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THE NETWORKS OF THE SOLAR ECLIPSES FROM THE COLUMN OF SAROS SERIES

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Abstract. This article demonstrates that the structure of Saros series – particularly the column of Saros series, enables the identification of networks composed of solar eclipses with identical durations, establishing links between different Saros series. We present examples of eclipse networks corresponding to cycles of 17, 20, 28, and 37 years from January-February 1972 to 2149.

We show that any three distinct eclipses form the vertices of a *temporal triangle*, where the longest edge equals the sum of the two shorter edges. A graphical analysis of cycle durations from George van den Bergh's catalog reveals three distinct regions, which also appear in plots of synodic, draconic, and anomalistic periods. This pattern suggests the potential existence of undiscovered cycles that could contribute to a smoother curve.

The use of eclipse cycle networks provides a novel method for identifying previously unknown eclipse cycles. In the studied period, known cycles include those of 9, 18, 19, 20, 29, 36, 50, 54, and 56 years. However, additional cycles – such as those spanning 8, 10, 16, 17, 27, 28, 30, 35, 37, 47, 48, 49, 50, 66, and 73 years, may also exist but remain unrecognized.

Key words: eclipses cycles, eclipse rosette diagrams, Saros column.

1. INTRODUCTION

As previously demonstrated, in the spiral representation of the Saros series a rosette is formed in which eclipses recurring over the Meton cycle are arranged radially, those recurring over the interval of one lunar year are displayed in a circular pattern, and the eclipses that repeat over the Saros cycle are arranged in a spiral, (Olenici, 2020).

Subsequently, by transforming the Saros series rosette into a column representation (shown in Figure 1), we discovered that certain connection cycles, ranging from 8 to 10 years, appear between the families of Saros series (Olenici, 2021).

After a careful analysis of the matrices that make up the Saros series column, we concluded that it is possible to graphically identify other, previously unknown cycles. For example, in the eclipse matrix spanning from January–February 1972 to 2149, we identified additional cycles with time spans of 8, 10, 16, 17, 27, 28, 30, 35, 37, 47, 48, 49, 50, 66, and 73 years. The key condition for these time intervals to

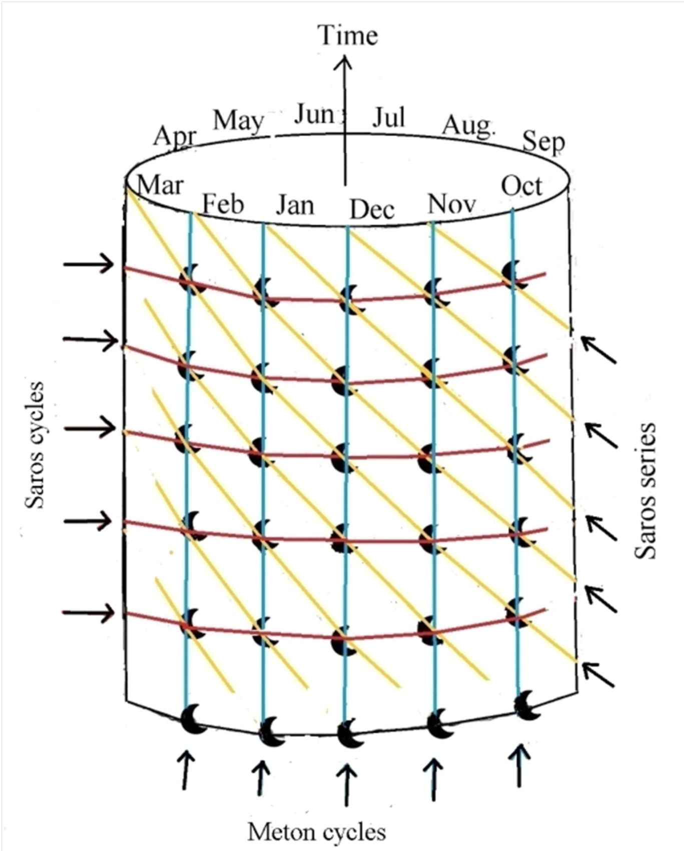

Fig. 1 – The column chart of the Saros series.

be considered as eclipse cycles is that they must repeat multiple times and, like the Saros cycle, correspond to an integer number of lunations (L).

In the following sections, we will present the existence of the 17-year, 20-year, 28-year, and 37-year cycles. For each cycle, we will provide: a diagram of the cycle, a table listing the start and end dates, the corresponding Saros series, and the time differences, as well as a diagram of the Gamma parameter. To compute the dates and generate the charts, we used eclipse data from the Catalogue of Fred Espenak and Jean Meeus (Espenak, 2020).

2. THE CONFIRMATION OF THE 17 YEARS CYCLE

If we carefully examine the eclipse matrix for January–February, we notice that some eclipses, arranged diagonally leftwards, recur over a 17-year interval. Notable examples include the periods 1973–1990, 1982–1999, and 2132–2139. To emphasize this pattern, these years are connected by thick red lines. The oblique thin lines in green, red, and yellow represent parts of the Saros series 121, 131, 141, 151, 122, 132, 142, 152, 123, 133, 143, and 153, as illustrated in Figure 2. Each eclipse is marked with symbols indicating a new moon, full moon, or waxing gibbous phase and is labeled with the month (bottom-left) and year (top-right).

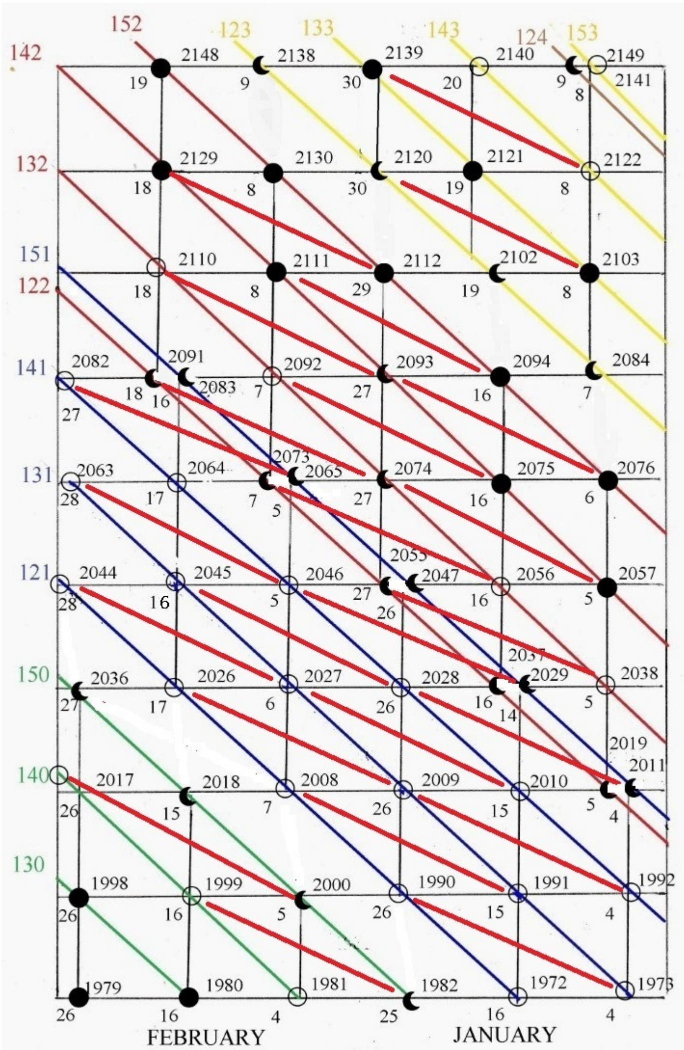

Fig. 2 – The network of the 17-year cycles.

