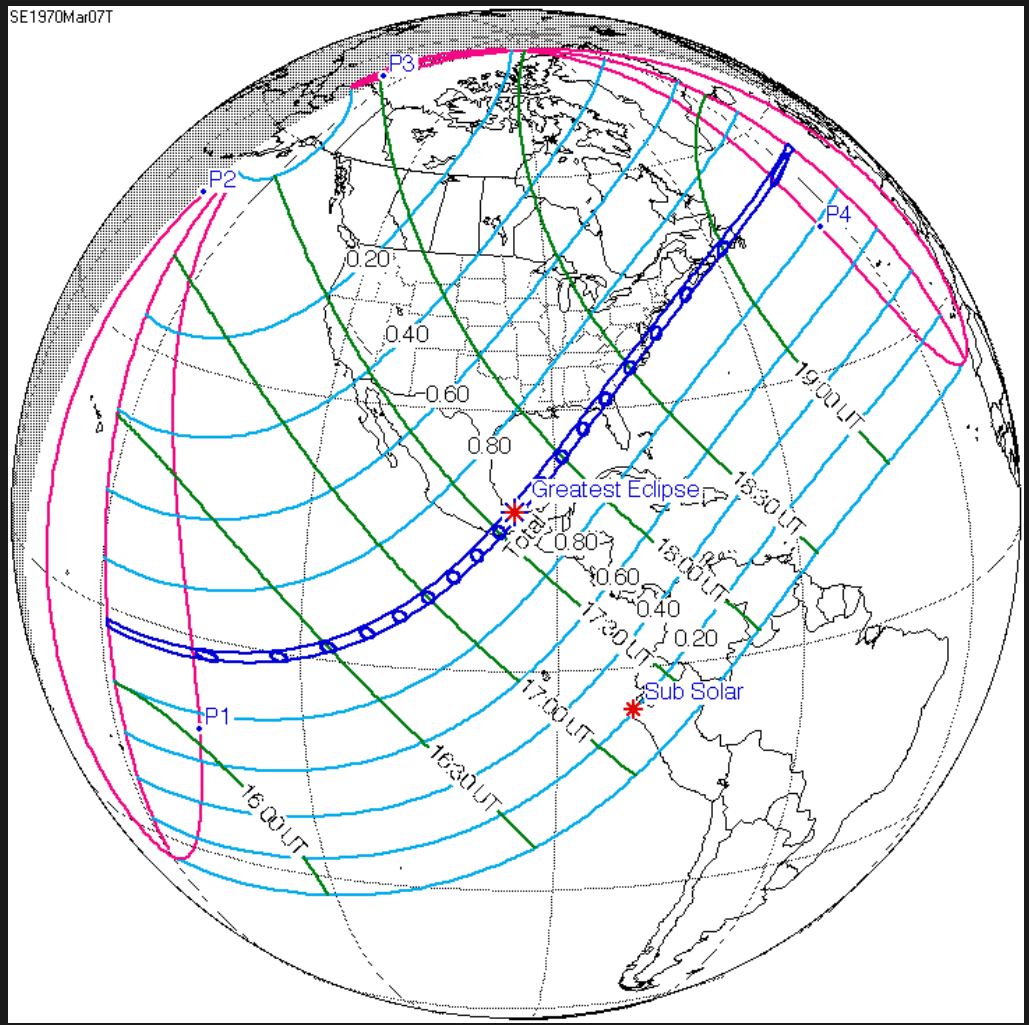
Solar eclipses:
Why they happen when they do

