still unknown in the 7th century." In how far the first part of this sentence is correct will be shown presently.

Kugler points out, moreover, very rightly, that the discovery of the saros is not so easy as is often thought[2]). In the first place because this period does not embrace a round number of days, but 8 hours more. If we take a list of the lunar eclipses[3]) visible at a particular spot, say Babylon, and then look up those which occur one saros period later, they will all be seen to take place 8 hours later, chiefly therefore by day: most of them will not be visible in Babylon. On the other hand there now appear a large number of eclipses the predecessors of which were not visible 18 years earlier, because they occurred before the beginning of the night.

Experience, therefore, by no means points in the direction of the saros period. To get eclipses at about the same daytime the period must be trebled; after 54 years the visible eclipses return to a great extent in the same order. If we arrange the visible eclipses in series of 54 or of 18 years, it is then not difficult to establish the existence of the saros period. But it is quite another matter to find or to discover this period. If someone who knew nothing of this period was given the task of finding from a complete list of lunar eclipses, e.g. from Oppolzer's Canon, a period after which they would return in the same manner, he would certainly find it a very difficult one. And how much more difficult the discovery must have been in Babylon may be seen when we consider the conditions that had to be fulfilled.

The first essential would be to have a complete list of all the visible eclipses. Now it is doubtful whether in the Assyrian period (8th and 7th centuries B. C.) a continuous list could be made of the eclipses observed, as, at least in all our extant reports of the astrologers, the year is not noted. Let us, however, suppose that for

[1]) F. X. Kugler, ibid Ergänzungen, p. 132

[2]) Ibid. Vol. II. p. 65—67.

[3]) We do not mention sun eclipses here, because for them owing to the influence of the parallax, the regularity is still much more difficult to find.

this the data were available — in later centuries they certainly were — it would first be necessary that someone should conceive the idea of compiling a continuous list of this sort and moreover of looking for a period in it, only then would he stand before a problem of the same nature, although more difficult, as the one we proposed above. "It is quite another thing, however, even to arrive at the idea that the eclipses would return periodically, and yet another to deduce the suspected law from a series of observations. The inadequate appreciation of these things amongst us is due to the fact that to-day we are so much accustomed to the discovery of new natural laws that it is difficult for us, to place ourselves in the position of those who did the first pioneer work in the field of natural science." (KUGLER p. 67). Indeed, it may be said that a superhuman genius was necessary for this, capable of conceiving, as it were from nothing, scientific aims and scientific methods in a world which did not yet know the meaning of science, and of applying them.

Looked at from this point of view it is not surprising that in the Assyrian period nothing should be known of a saros period. Indeed we should wonder that the saros could ever be discovered. But this is only true. if it had to be found in the way indicated here. This cannot, however, be the way in which science arose. Practical rules and regularities were first discovered, which obtruded itself to the mind through experience, found without intention or consciousness of scientific aim; much later from this the theoretical idea of regularity and periodicity in nature was formed, and the intentional search for them. If, therefore, we do not want to regard the origin of science as a miraculous creation, such a discovery as that of finding the saros may be conceived only as a gradual process, as the outcome of many steps each of which followed naturally and spontaneously from the former and in which several succeeding generations took part.

Whenever the prediction of eclipses is under consideration, the saros is always thought of, as if it were the only means available for this purpose. But there are other simpler and less perfect rules, which could be more easily discovered, and which were therefore certainly detected and made use of before the saros was known. They may be regarded as the precursors from which in the course of time the saros was developed. This development would thus fall in the centuries during which the astrological practice of the Assyrian period gradually grew to the height of astronomical science which it reached under the Seleucides and Arsacides — that is in the Babylonian-Persian period (6th and 5th centuries B.C.).

How this development took place is illustrated by a remarkable cuneiform text in the British Museum, Sp. II 71, of which STRASSMAIER gave a transcript in 1894[1]). There it is shown that this text contains a list of lunar eclipses arranged according to saros periods. STRASSMAIER thought that he could also deduce from it that the Babylonians used the saros as the foundation for their calendar, but this proved later on to be untrue. The importance of this text lies chiefly in the fact that it shows very clearly the origin of the saros from earlier phases. To understand its construction, it is first necessary to trace this development.

II.