Table 1

The timestamps and durations of the 17-year cycle eclipses

No.	Initial Saros Series	Start	Final Saros Series	End	Duration (over 17 years)
1	131	1973-01-04 15:46:21	121	1990-01-26 19:31:24	17y, +22d, +13:45:26h
2	150	1982-01-25 04:42:53	140	1999-02-16 06:34:38	17y, +22d, +01:05:45h
3	141	1992-01-04 23:05:37	131	2009-01-26 07:59:45	17y, +21d, +08:54:03h
4	131	1982-02-04 22:09:24	121	1998-02-26 17:29:27	17y, +21d, +19:20:53h
5	150	2000-02-05 12:50:27	140	2017-02-56 14:54:53	17y, +21d, +02:04:06h
6	151	2011-01-04 08:51:42	141	2028-01-26 15:08:59	17y, +22d, +06:17:17h
7	141	2010-01-15 07:07:39	131	2027-02-06 16:00:48	17y, +22d, +08:53:55h
8	131	2009-01-26 07:59:45	121	2026-02-17 12:13:06	17y, +22d, +04:23:55h
9	132	2038-01-05 13:47:11	122	2055-01-27 17:54:05	17y, +22d, +04:06:64h
10	151	2029-01-14 17:13:48	141	2046-02-05 23:06:26	17y, +22d, +06:52:38h
11	141	2028-01-26 15:08:59	131	2045-02-16 23:57:07	17y, +21d, +06:47:08h
12	131	2027-02-06 16:00:48	121	2044-02-28 20:24:39	17y, +22d, +04:23:41h
13	142	2057-01-05 09:47:52	132	2074-01-27 06:44:15	17y, +21d, +20:56:23h
14	132	2056-01-16 22:16:45	122	2073-02-07 01:55:59	17y, +21d, +03:39:04h
15	141	2046-02-05 23:06:26	131	2063-02-28 07:43:30	17y, +22d, +08:37:04h
16	152	2076-01-06 10:07:27	142	2093-01-27 03:22:16	17y, +20d, +17:14:19h
17	142	2075-01-16 18:36:04	132	1092-02-07 15:10:20	17y, +21d, +20:35:14h
18	132	2074-01-27 06:44:15	122	2091-02-18 09:54:40	17y, +22d, +03:20:25h
19	151	2065-02-05 09:52:26	141	2082-02-27 14:47:00	17y, +22d, +04:44:34h
20	152	2094-01-16 18:59:03	142	2111-02-08 12:05:33	17y, +22d, +17:06:30h
21	142	2093-01-27 03:22:16	132	2110-02-18 23:31:35	17y, +22d, +20:09:19h
22	133	2103-01-08 28:04:21	123	2120-01-30 11:09:56	17y, +21d, +17:05:35h
23	152	2112-01-29 03:49:52	142	2129-02-18 20:44:37	17y, +21d, +17:05:35h
24	143	2122-01-09 15:48:51	133	2139-01-30 11:42:25	17y, +21d, +19:53:34h

Table 1 lists the timestamps marking the beginning and end of the eclipses in the **17-year** cycle. The average duration of these intervals is **17 years, 21 days, 19 hours, 49 minutes, and 56 seconds**, or more precisely, **17 years and 21.83 days**. This translates to a total of:

- **6231.08 days**, calculated as 17×365.25 + 21.8662 ≈ 6231.08 days
- **17.060 years**, derived from $6231.08\ /\ 365.25 \approx 17.060$ years

Considering the average duration of a lunation (L), which is approximately 29.53 days, we find that approximately **211.01** lunations occur within the 17-year interval. Additionally, this interval contains approximately:

- **226.14 anomalistic periods** (A)
- **228.98 draconitic periods** (D)

These values are very close to integer values, which supports the argument that the **17.060-year** interval can frequently recur and, therefore, can be considered a significant solar eclipse cycle.

3. THE CONFIRMATION OF THE 20 YEARS CYCLE

Similarly, we have identified a set of solar eclipses that recur over a **20-year** interval, indicated by green lines in Figure 3.

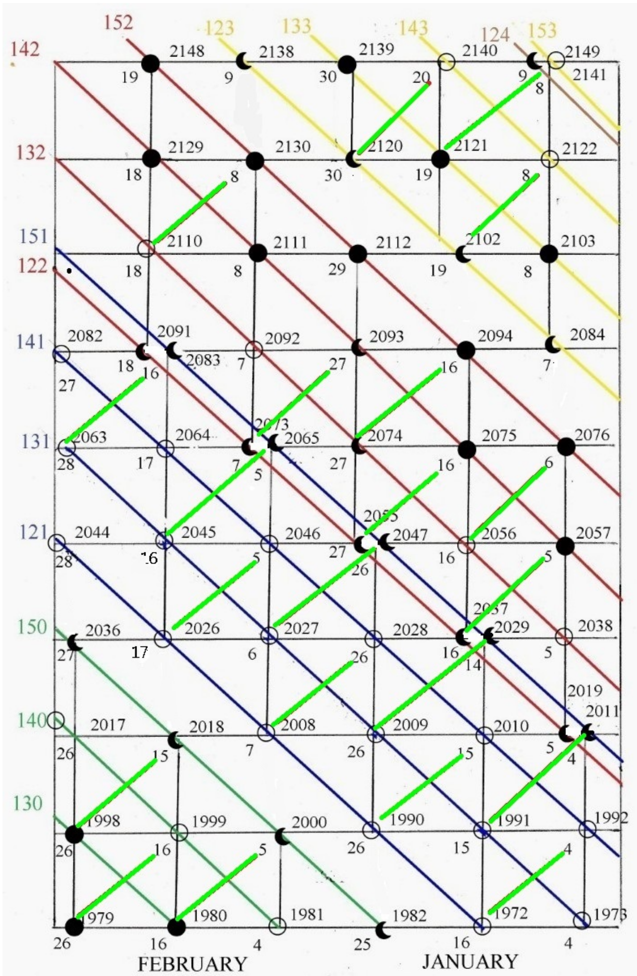

Fig. 3 – The network of the 20-year cycles.

Table 2

The timestamps and durations of the 20-year cycle eclipses

No.	Initial Saros Series	Start	Final Saros Series	End	Duration (over 20 years)
1	121	1972-01-16 11:03:22	140	1992-01-04 23:05:37	20y, +11d, +11:57:55h
2	130	1980-02-16 08:54:01	150	2000-02-05 12:50:27	20y, +10d, +20:03:33h
3	120	1979-02-26 16:55:06	140	1999-02-16 06:34:38	20y, +10d, +10:25:28h
4	131	1991-01-15 23:53:51	151	2011-01-04 08:51:42	20y, +11d, +15:02:09h
5	121	1990-01-26 19:31:24	141	2010-01-15 07:07:39	20y, +11d, +12:23:55h
6	130	1998-02-26 17:29:27	150	2018-02-15 20:52:33	20y, +10d, +20:35:54h
7	131	2009-01-26 07:59:45	151	2029-01-14 17:13:48	20y, +11d, +14:45:57h
8	121	2008-02-07 03:56:10	141	2028-01-26 15:08:59	20y, +11d, +12:47:11h
9	122	2037-01-16 09:48:56	142	2057-01-05 09:47:52	20y, +11d, +01:01:04h
10	131	2027-02-06 16:00:48	151	2047-01-26 01:33:18	20y, +11d, +14:27:30h
11	121	2026-02-17 12:13:06	141	2046-02-05 23:06:26	20y, +11d, +14:27:30h
12	132	2056-01.16 22:16:45	152	2076-01-06 10:07:27	20y, +10d, +12:09:18h
13	122	2055-01-27 17:54:05	142	2075-01-16 18:36:04	20y, +11d, +00:41:59h
14	131	2045-02-16 23:56:07	151	2065-02-05 09:52:26	20y, +11d, +14:03:41h
15	132	2074-01-27 06:44:15	152	2094-01-16 18:59:03	20y, +10d, +11:45:12h
16	122	2073-02-07 01:55:00	142	2093-01-27 03:22:16	20y, +10d, +22:32:44h
17	131	2063-02-28 07:43:30	151	2083-02-16 18:06:36	20y, +11d, +14:36:54h
18	123	2102-01-19 02:21:30	143	2122-01-08 15:48:51	20y, +10d, +10:32:39h
19	132	2110-02-18 21:31:35	152	2130-02-08 12:35:53	20y, +10d, +10:55:42h
20	133	2121-01-19 02:54:15	153	2141-01-08 06:12:38	20y, +10d, +20:41:37h
21	123	2120-01-30 11:09:56	143	2140-01-20 00:23:11	20y, +10d, +10:45:45h

The starting and ending timestamps, along with the durations of these 20-year cycle eclipses, are presented in Table 2.