Doug Ravenel
University of Rochester

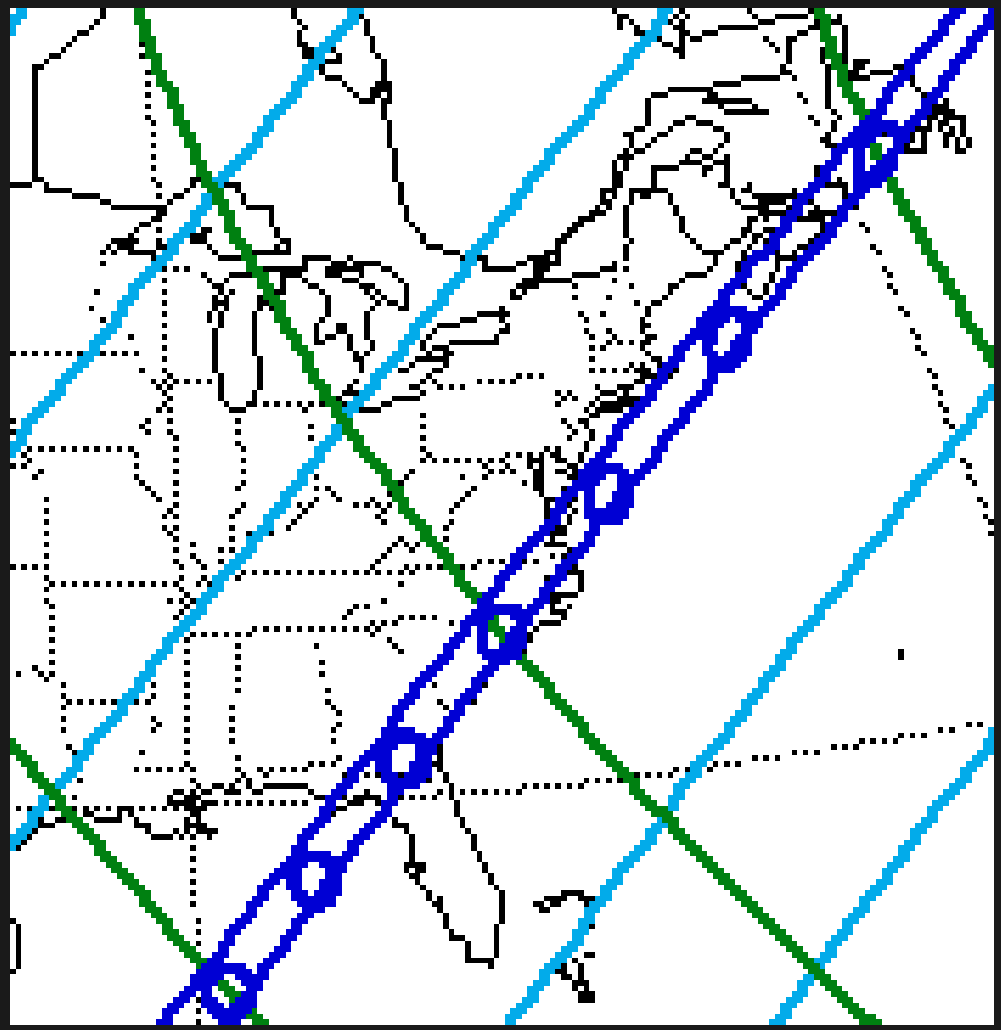
March 22, 2024

My first total solar eclipse



March 7, 1970

My first total solar eclipse (continued)



