Determining the Saros

By Brad Young

As you probably know, there is a New Moon every month*, where the Moon passes the Sun in our sky from morning to evening phases. So, why is there not a solar eclipse every month? The Moon is not in alignment with the ecliptic (the path the Sun appears to take), so the New Moon may pass north or south of the Sun. Because it is inclined to the ecliptic by 5° and the Sun and Moon only appear 1/2° wide in our sky, often there is no eclipse.

*It may be helpful to start off with a list of what "months" are:

- Sidereal Month = period for Moon to return to same position compared to distant stars
- Synodic Month = interval of return to the same lunar phase
- Draconic month = period for the Moon to pass through the same node
- Anomalistic month = time required for perigee to perigee

Most of us think of a month as a synodic month, for example, full moon to full moon. For determining the Saros, the synodic and the draconic month are of greatest interest.

ECLIPSE SEASONS

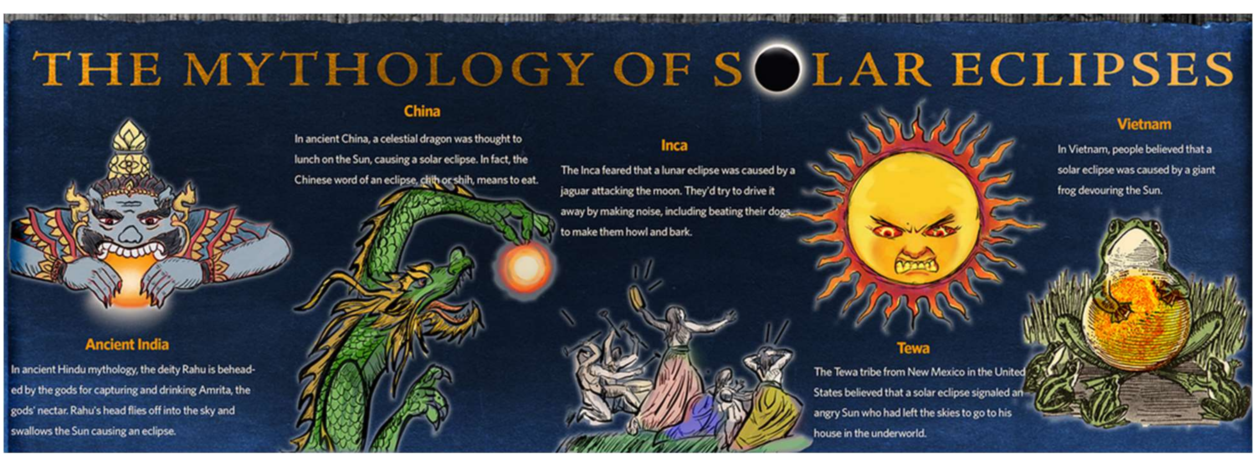
Black hole sun, won't you come, and wash away the rain? – Chris Cornell

The moon appears to cross the "orbit" of the sun at two points – at the Moon's ascending and descending nodes. New and Full Moons near these times – usually twice a year – may result in a lunar or solar eclipse. Lunar eclipses are wonderful sights, but can be seen from half the world when they occur. Solar eclipses, especially total ones, are much rarer for a specific location. Since astronomy began, we have tried to predict monumental events like solar eclipses. In fact, this is one of the quests that started astronomy, predicting eclipses, seasonal events, and the wandering planets.

Total solar eclipses, along with comets and perhaps meteor storms, were upsetting events that people strived to know about ahead of time. A stone in Ireland may record an eclipse that took place on 30 November 3340 B.C., contemporaneous the beginning of writing. Ancient Chinese eclipse records are accurate enough to allow us, millennia later, to calculate the slowing of Earth's spin and the rate at which the Moon is receding.

All over the world, different cultures reacted to solar eclipses in different ways:

- Native people in Colombia shouted to the heavens, promising to work hard and mend their ways.
- In Norse culture, an evil enchanter, Loki, was put into chains by the gods. Loki got revenge by creating wolflike giants, one of which swallowed the Sun—thereby causing an eclipse. (Another of the giant wolves chased the Moon, trying to eat it.)
- Fear led Chippewa people to shoot flaming arrows into the sky to try to rekindle the Sun. Tribes in Peru did the same for a different reason; they hoped to scare off a beast that was attacking the Sun.
- In India, the demon spirit Rahu steals and consumes the nectar of immortality but is beheaded before he can swallow it. His immortal head flies into the heavens. The Sun and Moon had alerted the gods to his theft, so he takes revenge on them: When Rahu swallows an orb, we have an eclipse—but the orb returns to view because Rahu has no body!
- Similarly, in China, Mongolia, and Siberia, beheaded mythical characters chase and consume the Sun and Moon—and we experience eclipses.
- In Indonesia and Polynesia, Rahu consumes the Sun—but burns his tongue doing so and spits it out!
- In Armenia, a dragon swallowed the Sun and Moon.
- In Transylvanian folklore, an eclipse stems from the angry Sun turning away and covering herself with darkness, in response to men's bad behavior.
- In India, many believe that when an eclipse occurs a dragon is trying to seize the two orbs. People immerse themselves in rivers up to their neck, imploring the Sun and Moon to defend them against the dragon.

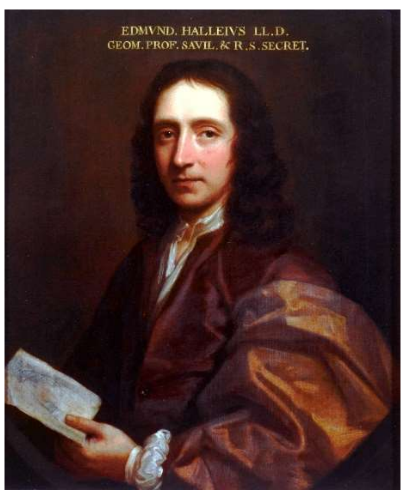


Meanwhile, attempts to predict a Total Solar Eclipse (TSE) met with mixed results. As amazing as sites like Chaco Canyon are, there is no evidence that people living in the SW US could predict eclipses. The Tewa of the Rio Grande dreaded the eclipse of the Sun. This may be because many Native Americans, such as the Dine, felt that “during the eclipse, we must always look down at the ground, cannot be looking up or outside.” These were real, sometimes terrifying events. Even today, some people commit violent acts against themselves or others during a TSE.

THE SAROS

The modern astronomical usage of the word saros is attributed to Edmond Halley, who based it on the word σάρος, defined in the Suda as "a measure and a number among Chaldeans."

It is not known exactly when a scheme for predicting eclipses was developed, but it was almost certainly before about 575 BC. Chinese and Babylonians both independently knew of the Saros cycle. This is the cycle of the lunar nodes, as the pull of the Sun and Earth cause changes in moon’s orbit known as perturbations. All the characteristics of the lunar orbit are perturbed, including the sidereal month (Moon returns to the same star field). But where the other features of its orbit affect the type of eclipse, the Saros cycle predicts when a similar eclipse may happen.



Modern studies of the Saros cycle began with Edmond Halley. He rediscovered Saros studying the Moon to determine longitude more accurately, which was the focus of astronomy in his day. He predicted a Total Solar Eclipse in London 1715 to within 4 minutes and 19 miles and crowdsourced reports of this TSE to correct errors in Moon’s orbit. Considering the width of the path, or greatest extent of shadow of a TSE is 167 miles, that was no mean feat.

In his study, which lasted nearly 20 years, he determined the precession of the plane of the Moon’s orbit. This included the Saros cycle that had been found by many ancient civilizations to be the period it takes the Moon’s ascending node to move through 360° relative to the vernal equinox. The period is 223 lunar (synodic) months, or over 18 years. The direction of motion is westward, i.e., in the direction opposite to the Earth’s orbit around the Sun, if seen from the celestial north. This is the reason that a draconic month or nodal period (the period the Moon takes to return to the same node in its orbit) is shorter than the synodic month. After one nodal precession period, the number of draconic months exceeds the number of synodic months by exactly one. The cycles line up, and, like a slot machine hitting, we are rewarded with an eclipse.

WINNER!

However, Saros is not an integer number of days, and the Earth rotates 120° to the point of the eclipse (1/3 of the way around the Earth, to the west). For instance, the eclipse of 2017 many of us saw will have a similar sister total solar eclipse on September 1-2, 2035, located in China and the Pacific. A Greek astronomical clock called the Antikythera ("turning of the wheel") mechanism used epicyclic gearing to predict the dates of consecutive exeligmoses and is the root of our modern word.

It is important to note that this does not mean that eclipses occur only with spacings of several years. At any time, there are many interleaved Saros cycles in action: 39 at present. This is why we may have up to five solar eclipses per year, though many of those may be only slightly partial, or located in extreme reaches near the poles. It also explains why the American eclipses of 2017, 2023, and 2024 can occur close together.