Astrology, which directed the gaze of men to all the heavenly bodies, caused by its great development in the Assyrian period an ever-increasing detailed knowledge of the heavenly phenomena to arise during that time. This regarded especially the moon and its eclipses. As a first regularity in the eclipses, the rule must have been noticed that after a lunar eclipse it was only 6 months afterwards that an eclipse could again occur. It is true that such an eclipse was often absent; but the reason for this could be found in the observations of the moon; *a lunar eclipse only occurs when sun and moon stand opposite to each other.*

The phenomena on the days lying around the full moon (i.e. in the middle of the month, which always began with the appearance of the sickle moon) were, on account of their astrological significance, always carefully observed: from the times of transit of sun and moon through the great circle of the horizon (the natural measuring circle of the Babylonians), from the rising and setting on those days, therefore, the moment of opposition could be ascertained with certainty. If the full moon rose in the evening before sunset or set before sunrise in the morning, the opposition was yet to come; if it was later, the opposition was past. As soon as this reason for the omission of an eclipse, namely that the opposition had taken place during daylight, has been noticed, the positive rule could be established: *when a lunar eclipse has taken place, another will follow six months later*; whether this will be visible depends upon whether the opposition takes place by day or by night.

This regularity was noticed as early as the Assyrian period. In the astrological reports notice is sometimes given of predictions that

[1]) EPPING u. STRASSMAIER, Ein babylonischer Saros-Canon. Zeitschrift für Assyriologie Vol. VIII. p. 176. The text itself is given Z. f. A. Vol. X p. 66.

did or did not come true. In one of the reports it says: "The eclipse passes by, it does not take place. If the king asks, what omens have you seen: the gods (that is the sun and moon) have not been seen with one another; ... at the beginning of the night [the moon rose, ... therefore] the eclipse passes by, [by day the moon] with the sun will be seen".[1]) Here, therefore, is given as a reason why an apparently predicted eclipse did not take place, that in the evening the moon rose after sunset, the opposition was therefore passed and had occurred in the day-time.

The above rule, however, was not always valid. After 6 lunar months (177.18 days) the longitude of the sun, and of the full moon also, has increased in the mean by 174°,645; during the same time the line of nodes has receded 9°,383. If the distance, therefore, between the full moon and the nearest node is $L—\Omega=P$, the distance of the full moon that follows six months later to the other node is $P — 5°,355 + 9°,383 = P + 4°,028$. The position of the full moon with regard to the node shifts 4° per six months. From this it follows that for a number of times the lunar eclipse will return regularly after six months; but this series will finally stop, when the distance between full moon and the node has become too great. A partial eclipse is still possible if the distance $L—\Omega$ is not greater than 10°—12½°. If at a certain full moon the value of $P = L — \Omega = — 15°$, this quantity for the full moons which come each six months later is:

—15°	—10°,97	—6°,94	—2°,92	+1°,11	+5°,14	+9°,17	+13°20
no eclipse.	?	partial.	total.	total.	total?	partial.	none.

Thus 5 or 6 eclipses follow each other regularly; the series begins with 1 or 2 partial eclipses, then follow a few total eclipses; these again are followed by 1 or 2 partial eclipses, and then the series is finished.

In such a favourable climate as that of Babylon, where, with the exception of a few winter months, every phenomenon in the heavens could be regularly observed every night, the priest-astrologers must have gradually noticed this regularity. If they observed a partial eclipse which had had no predecessor 6 or 12 months before, they knew that a fresh series had begun, and they could predict a number of coming eclipses with certainty.

SCHIAPARELLI has pointed out this simple method of prediction by

[1]) THOMPSON, The reports of the magicians and astrologers, N^o. 275A; KUGLER, Sternkunde etc. II, p. 64.

means of series of 5 or 6 successive eclipses, [1]) and he assumes that when, in the Assyrian period, predictions are made, this rule is made use of. No proof can be given of this, as there is no text in which mention is made of the means by which the results were obtained. And a prediction is possible, as shown above, with even more primitive knowledge. That these series of 5 or 6 were known in the succeeding centuries is certain, because a knowledge of them is a station on the line that leads to the discovery of the saros.

