University service, Professor and Mrs. Comstock traveled around the world, renewing friendships with scientific colleagues in many countries; they returned to settle in Beloit, Wisconsin, just around the corner from the great attraction of three little grandchildren.

In his later years Comstock became an ardent member of the Rotary Club of Beloit, and was made an honorary life member of the organization. He had the pleasure of visiting and afterwards reporting on various Rotary clubs in Europe. At home he was in constant demand as a speaker before service clubs, his topics ranging from club educational programs and popular talks on astronomy to philosophical discussions of a more severe order.

He was fortunate in maintaining his physical and mental vigor up to the end. He gave a public address just two weeks before he died, and at the last he was ill for only a few days. As has been aptly said, there is always an old school in a progressive science. Comstock lived to become one of the old school in point of years, but his outlook was always forward. He saw the astronomy of his youth grow into the astrophysics of the present, but his conception of all science was like that of the heavens described in his own text-book, "A universe which is ever becoming something else and is never finished."

The Saros Cycle Ending with the Partial Eclipse of January 5, 1935

By ALEXANDER POGO

The very small partial eclipse of 1935 January 5 is of interest from three points of view: first, on account of the circumstances under which it occurs; second, because it brings to a close a major saros cycle; and, third, because this eclipse makes the Gregorian calendar year 1935 a year with 5 solar eclipses.

On Friday, January 4, 1935, at 10:35 P.M., Mountain Standard Time, it will be night along the 110th meridian W of Greenwich—except within and near the Antarctic Circle. In a small area of the Pacific, about the size and shape of Lake Erie, near longitude 110° W and latitude 65° S, a partial eclipse of the setting sun will occur, around 10:15 P.M., local mean time. Its duration will be 7.6 minutes, and the magnitude of the greatest eclipse will be 0.001, according to the data of *The American Ephemeris*; according to the *Connaissance des Temps,* the eclipse will last 10.1 minutes, and will reach, at maximum phase, 0.0014 of the diameter of the sun; in any event, the eclipse will be little more than the grazing of the limb of the setting sun by the new moon; it is worth mentioning that in Oppolzer's *Canon der Finsternisse*[1] the eclipse is classified as "invisible on account of flattening" of the globe at the

[1] Denkschriften d. Akademie, math.-naturw. Cl., Bd. 52, Wien 1887.

poles. At the time of the eclipse, the earth will be near perihelion (January 2), and the moon near perigee (January 6). The eclipsed sun will be about 18° west of the ascending node of the moon's orbit, near the major ecliptic limit. The schematic Fig. 1 indicates the relative position of the sun and of the moon, in Sp″ and M″, respectively. A circle, on

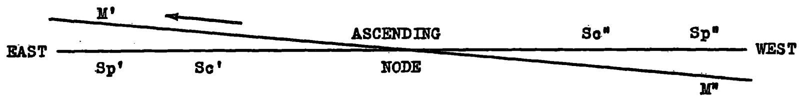

FIGURE 1.
WESTWARD MOTION, WITH RESPECT TO THE NODE, OF THE PARTIAL AND CENTRAL SOLAR ECLIPSES OF A SAROS CYCLE.

the chart of Fig. 3, marks the region of the Pacific which will brush against the surface of the swiftly moving penumbral cone. This antarctic sunset eclipse runs from E to W; the point of first contact is near the eastern end of the "eclipse begins at sunset" curve; the point of last contact is near the western end of the "eclipse ends at sunset" curve; between these two curves, and but a few miles from either of them, runs the "middle of eclipse at sunset" curve; the curve of simple contact forms the northern limit of the narrow region; the "eclipse ends at sunset" curve forms the southern limit.