Upon examining the data, we observe that the end date is consistently more recent than the start date by an average of **10 days, 13 hours, 56 minutes, and 52 seconds**. Therefore, the actual duration of the 20-year cycle is approximately **19.970 years**, or in days: **7294.21 days**.

Within this interval, there are approximately:

- **247.01 lunations** (L)
- **268.95 draconitic periods** (D)
- **264.72 anomalistic periods** (A)

It is noteworthy that the fraction of anomalistic periods is greater than the other fractions. This pattern has been observed in several other eclipses listed in Georg van der Bergh's catalog (WebspaceUtrecht, 2023).

This **19.970-year interval** appears to be another valid solar eclipse cycle.

Table 3

The timestamps and durations of the 28-year cycle eclipses

No.	Initial Saros Series	Start	Final Saros Series	End	Duration (as difference up to 28 years)
1	150	1982-01-25 04:42:53	141	2010-01-15 07:07:39	28y, -9d, -21:35:12h
2	140	1981-02-04 22:09:24	131	2009-01-26 07:59:45	28y, -9d, -14:09:39h
3	130	1980-02-16 08:54:01	121	2008-02-07 03:55:10	28y, -9d, -04:58:51h
4	141	2010-01-15 07:07:39	132	2038-01-05 13:47:11	28y, -9d, -17:20:28h
5	131	2009-01-26 07:59:45	122	2037-01-16 09:48:56	28y, -9d, -22:10:49h
6	151	2029-01-14 17:13:48	142	2057-01-05 09:47:52	28y, -9d, -07:25:56h
7	141	2028-01-26 15:08:59	132	2056-01-16 22:16:45	28y, -9d, -16:52:14h
8	131	2027-02-06 16:00:48	122	2055-01-27 17:54:05	28y, -10d, -06:06:53h
9	151	2047-01-26 01:33:18	142	2075-01-16 18:36:04	28y, -9d, -06:57:14h
10	141	2046-02-05 03:06:26	132	2074-01-07 06:44:15	28y, -9d, -20:22:11h
11	131	2045-02-17 23:56:07	122	2073-02-07 01:55:00	28y, -9d, -23:01:07h
12	142	2075-01-16 18:36:04	133	2103-01-08 18:04:21	28y, -8d, -23:28:17h
13	151	2065-02-05 09:52:26	142	2093-01-27 03:22:16	28y, -9d, -06:30:10h
14	141	2064-02-17 07:00:23	132	2092-02-07 15:10:20	28y, -9d, -15:50:13h
15	131	2063-02-28 07:43:30	122	2091-02-18 14:47:00	28y, -9d, -16:56:30h
16	152	2094-01-16 18:59:03	143	2122-01-08 15:48:51	28y, -9d, -03:10:12h
17	142	2093-01-27 03:22:16	133	2121-01-19 02:54:15	28y, -8d, -00:28:01h
18	132	2092-02-07 15:10:20	123	2120-01-30 11:09:56	28y, -8d, -04:00:24h
19	151	2083-02-16 18:06:36	142	2111-02-08 12:05:33	28y, -8d, -06:01:13h
20	141	2082-02-27 14:47:00	132	2110-02-18 23:31:35	28y, -8d, -15:15:25h
21	152	2112-01-29 03:49:52	143	2140-01-20 00:23:11	28y, -9d, -03:26:51h

4. THE CONFIRMATION OF THE 28 YEARS CYCLE

In the solar eclipses matrix, additional repetitions can be observed at an interval of approximately 28 years, marked with magenta lines in Figure 4. The specific intervals are presented in Table 3.

Similar to previous cycle, the end date is slightly more recent than the start date, resulting in an interval slightly shorter than 28 years. The average duration of this cycle is approximately:

- 28 years minus 9 days, 4 hours, 42 minutes, and 57 seconds
- In decimal form: **27.975 years**
- This translates to a total of: $28 \times 365.25 - 9.20 \approx 10217.80$ days

Within this interval, there are approximately:

- **346.01 lunations** (L)
- **370.82 anomalistic periods** (A)

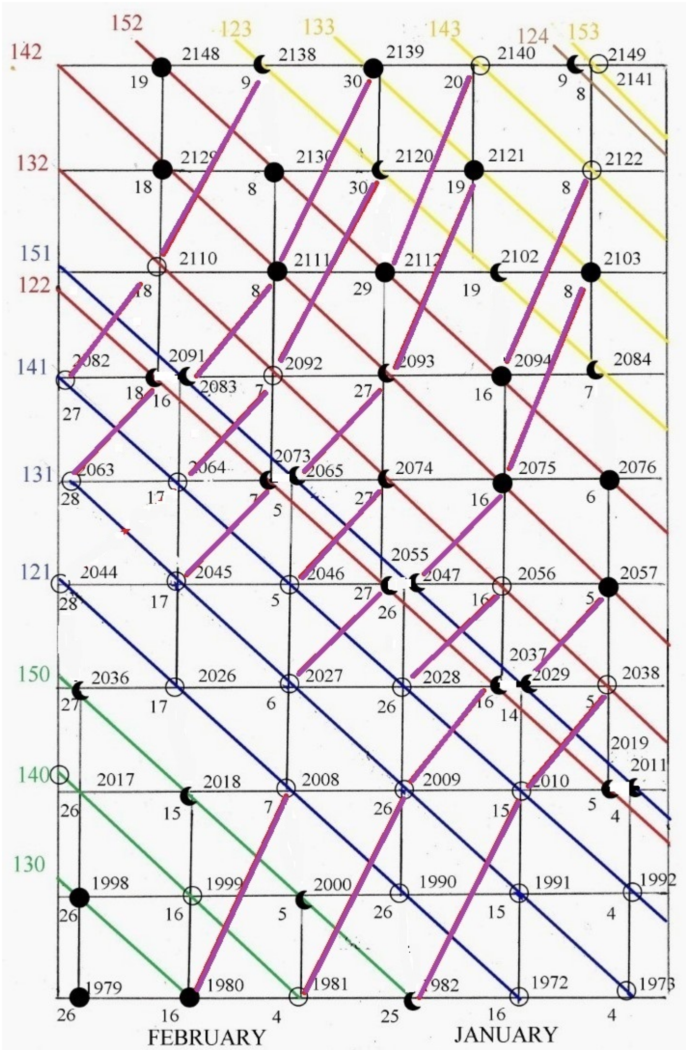

Fig. 4 – The network of the 28-year cycles.

- **375.35 draconitic periods** (D)

The similarity of these values to integers suggests that this **27.975-year** interval may also represent a valid solar eclipse cycle.

5. THE CONFIRMATION OF THE 37 YEARS CYCLE

Another interesting observation from the eclipse matrix is that many eclipses occur at **37-year** intervals.