March 7, 1970

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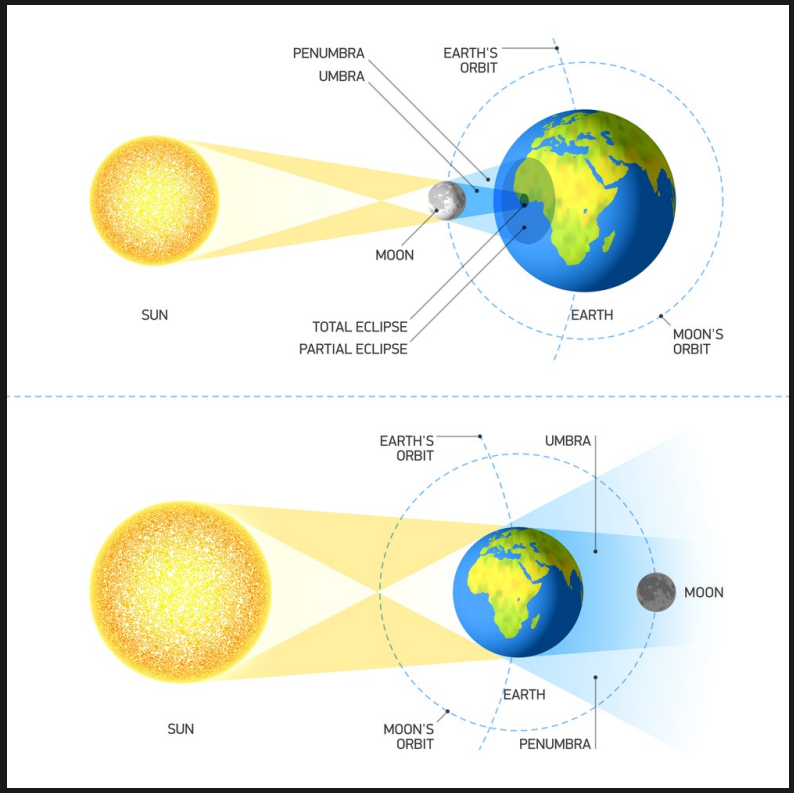
Basic facts about eclipses



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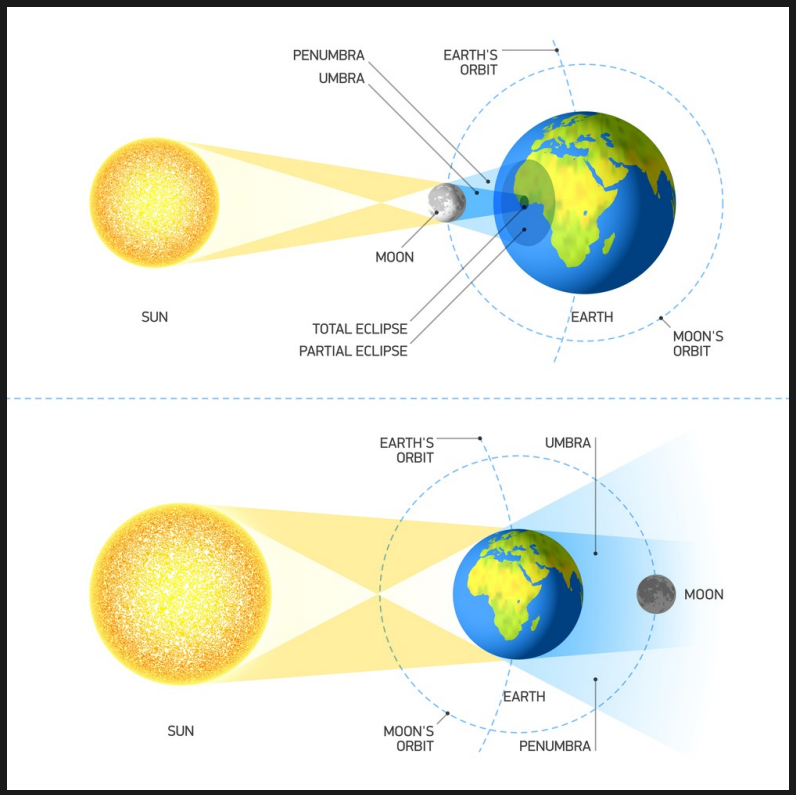