It is a familiar phenomenon, based on the stroboscopic principle, that by catching glimpses, at properly timed intervals, of revolving objects, their motion may appear slowed down, arrested, or reversed, according to the succession of the observed phases. This should be kept in mind when thinking of the saros cycle: we are catching glimpses of the eclipse mechanism at intervals of 6585.32 days. Thus, the saros is shorter, by about 208 days, than the sidereal period of regression, on the ecliptic, of the nodes of the moon's orbit (6793 days from star to star), or shorter, by about 213 days, than their tropical period of regression (6798 days from equinox to equinox); the node moving westward on the ecliptic at the rate of 1° in about 18.9 days, the next eclipse of the saros cycle will, therefore, find the node about 11° to the east of the position it

TABLE I

THE SAROS AND THE EXELIGMOS.

Period		Saros ($6585^d.3$)	Exeligmos (19756^d)
	d	d	d
Synodical month	29.530588	x 223 = 6585.32	x 669 = 19755.96
Nodical month	27.212220	x 242 = 6585.36	x 726 = 19756.07
Anomalistic month	27.554550	x 239 = 6585.54	x 717 = 19756.61
Tropical month	27.321582	x 241 = 6584.50	x 723 = 19753.50
Sidereal month	27.321661	x 241 = 6584.52	x 723 = 19753.56
	d	d	d
Eclipse year	346.6200	x 19 = 6585.78	x 57 = 19757.34
Tropical yr. (A.D. 1900)	365.2422	x 18 = 6574.36	x 54 = 19723.08
Tropical yr. (A.D. 1000)	365.2423	x 18 = 6574.36	x 54 = 19723.08
Gregorian year	365.2425	x 18 = 6574.36	x 54 = 19723.10
Julian year	365.2500	x 18 = 6574.50	x 54 = 19723.50
Sidereal year	365.2564	x 18 = 6574.61	x 54 = 19723.84

occupied at the time of the previous eclipse. The apparent eastward motion of the node during a saros cycle should not be confused with the changes in longitude of the successive ecliptic conjunctions of the cycle. A glance at Table I reveals two reasons for the rapid eastward motion of the eclipse region. As far as the sun is concerned, the saros exceeds 18 complete revolutions of the earth by about 11 days, so that the longitude of the eclipsed sun increases by about 11° from saros to saros during the cycle. As far as the moon is concerned, a saros exceeds 241 complete revolutions—from star to star, or from equinox to equinox,—by about ⅘ of a day; the mean daily motion of the moon being about 13°, the eclipsing moon moves eastward, with respect to the stars and the equinoxes, by about 10°, from saros to saros. The consequences of this rapid eastward motion of the eclipse region during a saros cycle are clearly shown, in Table II, by the names of the months: the eclipses of the cycle progress through the seasons, at the rate of about a month per exeligmos, returning to the same region of the ecliptic after the lapse of about six centuries. With respect to the nodes of the moon's orbit, however, the successive eclipses of the saros cycle move slowly westward, at the rate of less than the sun's diameter per saros. A passenger going to the observation platform of an eastbound express moves slowly westward with respect to the train, while both train and passenger move rapidly eastward with respect to the tracks. Similarly, the eclipsed sun moves slowly westward, with respect to the node, during the centuries of a saros cycle, while both node and sun move rapidly eastward on the ecliptic, when observed at intervals of 18 years and 11

TABLE II

THE 79 SOLAR ECLIPSES OF THE SAROS CYCLE ENDING 1935 JANUARY 5.