Table 4

The timestamps and durations of the 37-year cycle eclipses

No.	Initial Saros Series	Start	Final Saros Series	End	Duration (over 37 years)
1	131	1973-01-04 15:46:21	141	2010-01-15 07:07:39	37y, +10d, +15:21:18h
2	121	1972-01-16 11:03:22	131	2009-01-26 07:59:45	37y, +09d, +20:56:23h
3	140	1981-01-04 22:09:24	150	2018-02-15 20:52:33	37y, +10d, +22:43:09h
4	130	1980-02-16 08:54:01	140	2017-02-26 14:55:33	37y, +10d, +06:00:39h
5	141	1992-01-04 23:05:57	151	2029-01-14 17:13:48	37y, +09d, +18:07:51h
6	121	1990-01-26 19:31:24	131	2027-02-07 16:00:48	37y, +10d, +20:29:24h
7	141	2010-01-15 07:07:39	151	2047-01-26 01:33:18	37y, +10d, +18:25:39h
8	131	2009-01-26 07:59:45	141	2046-02-05 23:06:26	37y, +10d, +15:06:41h
9	122	2037-01-16 09:48:55	132	2074-01-27 06:44:15	37y, +10d, +20:55:19h
10	141	2028-01-06 15:08:59	151	2065-02-05 09:52:26	37y, +09d, +18:43:27h
11	142	2057-01-05 09:47:52	152	2094-01-16 18:59:03	37y, +11d, +16:11:11h
12	132	2056-01-16 22:16:45	142	2093-01-27 03:22:16	37y, +10d, +05:15:31h
13	141	2046-02-05 23:06:26	151	2083-02-16 18:06:36	37y, +10d, +19:50:10h
14	142	2075-01-16 18:36:04	152	2112-01-29 03:49:52	37y, +12d, +09:13:48h
15	132	2074-01-27 06:44:15	142	2111-02-08 12:05:33	37y, +12d, +05:21:18h
16	122	2073-02-07 01:55:59	132	2110-02-18 23:31:35	37y, +11d, +21:35:35h
17	123	2084-01-07 17:30:24	133	2121-01-19 02:54:15	37y, +11d, +09:23:51h
18	142	2093-01-27 03:22:16	152	2130-02-08 12:35:33	37y, +12d, +09:13:37h
19	132	2092-02-07 15:10:20	142	2129-02-18 20:44:37	37y, +11d, +05:34:17h
20	133	2103-01-08 18:04:21	143	2140-01-20 00:23:11	37y, +11d, +06:18:50h
21	123	2102-01-19 02:21:30	133	2139-01-30 11:42:25	37y, +11d, +09:20:55h
22	152	2112-01-09 03:49:52	123	2138-02-09 19:55:33	37y, +11d, +16:05:41h
23	142	2111-02-08 12:05:33	152	2148-02-19 21:18:00	37y, +11d, +09:12:27h

These eclipses are highlighted with yellow lines in Figure 5.

The starting and ending timestamps of these cycles, as well as the duration of the intervals, are presented in Table 4.

The average duration of these cycles is:

- **37 years, plus 10 days, 15 hours, 52 minutes, and 48 seconds**
- In decimal form: **37.029 years**
- This converts to: $38 \times 365.25 \approx 13524.91$ days

Within this period, there are:

- **458.01 lunations** (L)
- **490.84 anomalistic periods** (A)
- **497.02 draconitic periods** (D)

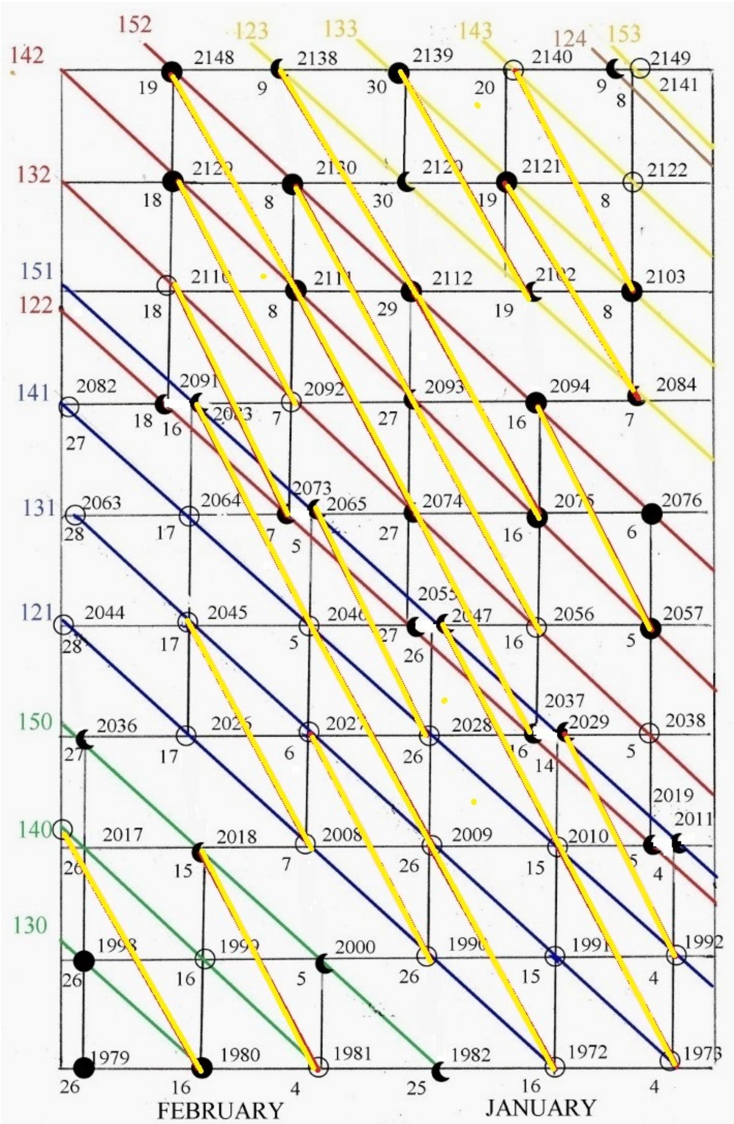

Fig. 5 – The network of the 37-year cycles.

Notably, only the number of lunations is close to an integer, while the numbers for the anomalistic and draconitic periods have relatively large decimal parts. This pattern is observed in most of the cycles from George van den Bergh's catalogue (WebspaceUtrecht, 2023), with the notable exception of the Saros cycle.

The similarity of the lunation value to an integer suggests that this **37.029-year** interval may also represent a valid eclipse cycle.

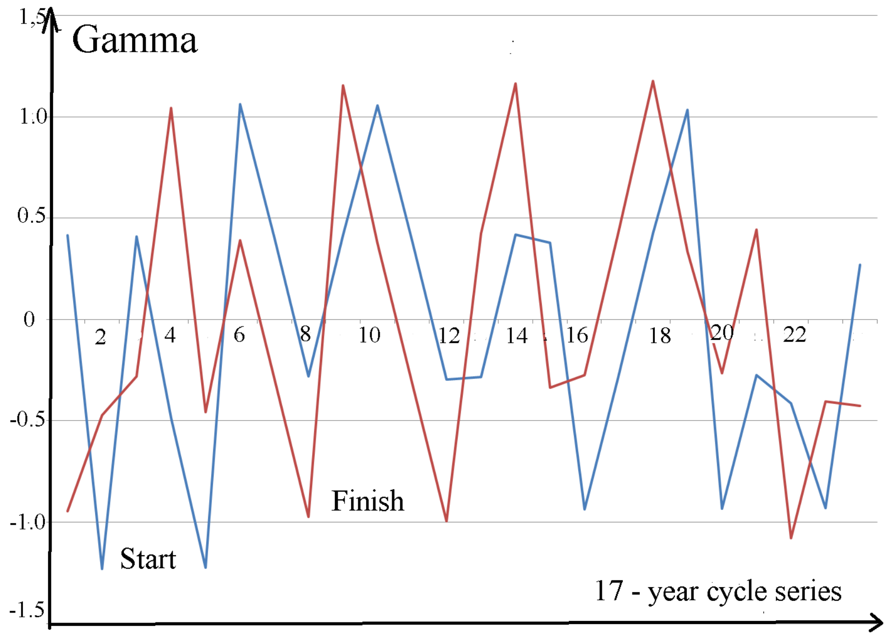

Fig. 6 – The Gamma parameter at the beginning and the end of the 17-years cycle.

6. THE CORRELATION WITH THE GAMMA PARAMETER

Let us now examine whether there is any pattern regarding the association of the Gamma parameter, or if the Sun-Moon axis crosses the Earth's surface randomly between the poles during these cycles. Figures 6, 7, 8, and 9 show the Gamma parameter values at the beginning and the end of the 17, 20, 28, and 37-year cycles.

It is observed that the Gamma parameter tends to reach extreme positive or negative values. The two series – the beginning (in blue) and the end (in red) – have similar shapes but are out of phase. The vertices of the curves exhibit similar values, which can be attributed to the fact that we analyzed short-term cycles from 1972 to 2149.

Because of the relatively small time interval, we cannot definitively determine when a network begins or ends, or if it constitutes a continuous series. However, from these charts, we can observe that in the majority of cases, **each cycle begins and ends in the same terrestrial hemisphere**.