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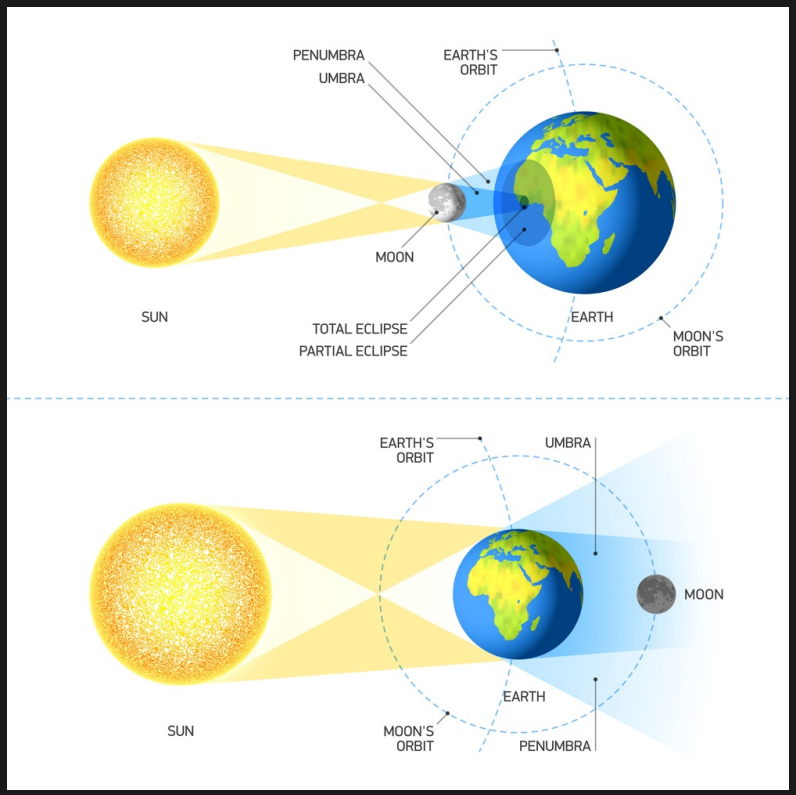

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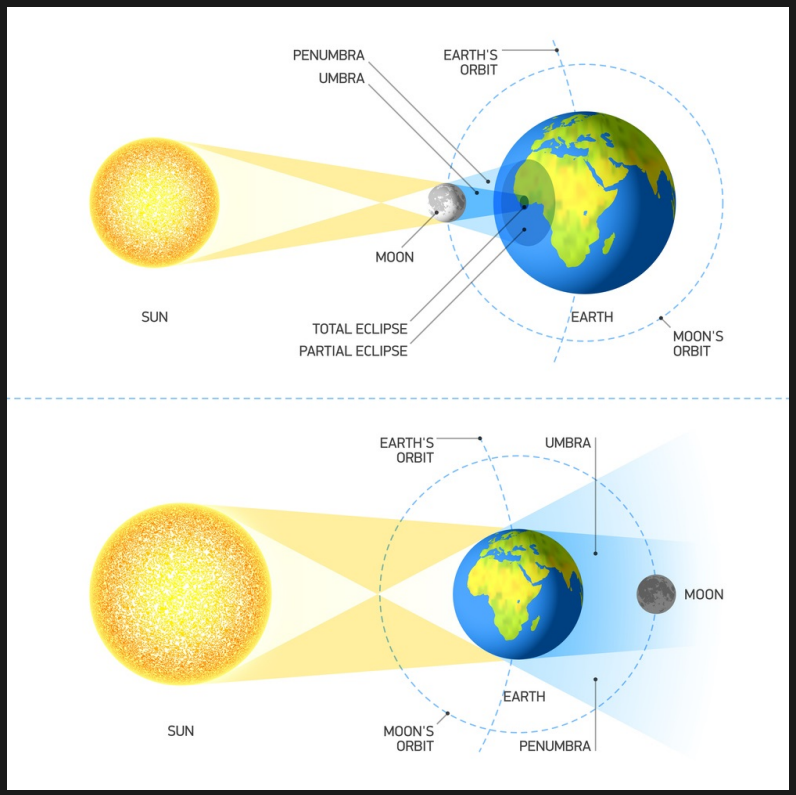