To trace this road we must first consider what phenomena and what regularity an attentive observer would further be able to notice in the lunar eclipses. If a certain series of full moons (by a series we here mean always full moons following each other with intervals of six lunar months) recedes more and more from the nodal line, the series of full moons preceding them constantly approaches it. The longitude of the former full moon is 29°,11 smaller, a month earlier the node lay upon 1°,564 greater longitude, therefore for this previous full moon $L - \Omega = P - 29°,11 - 1,564 = P - 30°67$. We will now tabulate P for both series beside each other beginning with the 4th of the above row, and beside it a few of the preceding full moons.

P two full moons back	P former full moon	P		
		+ 1.11	tot.	
		+ 5.14	tot?	1st series
	— 21.50	+ 9.17	part.	
	— 17.47	+ 13.20	—	
	— 13.44	+ 17.23	—	
	— 9.41	+ 21.26	part.	
	— 5.39		tot?	
— 32.03	— 1.36		tot.	2nd series
— 28.00	+ 2.67		tot.	
— 23.97	+ 6.70		part.	
— 19.95	+ 10.72		part?	
— 15.92	+ 14.75		—	
— 11.89			part?	3rd series

1) G. Schiaparelli, I primordi dell' astronomia presso i babilonesi. (Scientia IV p. 36).

We now see that when the first series has expired, it is quickly followed by a new series of eclipses, which falls a month earlier than the continuation of the old series. Instead of always counting by 6 months occasionally only five months need to be passed over, and we then come to the beginning of a new series.

When, therefore, a continuous list of eclipses was composed, this at once divided into series of five or six eclipses following each other with a 6 months' interval; each succeeding series was the continuation of the preceding one if at the end of a series 5 months instead of 6 were passed over. Between two succeeding series there were always a few missing, so that eleven, seventeen or twenty-three months passed without eclipses (the full moons in our list, in which P lies between 12° and 15°). If these full moons before and after each series were added so that the series succeeded with an interval of five months, *a continuous list of eclipse moons was obtained divided into series by the five-monthly intervals*, and for which the rule was: in the middle of each series lie the total eclipses, beside them on either side the partial, and beside these, where the series join, they drop out. In such a list let us tabulate the value of P, beginning with the arbitrary value —15°, in such a way that we pass over 5 months, as soon as P obtains a smaller value in the following series than in the preceding one.

1st series	2nd series	3rd series	4th series	5th series	6th series
— 15°.00	— 13.44	— 11.89	— 14.35	— 12.80	— 15.28
— 10.97	— 9.41	— 7.85	— 10.32	— 8.77	— 11.25
— 6.94	- 5.39	— 3.82	— 6.29	— 4.75	— 7.22
— 9.29	— 1.36	+ 0.21	— 2.27	— 0.72	— 3.20
+ 1.11	+ 2.67	+ 4.24	+ 1.76	+ 3.31	+ 0.83
+ 5.14	+ 6.70	+ 8.26	+ 5.79	+ 7.33	+ 4.86
+ 9.17	+ 10.72	+ 12.29	+ 9.81	+ 11.36	+ 8.89
+ 13.20	+ 14 75	5 m.	+ 13.84	5 m.	+ 12.92
5 m.	5 m.		5 m.		5 m. etc.

Here it shows that the successive series contain sometimes eight and sometimes seven moons. There occur sometimes 7, sometimes 6 intervals of 6 months successively, separated by intervals of 5 months.

The alternation in these figures is, however, not altogether without rule; the 6th series begins with a value for P which differs very little from that of the 1st series. *All the values of P, therefore, very nearly return after 5 series,* therefore the same alternation of long and short series will return again after five series:

8 8 7 8 7 | 8 8 7 8 7 | 8 8 7 8 7.

In the succession of the series of eclipse moons a periodicity takes place, therefore, with a period of five series. In a period of this sort $7 + 7 + 6 + 7 + 6 = 33$ intervals of six months occur, and 5 intervals of 5 months; they embrace, therefore, $33 \times 6 + 5 \times 5 = 223$ lunar months. *This period is the saros.*

III.

It is, however, not probable that this periodicity in the series of the eclipse moons taken by themselves can be easily discovered. For the Babylonian observers had not a list of values of P of this sort at their disposal; what is expressed in our list as quantity they observed only as quality: total eclipse, partial eclipse, no eclipse. As the eclipses are missing at the transition from one series to the next the position of the transition cannot he distinctly marked, and the interval of 5 months could be assumed equally well earlier or later. This would cause a disturbance in the regular repetition of long and short series, and the period was no longer so conspicuous.