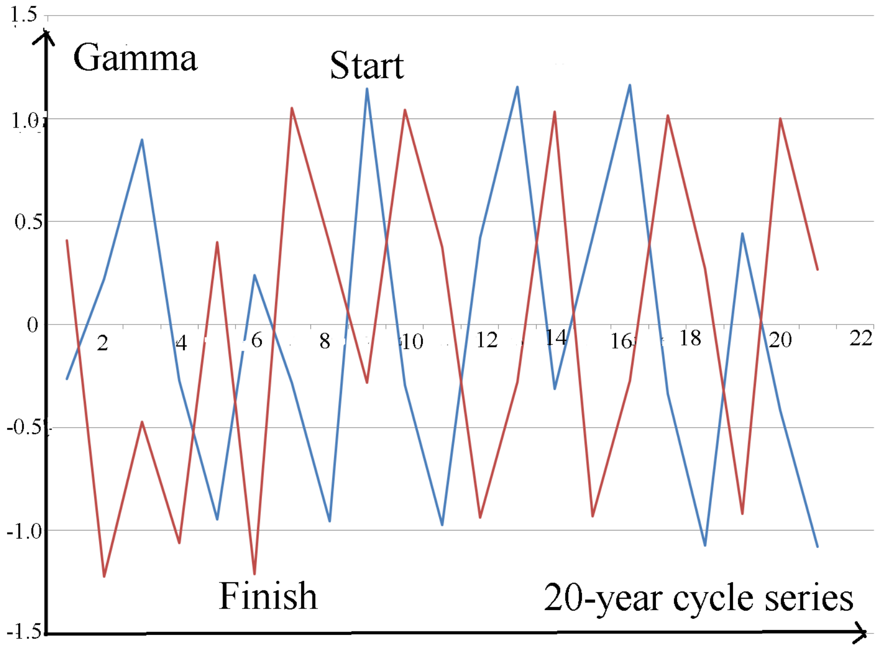

Fig. 7 – The Gamma parameter at the beginning and the end of the 20-years cycle.

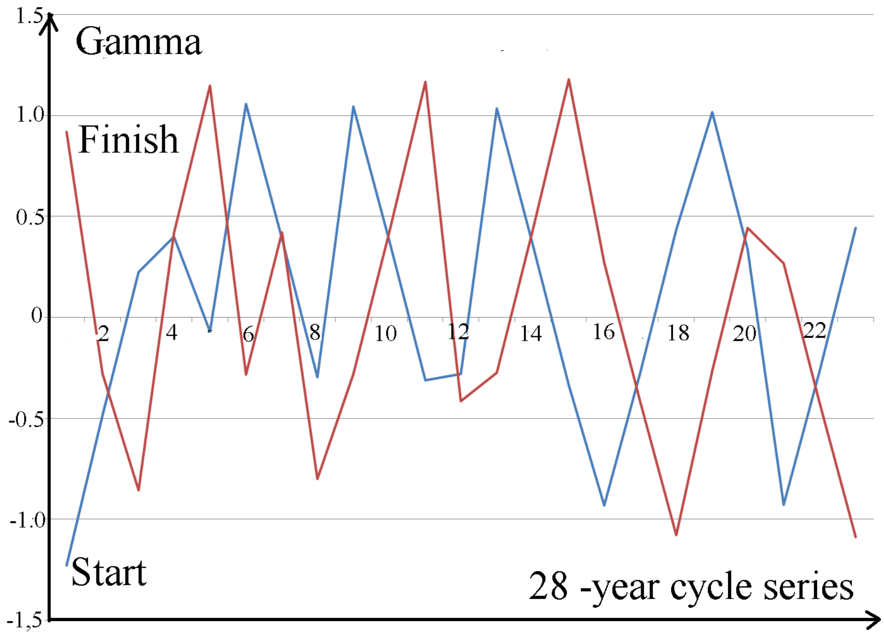

Fig. 8 – The Gamma parameter at the beginning and the end of the 28-years cycle.

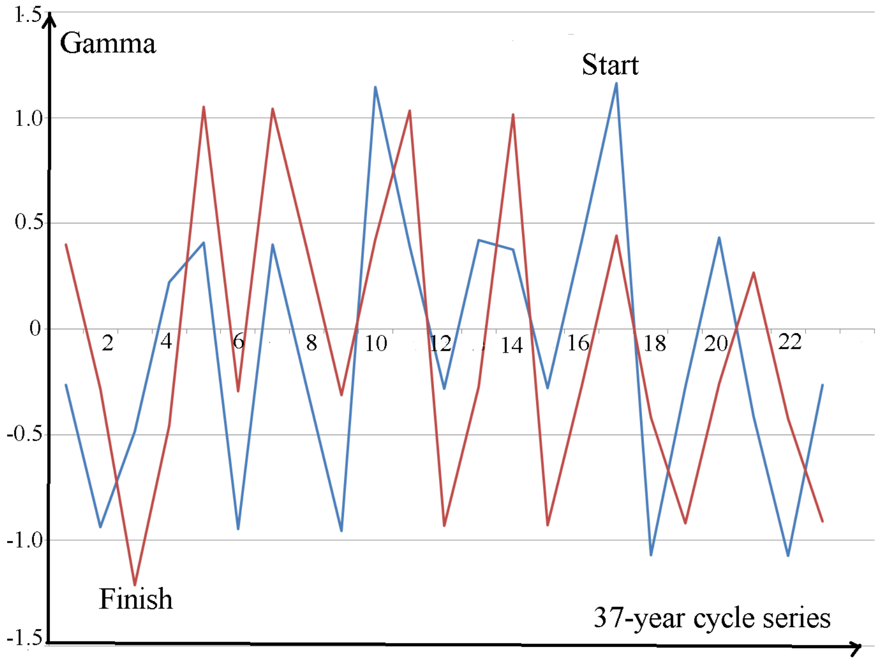

Fig. 9 – The Gamma parameter at the beginning and the end of the 37-years cycle.

7. THE SUM OF THE CYCLES AND THE RULE OF TEMPORAL TRIANGLE

Upon analyzing the durations of the previously identified eclipse cycles, we observe a fascinating pattern: a longer cycle can always be expressed as the sum of two shorter cycles. Specifically:

- $17 = 10 + 7$
- $20 = 10 + 10$
- $28 = 20 + 8$
- $37 = 20 + 17$

This relationship is reminiscent of the *triangle inequality theorem*, where the sum of two sides of a triangle is always greater than the third side. Similarly, in eclipse cycles, a longer cycle can be expressed as the sum of two shorter ones, revealing a structured pattern in their recurrence over time.

To further validate this observation, we analyze the time differences between eclipse years in the **January–February matrix**, focusing on eclipses occurring between **1972 and 2076**.

7.1. THE TRIANGLES OF CONNECTION CYCLES BETWEEN THE SAROS SERIES FAMILIES

The previously identified **8-year** and **10-year** cycles serve as bridges between different families of Saros series. As an example, let us consider the cycles from the **January–February eclipse matrix**, which establish connections between the Saros series families **120, 130, 140, 150** and **121, 131, 141, 151**, as illustrated in Figure 10.

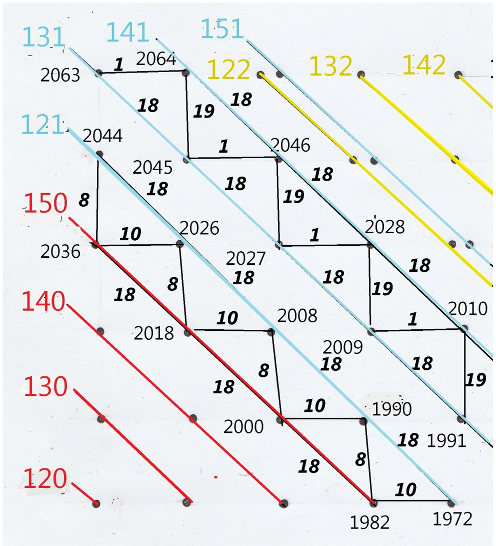

Fig. 10 – The bridge cycles between the Saros series 150–121 and 131–141.

Within this framework, we observe that the Saros series **150** and **121** are linked through a pattern of **seven triangular connections**, each defined by edges of **8, 10, and 18 years**. We analyze these cases individually.