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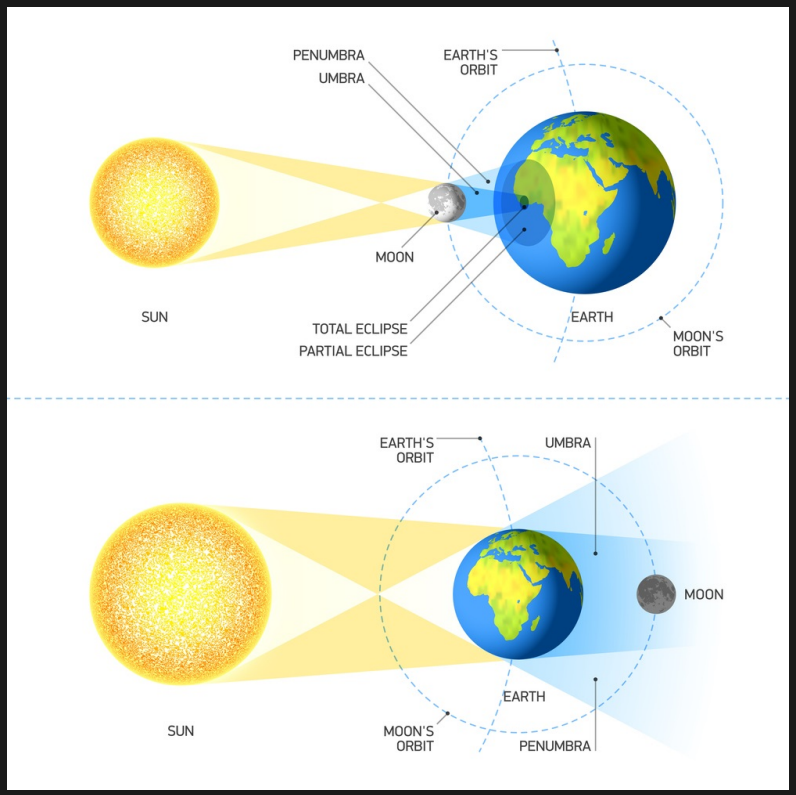