Julian Calendar															Gregorian Calendar				
1	p	528	Aug	30.8	21	p	889	Apr	4.2	41	at	1249	Nov	6.3	60	t	1592	Jun	9.8
2	p	546	Sep	11.1	22	a	907	Apr	15.5	42	at	1267	Nov	17.7	61	t	1610	Jun	21.1
3	p	564	Sep	21.4	23	a	925	Apr	25.8	43	at	1285	Nov	28.0	62	t	1628	Jul	1.4
4	p	582	Oct	2.7	24	a	943	May	7.1	44	at	1303	Dec	9.4	63	t	1646	Jul	12.8
5	p	600	Oct	13.0	25	a	961	May	17.3	45	at	1321	Dec	19.8	64	p	1664	Jul	23.1
6	p	618	Oct	24.3	26	a	979	May	28.6	46	at	1339	Dec	31.1	65	p	1682	Aug	3.4
7	p	636	Nov	3.7	27	a	997	Jun	7.9	47	t	1358	Jan	10.5	66	p	1700	Aug	14.7
8	p	654	Nov	15.0	28	a	1015	Jun	19.2	48	t	1376	Jan	21.8	67	p	1718	Aug	26.0
9	p	672	Nov	25.3	29	a	1033	Jun	29.5	49	t	1394	Feb	1.2	68	p	1736	Sep	5.3
10	p	690	Dec	6.7	30	a	1051	Jul	10.8	50	t	1412	Feb	12.5	69	p	1754	Sep	16.7
11	p	708	Dec	17.0	31	a	1069	Jul	21.1	51	t	1430	Feb	22.9	70	p	1772	Sep	27.0
12	p	726	Dec	28.3	32	at	1087	Aug	1.4	52	t	1448	Mar	5.2	71	p	1790	Oct	8.4
13	p	745	Jan	7.7	33	at	1105	Aug	11.7	53	t	1466	Mar	16.6	72	p	1808	Oct	19.7
14	p	763	Jan	19.0	34	at	1123	Aug	22.9	54	t	1484	Mar	26.9	73	p	1826	Oct	31.0
15	p	781	Jan	29.3	35	at	1141	Sep	2.3	55	t	1502	Apr	7.2	74	p	1844	Nov	10.4
16	p	799	Feb	9.7	36	at	1159	Sep	13.6	56	t	1520	Apr	17.6	75	p	1862	Nov	21.8
17	p	817	Feb	19.9	37	at	1177	Sep	23.9	57	t	1538	Apr	28.9	76	p	1880	Dec	2.1
18	p	835	Mar	3.3	38	at	1195	Oct	5.3	58	t	1556	May	9.2	77	p	1898	Dec	13.5
19	p	853	Mar	13.6	39	at	1213	Oct	15.6	59	t	1574	May	20.5	78	p	1916	Dec	24.9
20	p	871	Mar	24.9	40	at	1231	Oct	26.9						79	p	1935	Jan	5.2

NOTE: The decimal fractions refer to Universal Time, counted from Greenwich mean midnight.

Partial, annular, annular-total, and total eclipses are designated by p, a, at, and t, respectively.

days. The reason for this slow westward motion of the eclipsed sun with respect to the node is shown in Table I: 19 eclipse years exceed the saros by almost half a day, so that the new eclipse occurs when the disc of the sun is almost a full diameter to the west of its position at the time of the previous eclipse of the cycle.

The saros cycle ending 1935 January 5 began A.D. 528 August 30; the sun was east of the ascending node, near the maximum ecliptic limit, in a position indicated by Sp′ on the sketch of Fig. 1; the moon was north of the ecliptic, and the oblique penumbra skimmed the arctic