Table 5 lists the **start and end dates** of the 8-year and 10-year cycles, alongside their sum (*8 + 10*), and the corresponding **18-year Saros cycles** within the Saros series **150**. Notably, the sum of the 8-year and 10-year cycles matches the duration of an *18-year Saros cycle*.

Similarly, Table 5 presents the values for the *10-year + 8-year* cycles, which correspond to the Saros cycles of the Saros series **121**. As before, the sum of these shorter cycles equals the duration of a single Saros cycle (S).

7.2. TRIANGLES OF CONNECTION CYCLES THAT BELONG TO THE SAME SAROS SERIES FAMILY

We now examine whether the connection cycles between two Saros series within the **same family**, when summed, yield consistent results.

Table 5

The values of the cycles of the Saros series 150

Cycle	Start date (yyyy-mm-dd hh:mm:ss)	End date (yyyy-mm-dd hh:mm:ss)	Duration (y, d, h:m:s)
8	1982-01-25 04:43:53	1990-01-26 19:31:24	08y, 00d, 14:48:41h
10	1990-01-26 19:31:24	2000-02-05 12:50:27	10y, 10d, 17:19:03h
S	1982-01-25 04:42:53	2000-02-05 12:50:27	**18y, 10d, 08:07:34h**
8+10			***18y, 10d, 08:17:44h***
8	2000-02-05 12:50:27	2008-02-07 03:55:10	08y, 01d, 15:04:04h
10	2008-02-07 03:55:10	2018-02-15 20:52:33	10y, 08d, 16:57:23h
S	2000-02-05 12:50:27	2018-02-15 20:52:33	**18y, 10d, 08:02:07h**
8+10			***18y, 10d, 08:01:26h***
8	2018-02-15 20:52:33	2026-02-17 12:13:06	08y, 01d, 15:20:33h
10	2026-02-17 12:13:06	2036-02-27 04:46:49	10y, 9d, 15:13:43h
S	2018-02-15 20:52:33	2036-02-27 04:46:49	**18y, 11d, 07:52:16h**
8+10			***18y, 11d, 07:36:16h***

Table 6

The values of the 10+8-years cycles of the Saros series 121

Cycle	Start date (yyyy-mm-dd hh:mm:ss)	End date (yyyy-mm-dd hh:mm:ss)	Duration (y, d, h:m:s)
10	1972-01-16 11:03:22	1982-01-25 04:52:53	10y, 8d, 17:39:31h
8	1982-01-25 04:42:53	1990-01-26 19:31:24	8y, 1d, 14:48:31h
S	1972, 01-16 11:03:22	1990-01-26 19:31:24	**18y, 10d, 08:28:02h**
10+8			***18y, 10d, 08:28:02h***
10	1990-01-26 19:31:24	2000-02-05 12:50:27	10y, 9d, 17:19:03h
8	2000-02-05 20:50:27	2008-02-07 03:55:10	8y, 1d, 15:04:43h
S	1990-01-26 19:31:24	2008-02-07 03:55:10	**18y, 11d, 08:23:46h**
10+8			***18y, 11d, 08:23:46h***
10	2008-02-07 03:56:10	2018-02-15 20:52:33	10y, 8d, 20:52:33h
8	2018-02-15 20:52:33	2026-02-17 12:13:06	8y, 1d, 15:20:23h
S	2008-02-07 03:56:10	2026-02-17 12:13:06	**18y, 10d, 08:16:56h**
10+8			***18y, 10d, 08:12:56h***
10	2026-02-07 12:13:06	2036-02-27 04:46:49	10y 9d, 16:33:43h
8	2036-02-27 04:46:49	2044-02-28 20:24:39	8y, 1d, 15:37:50h
10+8	2026-02-07 12:13:06	2044-02-28 20:24:39	**18y, 11d, 08:11:33h**
S			***18y, 11d, 08:11:33h***

Table 7

The connection cycles between Saros series of the same Saros family

Cycle	Start date (yyyy-mm-dd hh:mm:ss)	End date (yyyy-mm-dd hh:mm:ss)	Duration (y, ±d, ±h:m:s)
18 (S)	1973-01-04 15:46:21	1991-01-15 23:53:52	18y, 1d, 08:07:30h
1	1991-01-15 23:53:51	1992-01-04 23:55:07	1y, 10d, 23:58:44h
Me	1973-01-04 15:46:21	1992-01-04 23:55:07	**19y, 0d, 08:08:46h**
18+1			***19y, 0d, 08:08:46h***
18 (S)	1991-01-15 23:53:51	2009-01-26 07:49:55	18y, 10d, 08:05:54h
1	1992-01-04 23:55:07	2010-01-15 07:07:39	1y, 11d, 00:42:26h
Me	1991-01-15 23:53:51	2010-01-15 07:07:39	**19y, 0d, 16:45:12h**
18+1			***19y, 0d, 16:36:32h***
18 (S)	2009-01-26 07:49:55	2027-02-06 16:00:48	18y, 11d, 08:01:03h
1	2027-02-06 16:00:48	2028-01-26 15:05:59	19y, 0d, 07:09:14h
Me	2009-01-26 07:49:55	2028-01-26 15:05:59	**19y, 0d, 07:09:14h**
18+1			***19y, 0d, 07:09:14h***
18 (S)	2027-02-06 16:00:48	2045-02-17 23:56:07	18y, 11d, 07:55:19h
1	2045-02-17 23:56:07	2046-02-05 23:06:26	1y, -12d, -00:49:41h
Me	2027-02-06 16:00:48	2046-02-05 23:06:26	**19y, -0d, -16:54:22h**
18+1			***19y, -0d, -16:54:22h***
18 (S)	2045-02-17 23:56:07	2063-02-28 07:43:30	18y, 10d, 07:47:23h
1	2063-02-28 07:43-30	2064-02-17 07:00:23	1y, -11d, -0:43:07h
Me	2045-02-17 23:56:07	2064-02-17 07:00:23	**19y, -0d, -16:55:44h**
18+1			***19y, -0d, -16:55:44:h***

To investigate this, let us analyze the cycles that form the connection between the **Saros series 131 and 141**. In this case:

- Along the **oblique axis**, we find the **18-year cycles** – the *Saros cycles (S)*.
- Along the **vertical axis**, we observe the **19-year Metonic cycles** – denoted as *Me*.
- Along the **horizontal axis**, we identify the **1-year cycle**, which corresponds to a lunar year of approximately 354 days.

Table 7 presents the values of the **18-year Saros 131 cycles** and the **1-year cycle**, whose sum forms the **Metonic cycles**. We observe that the summed cycle durations, *18 + 1*, match the duration of a **Metonic cycle (Me)**.

7.3. THE TEMPORAL TRIANGLE OF SOLAR ECLIPSES

Consider the triangles formed in the January–February eclipse matrix shown in Figure 11. In these triangles:

- The **nodes** represent the **years of eclipses**.

- The **edges** display the time differences between these years, written in **bold and italic** characters.