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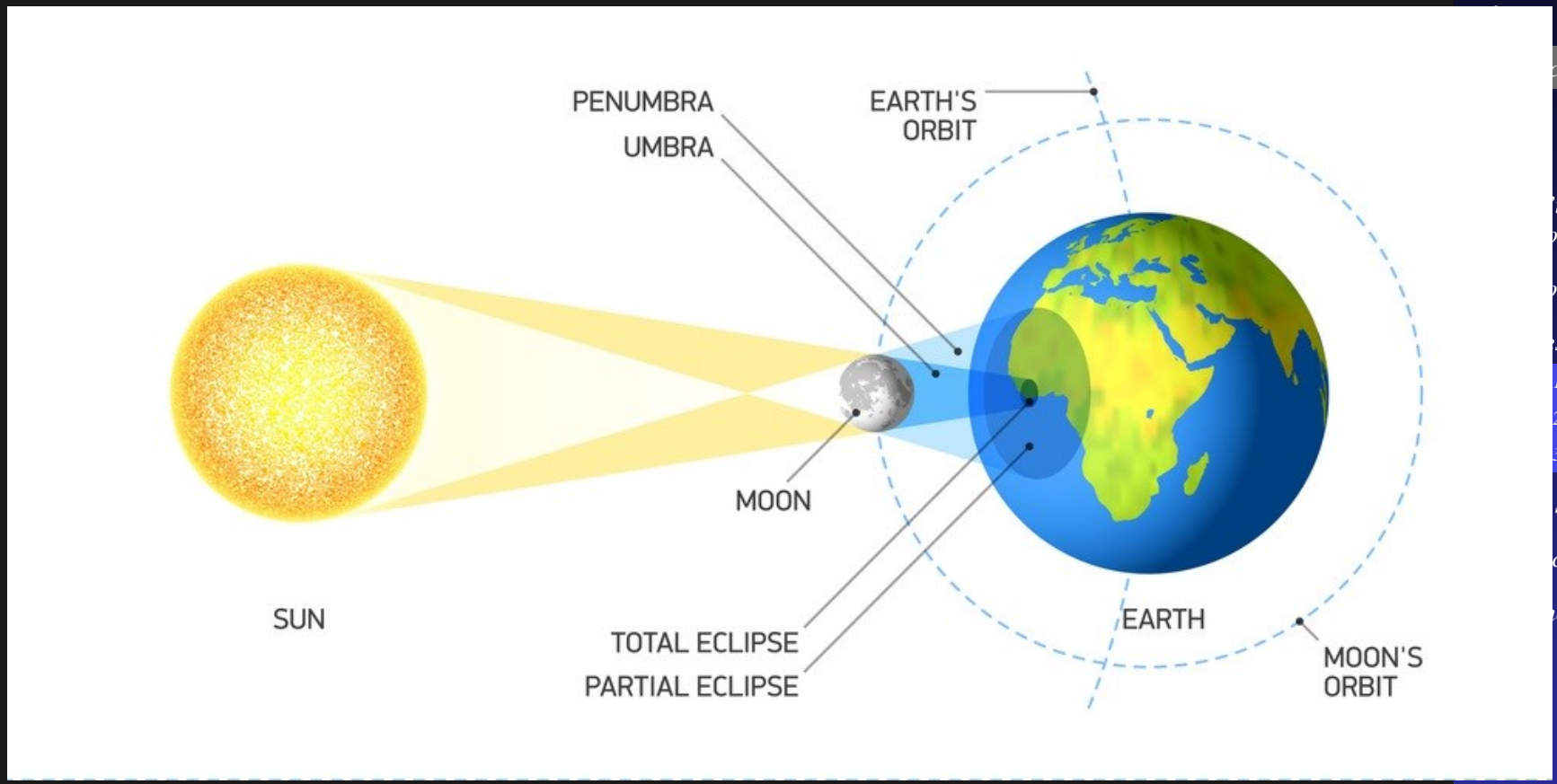
Basic facts about eclipses (continued)