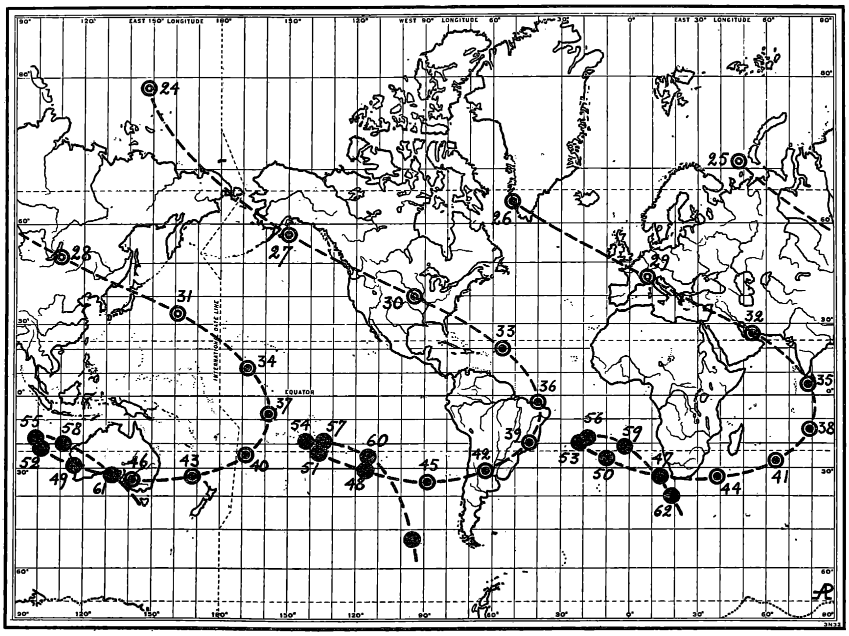

FIGURE 2.

EXELIGMOS CURVES JOINING THE NOON POINTS OF THE CENTRAL ECLIPSES OF THE SAROS CYCLE ENDING 1935 JANUARY 5.

regions, producing the first partial eclipse of the cycle. A series of partial eclipses, at saros intervals, followed, the moon overtaking the sun closer to the node; the autumnal equinox eclipse No. 3 was an inconspicuous event in the Arctic; eclipse No. 14 was one of the seven eclipses of that year, in the Julian calendar. As the sun, slowly proceeding from Sp′ toward Sc′, was overtaken by the moon closer to the ascending node, the southern limit of the penumbra gradually reached lower latitudes; the narrow cone of the shadow, still piercing the arctic stratosphere, gradually approached the surface of the globe; the partial eclipses became conspicuous in Europe, North America, and Asia. In the beginning of the Xth century, the eclipses of our cycle became annular: the central eclipse limit was reached by the sun in Sc′, and the line joining the centers of the eclipsed sun and of the eclipsing moon touched the surface of our globe. Eclipse No. 22 was a sunrise eclipse, from the beginning to the end, in the Hudson Bay region and eastern and northern Canada; eclipse No. 23 was an eclipse of the midnight sun at the North Pole—the tracks of the annulus ran across the Arctic, from the Pacific over Alaska to Novaya Zemlya. The noon points of the central eclipses Nos. 24 to 62 are shown on the chart of Fig. 2; the succession of the numbers attached to the noon points clearly shows the