The saros period has, however, another peculiarity. Not only do full moon and node return in it to the same position with respect to each other, but also *the anomaly of the moon returns to almost the same value* In one saros period the major axis of the lunar orbit revolves a little more than twice and returns therefore to almost the same position with regard to node line and full moon, both of which have acquired 10° greater longitude. The anomaly of the full moon during an eclipse determines to a great extent the varying circumstances: velocity of the moon, diameter of the earth's shadow and diameter of the disk of the moon. Return to the same anomaly, when the position with regard to the node is also the same, means the return of the same aspect of the eclipse.

For the series of eclipses tabulated above we can calculate the anomaly and from that the external circumstances, starting from a hypothetical initial value of 0° for the first full moon, Per 6 lunar months the perigee advances by 19°,739, the following full moon, therefore, advances on the perigee by 174,645—19,739 = 180°—25°,09. Per 5 months these values are 145,54—16°,449 = 180°—

50°,91. The distance of the full moon to the perigee $L - \pi = v$ thus decreases at each leap of 6 months by 180° + 25°,09, and at each leap of 5 months by 180° + 50°,91. If the apparent radii of the moon and the sun be called r and r', the lunar parallax p (the solar parallax may be neglected), the inclination of the lunar orbit i, the radius of the earth's shadow is $R = \frac{41}{40}(p - r')$ and the latitude of the moon i sin (P — 0°,4 sin V). The distance from the edge of the shadow, where it is nearest to the moon, expressed in 12ths of the lunar equator, (this is always called the magnitude of the eclipse in inches) is the quantity which determines the external aspect and the duration of the eclipse. It is

$$m = \frac{R + r - i \sin(P - 0°{,}4 \sin v)}{{}^{1}/_{6}\, r} = 6 \times \frac{1{,}025\,(p - r') + r - i \sin(P - 0°{,}4 \sin v)}{r}$$

As $\frac{p}{r} = 3{,}67$ and $\frac{i}{r} = 20$, whereas in the syzygies

$$\frac{1}{r} = \frac{1}{r_0}(1 - 0{,}065 \cos v) \quad \text{and} \quad \frac{r'}{r^0} = 1{,}05$$

this gives, as 0°.4 *cos* P may always be replaced by 0°.4,

$$6 \times (4{,}76 - 1{,}05 + 0{,}065 \cos v - 20 \{\sin P (1 - 0{,}065 \cos v) + \tfrac{0{,}4}{57} \sin v)\} =$$
$$6 \times (3{,}71 + 0{,}065 \cos v - 20 \sin P (1 - 0{,}065 \cos v) + 0{,}14 \sin v).$$

If this quantity is negative there is no eclipse; if it is smaller than 12 the eclipse is partial; if it is greater than 12 the eclipse is total, and the totality lasts longer according as the number is larger. Of course in these calculations only mean circumstances are taken into consideration; owing to the perturbations of the moon and the eccentricity of the earth's orbit the actual course will deviate somewhat from the mean.

The results of our calculation are found in Table I; under "Aspect" is given what an observer could note in the various eclipses. For partial eclipses "upper" or "lower" is given according as the N. or S. portion of the moon remains uncovered; the same is also given for total eclipses when the moon passes distinctly through the upper or lower part of the shadow ($m < 17$), and therefore at the beginning and end the N. or S. portion remains longer light; if the moon disappears only for a short time in the shadow (m between 12 and 14), this is indicated by "short". It now appears that each of the successive series has a different peculiar character in the aspect of the successive eclipses. But in the 6th series the character is exactly the same as that of the 1st series, as P and v are almost the same; similarly the 7st 8th and 9th series will correspond in character to the 2nd 3rd and 4th. This agreement is strengthened by

TABLE I.