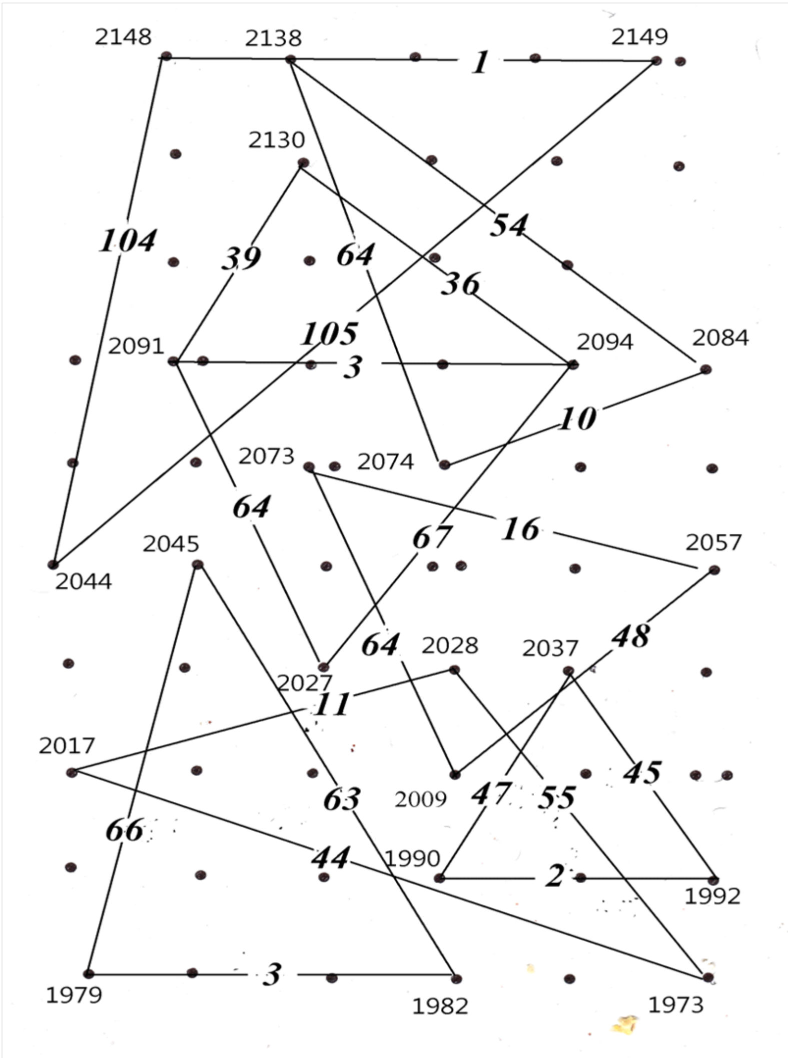

Fig. 11 – Some temporal triangls from the January–February matrix of 1973–2149 period.

Table 8 presents the exact durations and differences between these eclipses. Analyzing this data, we observe that the sum of the durations of the two shorter edges closely matches the duration of the longest edge. However, there is a small discrepancy of approximately **14 hours** in the **2091–2094–2130** triangle – an anomaly yet to be explained.

Table 8

Duration between the occurences of eclipses from the matrix of 1973–2149

Cycle	Start date (yyyy-mm-dd hh:mm:ss)	End date (yyyy-mm-dd hh:mm:ss)	Duration (y, ±d, ±h:m:s)
44	1973-01-04 15:46:21	2017-02-26 14:54:33	44y, 52d, 23:08:22h
11	2017-02-26 14:54:33	2028-01-26 15:08:59	11y, -30d, -23:45:34h
55	1973-01-04 15:46:21	2028-01-26 15:08:59	**55y, 21d, 23:32:28h**
44+11			***55y, 21d, 23:22:28h***
3	1979-02-26 16:55:06	1982-01-05 04:42:53	3y, -51d, 12:12:13h
63	1982-01-05 04:42:53	2045-02-17 23:56:07	63y, 42d, -19:13:14h
66	1979-02-26 16:55:06	2045-02-17 23:56:07	**66y, -8d, -16:58:59h**
3+63			***66y, -8d, -16:58:59h***
2	1990-01-26 19:31:24	1992-01-04 23:55:07	2y, -21d, -19:36:17h
45	1992-01-04 23:55:07	2037-01-16 19:48:56	45y, 11d, 09:52:49h
47	1990-01-26 19:31:24	2037-01-16 19:48:56	**47y, -10d, -09:43:28h**
2+45			***47y, -10d, -09:43:28h***
48	2009-01-06 07:59:45	2057-01-05 09:47:52	48y, -20d, -17:43:52h
16	2057-01-05 09:47:52	2073-02-07 01:55:59	16y, 32d, 05:55:37h
64	2009-01-06 07:59:45	2073-02-07 01:55:59	**64y, 11d, 17:56:14h**
48+16			***64y, 11d, 12:24:15h***
64	2027-02-06 16:00:48	2091-02-18 09:54:40	64y, 11d, 17:43:52h
3	2091-02-18 09:54:40	2094-01-16 18:59:04	3y, -32d, 05:55:37h
67	2027-02-06 16:00:48	2094-01-16 18:59:03	**67y, -20d, -21:00:58h**
64+3			***67y, -21d, -11:48:15***
10	2074-01-27 06:44:15	2084-01-07 17:30:24	10y, -19d, -13:13:51h
54	2084-01-07 17:30:24	2138-02-09 19:55:33	54y, 33d, 02:25:09h
64	2074-01-27 06:44:15	2138-02-09 19:55:33	**64y, 13d, 13:01:18h**
10+54			***64y 13d, 13:11:18h***
44	2044-02-28 20:24:39	2148-02-19 21:18:00	44y, -9d, -00:00:08h
1	2148-02-19 21:18:00	2149-01-09 21:30:38	1y, -40d, -23:47:22h
45	2044-02-28 20:24:39	2149-01-09 21:30:38	**45y, -49d, -22:54:01h**
44+1			***45y, -49d, -23:47:30h***
3	2091-02-18 09:54:40	2094-01-16 18:59:03	3y, -32d, -05:55:37h
36	2094-01-16 18:59:03	2130-02-08 12:35:23	36y, 22d, 17:36:20h
39	2091-02-18 09:54:40	2130-02-08 12:35:23	**39y, -9d, -21:19:17h**
3+36			***39y, -10d, -11:40:43h***

8. THE LUNAR PERIODS AND CYCLES SIZE

Now, let us plot the sizes of the **85 cycles** from the catalogue of eclipse cycles compiled by **George Van den Bergh**, as shown in Figure 12.

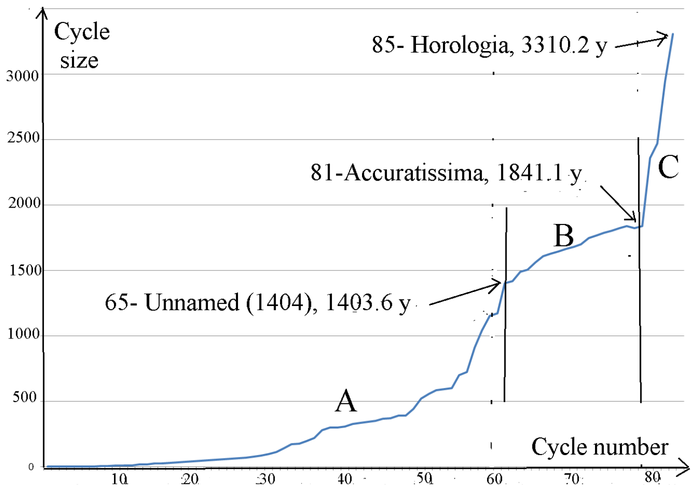

Fig. 12 – The plot of the solar eclipses cycles from the Van den Beergh catalogue.

We observe that the line chart depicting the sizes of these cycles can be divided into **three distinct segments**:

- **A**: An **ascending segment**, with an **asymptotic trend** reaching up to cycle **65**.
- **B**: A **gradually ascending segment**, which **levels off** as it approaches cycle **81**.
- **C**: A **steeply ascending final segment**, spanning cycles **81 to 85**.

This curve tends toward an **asymptotic shape**, with a central region that appears nearly linear.

Breaking down the segments:

- Segment A spans **1404** years, comprising **66 cycles**, with an average cycle duration of **21.25 years**.
- Segment B extends over **437** years, containing **15 cycles**, with an average duration of **29 years per cycle**.
- Segment C covers **1469** years, but includes **only 4 cycles**, with an average duration of **367 years per cycle**.

8.1. REFINING THE MODEL

To make this curve **smoother**, we propose that **segments A and B should contain more cycles**. To support this hypothesis, we plot the durations of **every tenth** cycle among the **367 cycles shorter than 55 years**. These durations were calculated using:

$T = aI + nS$

where:

- T is the duration of the cycle,
- I is the duration of the Inex cycle,
- S is the duration of the Saros cycle,
- a and n are two integers.

As shown in Figure 13, the **additional points** align along a **straight line**, reinforcing our hypothesis.

Next, in Figure **14**, we introduce **10 additional consecutive cycles** into the central segment, with durations ranging between **26.11 and 27.9 years**. This modification significantly reduces the slope of Segment B, making it more consistent with the **trend observed in Figure 12**.