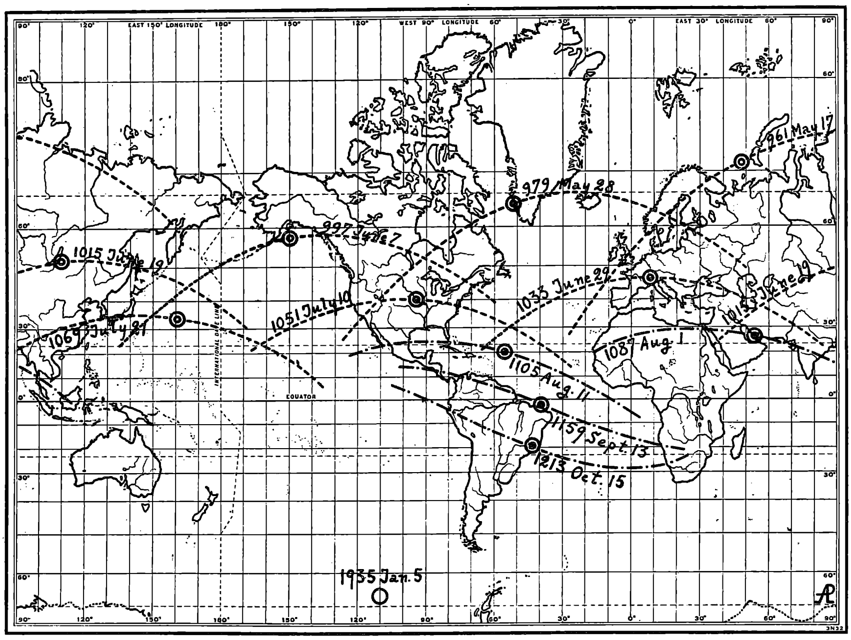

FIGURE 3.
APPROXIMATE TRACKS OF THE UMRBA DURING SOME OF THE CENTRAL ECLIPSES BELONGING TO THE SAROS CYCLE ENDING 1935 JANUARY 5.

gradual southward progress of the eclipses of the ascending-node cycle; the tropical loops of the exeligmos curves show the value of the exeligmos as a means of predicting eclipses. The central eclipse limit was again reached by the sun in Sc″, in the middle of the XVIIth century: the umbra ceased to touch the antarctic regions, and the second series of partial eclipses of our saros cycle began. While the eclipsed sun moved from Sc″ to Sp″, the northern limit of the penumbra receded to higher southern latitudes; at the time of the last partial eclipse of our cycle, the oblique penumbra will barely touch our flattened globe. A saros cycle of solar eclipses near the descending node begins with partial eclipses in the antarctic regions, forms its tropical exeligmos loops north of the equator, and winds up with partial eclipses in the arctic regions.

The approximate tracks of the historically valuable central eclipses of our saros cycle are shown on the chart of Fig. 3; they are based on Oppolzer's charts, and may be considerably in error between the computed sunrise, noon, and sunset points. The eclipses of 1105 August 11 and 1159 September 13 must have been conspicuous in the Maya territory. As far as mediaeval Europe is concerned, the eclipses Nos. 25, 26, and 29 deserve a few words of comment. The eclipse of 961 May 17 is mentioned in contemporary annals; Ginzel[2] estimated that the Bretagne, the coasts of France and of the Netherlands, and Sweden

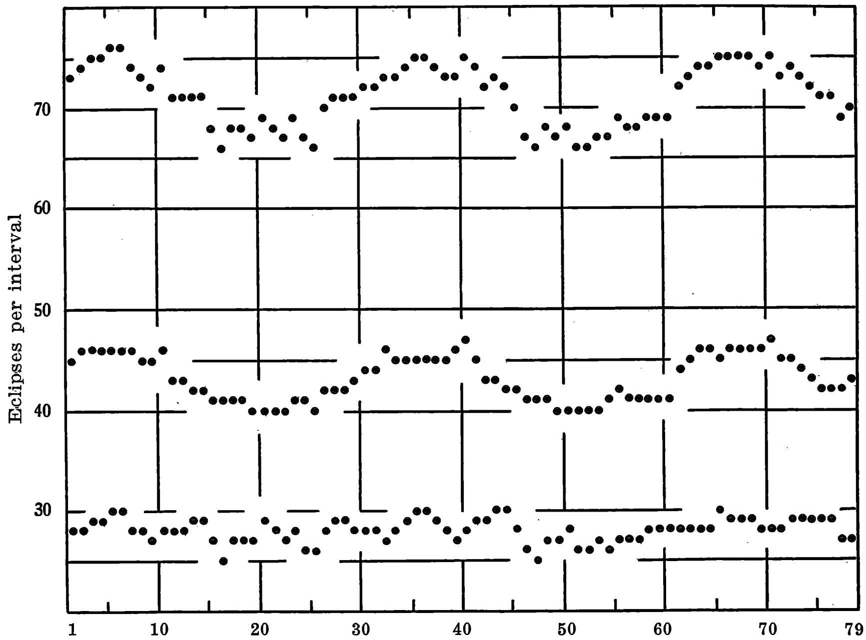

FIGURE 4.

DISTRIBUTION PATTERNS OF SOLAR AND LUNAR ECLIPSES DURING THE 78 SAROS INTERVALS OF THE CYCLE ENDING 1935 JANUARY 5.