P	v	m	Aspect	P	v	m	Aspect
— 15°.00	0°	— 6.4	—	— 14°.35	345°	—13.3	—
— 10.97	155	— 2 5	—	— 10.32	40	1.6	part. lower 2[d]
— 6.94	310	9.2	part. lower 9[d]	— 6.29	195	8.2	part. upper 8[d]
— 2.92	105	15.1	tot. upper	— 2.27	350	18.3	tot.
+ 1.11	260	19.0	tot.	+ 1.76	145	18.6	tot.
+ 5 14	54	12.9	tot. low. short.	+ 5.79	300	10.0	part. upper 10[d]
+ 9.17	209	1.3	part. upper 1[d]	+ 9.81	95	2.5	part. lower 2[d]
+ 13.20	4	— 2.9	—	+ 13.84	250	— 7.9	—
			5 months.				5 months.
— 13.44	133	— 7.7	—	— 12.80	19	— 2.6	—
— 9.41	288	4.0	part. upper 4[d]	— 8.77	174	2.3	part. lower 2[d]
— 5.39	83	10.3	part. lower 10[d]	— 4 75	329	13.6	tot. upper short.
— 1.36	238	19.9	tot.	— 0.72	124	19.7	tot.
+ 2.67	33	17.8	tot.	+ 3.31	279	14.6	tot. lower
+ 6.70	188	6.9	part. lower 7[d]	+ 7.33	74	8.2	part. upper 8[d]
+ 10 72	343	1.4	part. upper 1[d]	+ 11.36	229	— 3.3	—
+ 14.75	138	— 9.4	—				5 months.
			5 months.	— 15.28	358	— 6.9	—
— 11.89	267	— 1.7	—	— 11.25	153	— 3.2	—
— 7.86	61	5.8	part upper 6[d]	— 7.22	308	8.7	part. lower 9[d]
— 3.82	216	14.0	tot. low. short.	— 3.20	103	14.5	tot. upper
+ 0.21	11	22.3	tot.	+ 0.83	258	19.6	tot.
+ 4.24	166	12.7	tot. upper short.	+ 4.86	52	13.5	tot. lower short.
+ 8.26	321	5.7	part. lower 6[d]	+ 8.89	207	1.9	part. upper 2[d]
+ 12.29	116	— 3.4	—	+ 12.92	2	— 2.4	—
			5 months.				

the fact that the more or less sloping direction of the movement of the moon with regard to N—S also returns after a saros period, because this direction depends upon the time of year, and the saros differs only 11 days from a year [1]).

[1]) As the v shifts over 2° per saros, the initial value will be after say 10 of these periods considerably changed, and the character of the series will become

Only the fact, therefore, *that after* 5 *series the same aspect in each eclipse and the same character in the eclipse series returned* makes it comprehensible, how the periodicity could at last be discovered. The omission of a number of eclipses, which were invisible owing to daylight and cloudiness still made it difficult; it wasonly possible in the very favourable climate of Babylon. But when once the regularity of the series was discovered, in the course of centuries, when the successive eclipses were collected in lists, their periodical recurrence after five series must be noticed at last.

IV.

That the saros really came into existence in this way, can be seen from the construction of the above mentioned text. In the clearly legible portion (on the right and left columns are broken off) in 6 columns every time a number is found (which rises by one each 2 lines downwards and evidently represents the year) side by side with the name of a month (in our table on the next page indicated by Roman figures I—XII). The months follow each other with intervals of 6, except at the horizontal lines, where they follow each other with an interval of 5; after the name under the horizontal line there is always added "5 months" Sometimes the interval in other places seems to be only 5, but then a second 12th month has been inserted, and under the year-number then stands "dir" (sometimes VI dir, when a 2nd Ululu is introduced).

The year numbers begin again every time with 1, accompanied by the first syllable of a King's name; from these names it appears that the beginning of the table is year 31 of Artaxerxes II (—373), which are followed by those of Ochus (Umasu), Arses, Darius, Alexander, Philip, Antigonus, and Seleucus: the last years are continued as Seleucidean era EPPING and STRASSMAIER, by comparison with OPPOLZER's Canon, have established the fact that the total eclipses always fall in the middle of the divisions separated by horizontal lines.

We here have, therefore, the same kind of list of eclipse moons as we supposed above; each column contains 5 series, some of 8, some of 7 names of months, which together form a saros; the columns placed next to each other are 6 successive saros periods. This text, therefore, is in the first place a proof that the Babylonians

different from those in the examples we have taken. This is the reason why, as SCHIAPARELLI noticed from OPPOLZER's Canon, sometimes for several centuries in succession some series consist of only 4 eclipses, while after that for several centuries each series consists of 5 or 6 eclipses.

TABLE II. Saros-Canon Sp. II. 71.