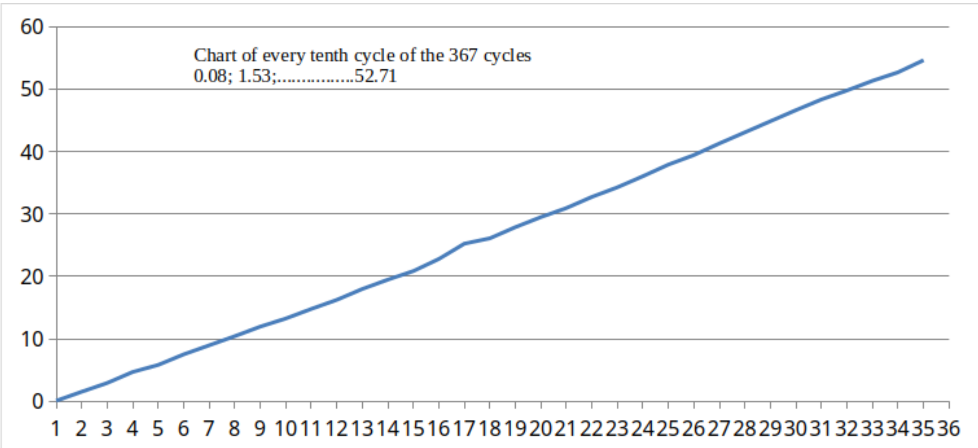

Fig. 13 – The plot of the every tenth cycle of the 367 with periods of less than 55 year.

8.2. CORRELATION WITH LUNAR PERIODS

Similarly, let us now examine the three lunar periods – **synodic**, **draconic**, and **anomalistic**, associated with these cycles. The resulting chart is displayed in 15.

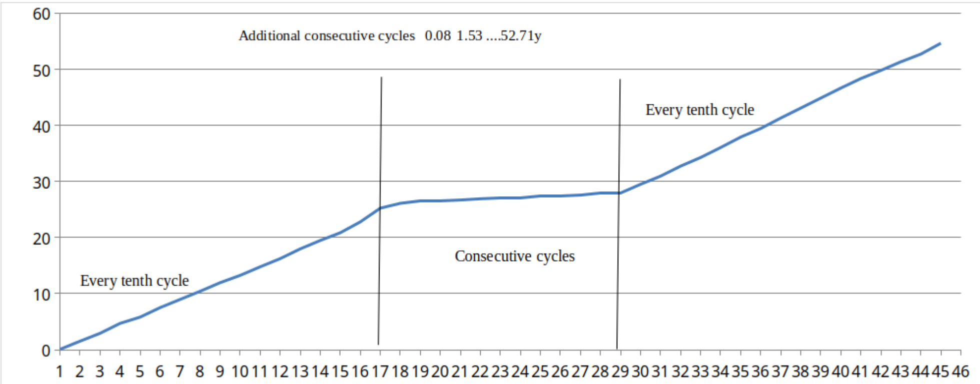

Fig. 14 – Additional consecutive cycles to the plot of the every tenth cycle of the 367 with periods of less than 55 year.

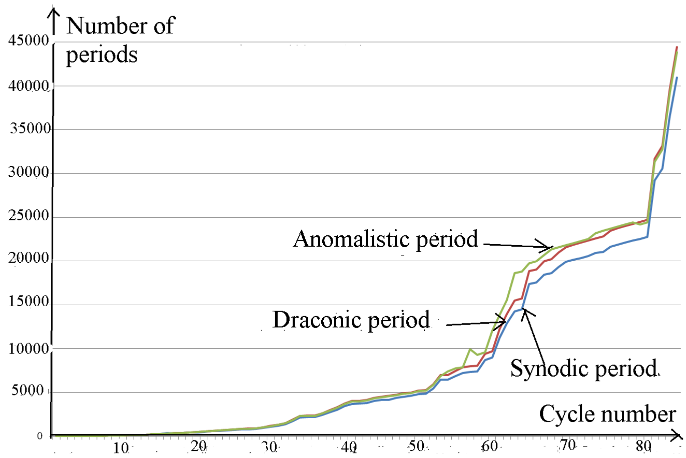

Fig. 15 – The plot of the number of synodic, draconitic and anomalistic periods.

Upon further analysis of the number of lunar periods contained within each cycle, we notice that each cycle has both an **integer** and a **decimal** part for the periods. For example, in the Meton ic cycle, we find:

- **223.0044 synodic periods**
- **251.8541 anomalistic periods**
- **275.0222 draconic periods**

By isolating the decimal parts and plotting them separately, we observe that this chart closely resembles the **eclipse cycle duration chart**, as illustrated in Figure 16.

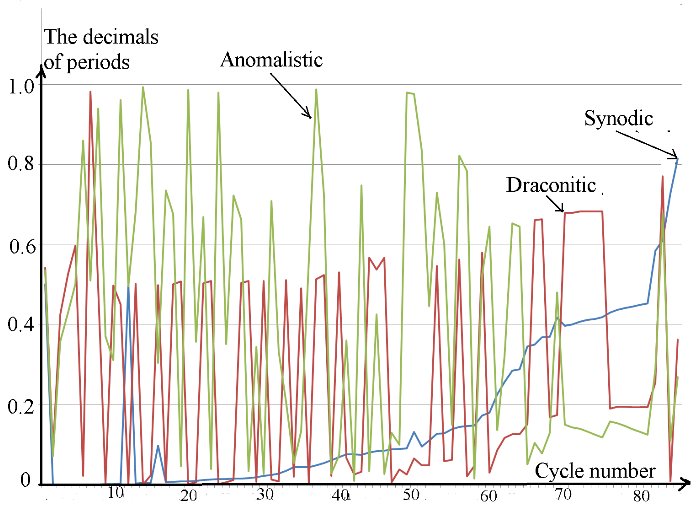

Fig. 16 – The plot of the decimal parts of the durations of the Moon periods.

Additionally, we note that while the decimal parts of **synodic durations remain relatively constant**, the **decimal parts of anomalistic and draconic periods** tend to mimic each other, oscillating between **0.2** and over **0.5**.

9. THE SAROS CYCLE, A DISTINCT CASE WITHIN THE SERIES OF SOLAR ECLIPSES CYCLES

Let us now recall that the **Saros cycle** consists of:

- **223 synodic months – 6585.3223 days**
- **239 anomalistic months – 6585.5375 days**
- **242 draconic months – 6585.3575 days**

In fact, the decimal parts of these periods are extremely small:

- **223.0045 for the synodic periods**
- **239.0013 for the anomalistic periods**
- **242.0019 for the draconic periods**

These minute decimal differences make the **Saros cycle** unique within the series of **85 cycles** in the eclipse cycle catalog. This pattern of small decimal parts is only evident in **Saros multiples**, such as the **Double Saros (No. 20)** and the **Triple Saros (Exeglimos, No. 24)**.

No other cycle exhibits such small decimal parts for the number of months in all three lunar periods.

10. CONCLUSIONS

1. The Saros series column chart enables the identification of **previously unknown** solar eclipse cycles.

2. By analyzing the January–February eclipse matrix for the period 1973 to 2149, we identified **cycles of 17, 20, 28, and 37 years**. When combined with the **previously discovered 8-year and 10-year cycles**, the total number of known solar eclipse cycles increases from **85 to 91**.

3. Extending the study period well **beyond 2149** could potentially reveal **additional eclipse cycles**.

4. By linking three eclipses within the eclipse matrix, we consistently obtain a **temporal triangle**, where the longest side equals the sum of the two shorter sides.

5. By plotting the cycle durations in the order they appear in the eclipse catalogue, we observe a chart with three distinct segments:

   - Segment A – Exhibits an **asymptotic** trend, covering 1403.6 years and extending up to cycle 64.
   - Segment B – Shows a **gradual increase**, spanning from 1403.6 to 1841.1 years.
   - Segment C – Features a **sharp rise**, consisting of the last 4 cycles, with durations ranging between 1841.1 and 3310.2 years.

   However, if additional cycles were identified in **segments A and C**, the curves would become **significantly smoother**. We propose that these missing cycles could be discovered by studying **network cycles within the Saros column over longer time intervals**.

   item The chart of the decimal parts of synodic periods for each cycle exhibits a **striking resemblance** to the cycle duration chart. This suggests that **eclipse recurrence is strongly influenced by the synodic period**.

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