Bottom ....lunar eclipses
Center ....solar eclipses
Top...............solar and lunar eclipses

were on the tracks of the annulus; according to Schroeter,[3] the eclipse was central in Spain, France, Germany, southern Sweden, and Finland. The eclipse of 979 May 28 must have been central in Iceland, according to Schroeter. The eclipse of 1033 June 29 was an important event; it is mentioned—and, occasionally, well described—in numerous[4] French,

[2] Astronomische Untersuchungen über Finsternisse. Sitzungsber. d. Akad., math.-naturw. Cl., Bd. 89, Abt. 2, 552, Wien 1884.
[3] Spezieller Kanon der zentralen Sonnen- und Mondfinsternisse. Kristiania 1923.
[4] Astron. Untersuchungen, *Loc. cit.*, Bd. 88, Abt. 2, 682-87, Wien 1883.

German, Austrian, Swiss, Italian, and Armenian[5] chronicles; the tracks of the annulus on Schroeter's chart are, of course, essentially the same as on Oppolzer's.

The number of solar eclipses in a saros cycle running between the minor ecliptic limits is about 70; saros cycles running between the major ecliptic limits have about 80 solar eclipses. In the case of lunar eclipses, the corresponding lengths of the saros cycles are about 40 and 50, respectively. These average numbers of eclipses in a saros cycle should not be confused with the average numbers of solar and lunar eclipses in saros intervals chosen at random; in other words, the average lengths of the four types of saros cycles should not be confused with the average numbers of saros cycles running simultaneously. An interval of 18 years always contains 38 eclipse seasons, and since the sun must be eclipsed at least once when it is in the neighborhood of a node, the minimum number of solar eclipses in any interval of 18 years is 38; the average number of solar eclipse cycles running simultaneously is 43. The average number of lunar eclipses, during 18 consecutive years taken at random, is 28. A saros interval contains, on the average, 71 eclipses both of the sun and of the moon. These matters, and the percentages of partial eclipses, will be discussed in a separate paper. Eclipses Nos. 1 and 79 of our cycle bear, in Oppolzer's *Canon,* the numbers 4124 and 7487, respectively. The distribution patterns of the 3363 solar and 2183 lunar eclipses which occurred during the 78 saros intervals of our cycle, are shown in Fig. 4. The patterns covering the VIth to XXth centuries do not change, except in minor details, if we substitute, for our saros cycle, parts of other saros cycles, chosen at random. During the XIXth and XXth centuries, the number of saros cycles of solar eclipses coming to an end exceeds the number of newly added solar saros cycles. Between the years 1973 and 2009 there will be but 39 solar saros cycles in operation; and since there will be but 26 lunar saros cycles running simultaneously between 1970 and 2030, the total number of both solar and lunar saros cycles crossing the threshold of the XXIst century will be 65. The combined number of solar and lunar saros cycles which ran through the IVth-century minimum, was 66, as in the case of the two minimum regions of Fig. 4; during the minimum of the IIIrd century B.C., the combined number of saros cycles in operation did not fall below 66; the coming "depression in saros-cycle activity," at the end of the present century, will, therefore, be unusually "severe."

If it were not for the small partial eclipse of January 5, the Gregorian calendar year 1935 would not be a seven-eclipse year. Since the introduction of the Gregorian calendar, the following years had seven eclipses: 1591, 1656, 1787, 1805, and 1917; future seven-eclipse years, after 1935, are 1982 and 2094. Thus, in five centuries, there will be but eight years with seven eclipses between January 1 and December 31; the years 1805 and 1935 have 5 solar and 2 lunar eclipses; the remaining

[5] Beiträge zur Kenntnis der historischen Sonnenfinsternisse. Abhandlungen d. Akad., phys.-math. Kl., 4, 13-15, Berlin 1918.