X	X	dir XI	XI	XI	dir XII
32 IV	4 IV	1 Ar. IV	5 V	11 V	29 V
dir X	X	X	1) XI	XI	XI
33 II 5 m.	5 III 5 m.	2 III 5 m.	6 III 5 m.	12 IV 5 m.	30 IV 5 m.
VIII	dir IX	IX	IX	1) X	X
34 II	6 II	1 Da. III	1 An. III	13 III	31 IV
dir VIII	VIII	dir IX	IX	IX	dir X
35 I	7 II	2 II	2 III	14 III	32 III
VII	VIII	VIII	dir IX	IX	IX
36 I	8 II	3 II	3 II	15 III	33 III
VII	VIdirVII	VIII	VIII	dir IX	IX
XII 5 m.	XII 5 m.	4 I 5 m.	4 I 5 m.	16 I 5 m.	34 II 5 m.
37 VI	9 VI	VIa	VII	VII	dir VIII
dir XII	XII	XII	5 I	17 I	35 I
38 V	10 VI	5 VI	VIa	VII	
XI	dir XII	XII	XII	18 I	
39 V	11 V	1 A VI	6 VI	VIa	
XI	XI	dir XII	XII	XII	
40 IV 5 m.	12 IV 5 m.	2 IV 5 m.	1 Si. V 5 m.	19 V 5 m.	
dir X	X	X	dir XI	XI	
41 III	13 IV	3 IV	2 IV	20 V	
IX	dir X	X	X	dir XI	
42 III	14 III	4 IV	3 IV	21 IV	
IX	IX	dir X	X	X	
43 III	15 III	5 III	4 IV	22 IV	
dir IX	IX	IX	dir X	X	
44 I 5 m.	16 II 5 m.	6 II 5 m.	5 II 5 m.	23 III 5 m.	
VII	dir VIII	VIII	VIII	dir IX	
45 I	17 I	7 II	6 II	24 II	
VII	VII	dir VIII	VIII	VIII	
XIIa	18 I	1 Ph. I	7 II	25 II	
46 VI	VII	VII	dir VIII	VIII	
XII	XIIa	2 I	8 I	26 II	
1 U. VI	19 VI	dir VII	VII	VIII	
XI 5 m.	XI 5 m.	XII 5 m.	XII 5 m.	XIIa 5 m.	
2 V	20 V	3 V	9 VI	27 VI	
dir XI	XI	XI	dir XII	XII	
3 IV	21 V	4 V	10 V	28 VI	

1) »dir« ought to have been given here too.

actually were acquainted with the series of lunar eclipses belonging together, as SCHIAPERELLI supposed. Further it shows that the Babylonian saros was not simply a period of 223 lunar months, but a group of 5 series, each of which consists of 7 or 8 full moons, excepting the extreme, all eclipse moons. It clearly demonstrates, therefore, that the saros must have arisen, as suggested above, from the knowledge of SCHIAPARELLI's series, which represent a more primitive stage of science, by noticing another periodicity in them. It is worth notice, that arising in this way, the fact which at first seemed to be a difficulty, viz. that the saros is 8 hours more than a round number of days, becomes of absolutely no importance. In this genesis of the saros the time of day at which an eclipse occurs plays no part at all.

The text of STRASSMAIER gives us no conclusive evidence as to the time at which the saros originated. It dates at its very earliest from the 3rd century B. C., when the Seleucidean era was already in use, and it represents a somewhat higher development of knowledge already. For in it not only the saros itself occurs, but apparently also a knowledge of the imperfection of the saros. As, after this period, the value $P = L - \Omega$ does not return to exactly the same value, the first terms of each series must after a time become the last of the previous series, the 5 lunar intervals must leap forward one interval; and in the Babylonian Canon, therefore, the horizontal lines must come down one line after a certain number of saros periods. STRASSMAIER assumes that the reason for the top line of the Canon falling in the middle of a series is, that originally there were a great number of columns on the left, that the list, therefore, began in very ancient times and that by this constant leaping over the top dividing line has come down 3 lines. This would show, again, that the compilers of this Canon already knew that the saros was not exact. The first knowledge of the saros itself, therefore, must be looked for in the previous centuries, perhaps the 4th or 5th B. C. This shows at the same time that the familiar story according to which the Greek philosopher THALES predicted a total suneclipse (that in 585 B. C.) by means of a knowledge of the saros borrowed from the Babylonions, can only be regarded as a fiction. At that time the saros was still unknown, and moreover the saros of later times referred only to the return of lunar eclipses.