Determining Saros

We will either find a way…or make one – Hannibal

By following a method carefully, over several months, you too can determine the Saros Cycle by simple means.

Assumptions

- Assume Moon's orbit is circular (this will remove effect of the anomalistic month)
- Assume the orbits of the Moon and Earth remain unchanged over the entire cycle of interest (no perturbations)
- Choose field stars and moon phases to make the calculation easier, e.g.:
    - Choose a bright star to check the sidereal month
    - Choose a phase around first quarter to get the synodic month
    - The difficult nodal crossing observations will be near New Moon, so start the project soon after a solar eclipse (even a poor one, or one you could not see)

This will give you several months before the sun reaches the other nodal crossing, at the next eclipse season

- Don't forget there are two nodes; eclipses occur at either one, but each should be considered separately for the calculation

Methodology
In recording the position of the moon, we will start near the positions of the last eclipses. So, if the last eclipse was a lunar one in Aries, concentrate on the Moon in Aries, and the mirror of it in Libra. One of these is the Ascending, the other the Descending node.

Method:

- Sketch or image moon, capturing a few stars in the field
- Record time to nearest minute
- Use those nearby stars and a star chart to find the Moon's position
- Find position within +/- 2° (4 moon widths)
- Repeat for at least 6 months (more preferred)

Note that you should concentrate on getting positions around the node crossings; the sidereal month is not needed for the calculations; however, you may find calculating it to be an interesting exercise also.

Calculations:
From your careful records, you should easily notice the time required to return to the same field of stars (sidereal month - optional), back to the same phase as before (synodic month) and, less easily, the motion of the nodes over several months. Once you see the approximate motion, you can extrapolate to determine the time of entire circuit. There will be a solar eclipse of similar type as before at the point where the draconic month and synodic month line up. The period from the previous eclipse to this line up point is the Saros and is attended by another eclipse.

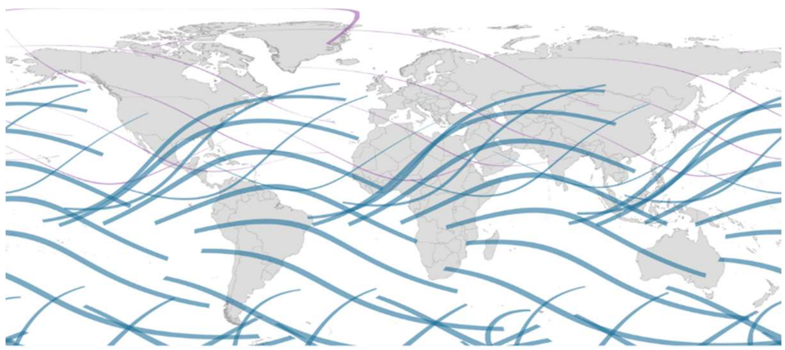
We can't say the next eclipse will be at the same location, as this is affected by rotating Earth. If the Saros cycle was exact in days, it would be located very close to the previous spot, but as it is not, the eclipse will occur at a location to the west. There is another cycle (the Exeligmos) which determines when you will see an eclipse at the same location, but that is a topic for another day. There is also the matter of the type of eclipse; it will be solar, but whether it is Total, Annular, or Partial is determined by the anomalistic cycle (the effect of the Moon's orbit being an ellipse, not a circle).

Numbering Saros
The Saros Cycles are numbered, for instance the TSE on April 8, 2024, is in Saros 139. The system for numbering was developed by Dutch astronomer G. van den Bergh in the 19th century. The upcoming American Eclipse (the Sequel) on April 8,2024 is #30 of Cycle 139. Saros cycles usually start and end at the poles, usually with poor partial eclipses seen only by polar bears. #1 of Cycle 139 occurred on May 17,1501, as a partial eclipse of the sun with 9%

covered. The “Last of Us” moment for Cycle 139 will occur on July 3, 2763 at 6% covered for the penguins to watch as they stand on their eggs.

I find it interesting that #30 is an amazing total solar eclipse, its path through our state, to be seen by millions on my son’s birthday, while the final hurrah of this Saros cycle is on my 797th birthday. I might not be there with the penguins, but I will be there with Gus next year, standing under the dark side of the Moon.

SAROS CYCLE 139



Suggested resource: **[March 2023 Astronomy Club of Tulsa Presentation Observing Session 5]**

There will be no doubt an avalanche of new books on the 2023/2024 solar eclipses, but here is a selected bibliography and the sources for this article:

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SAROS

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