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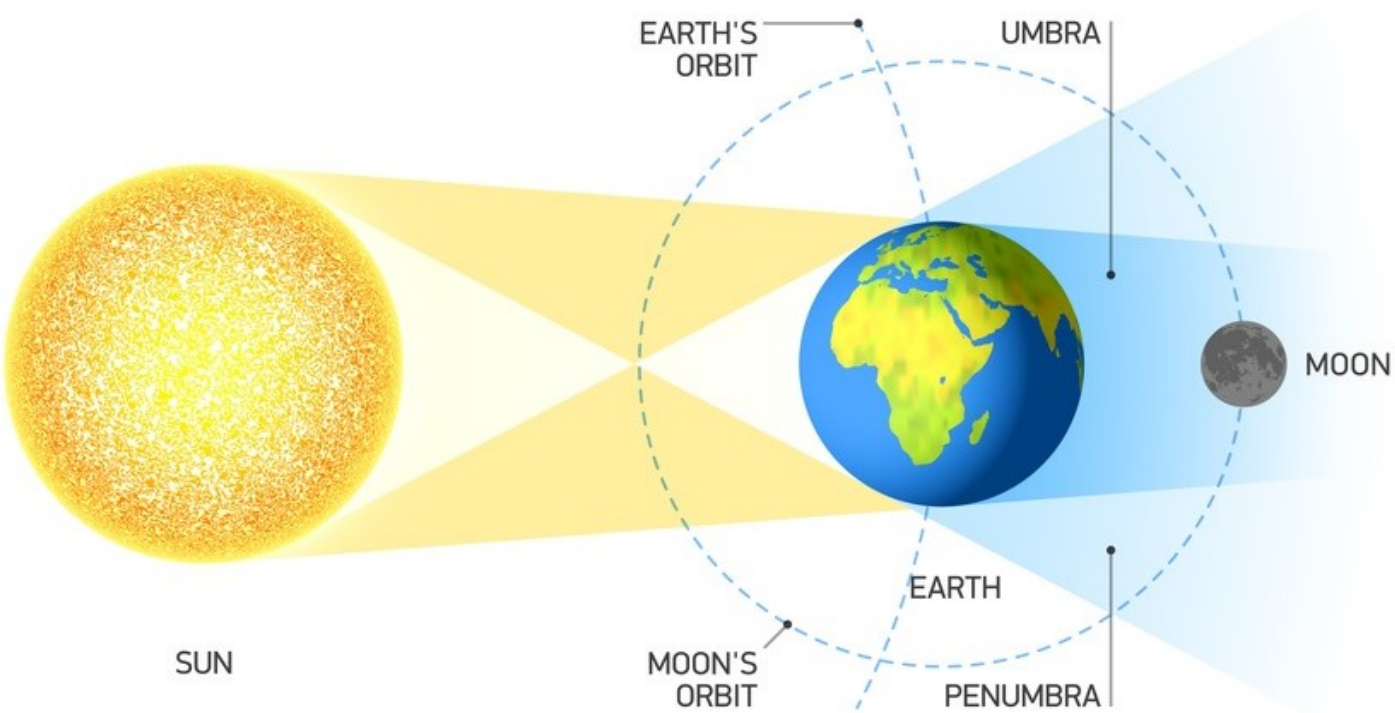

Basic facts about eclipses (continued)

The eclipse of March 8-9, 2016 seen from space.
The moon's shadow is over Indonesia.

More basic facts about eclipses

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No other moon in the solar system has this property.

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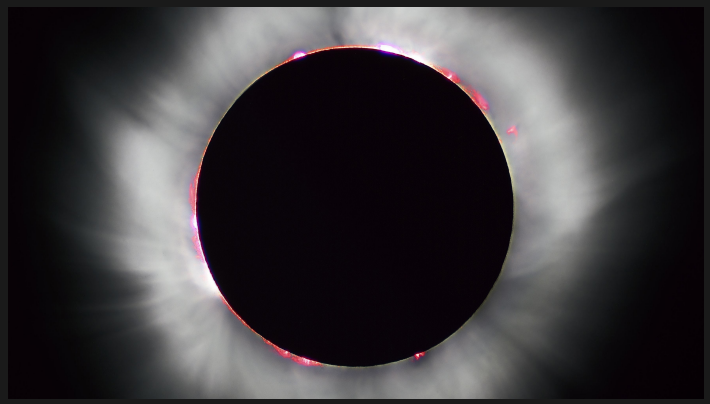

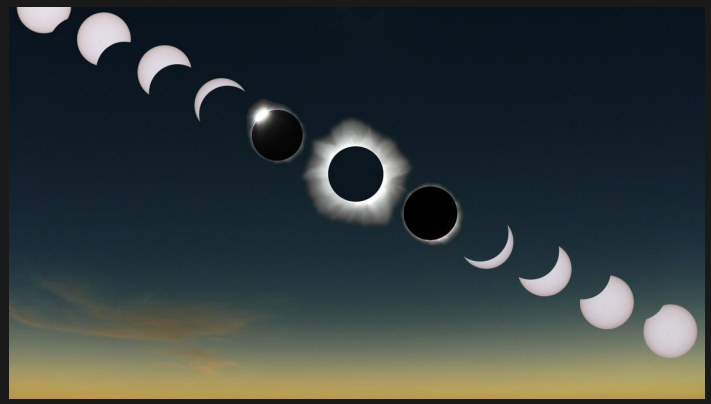

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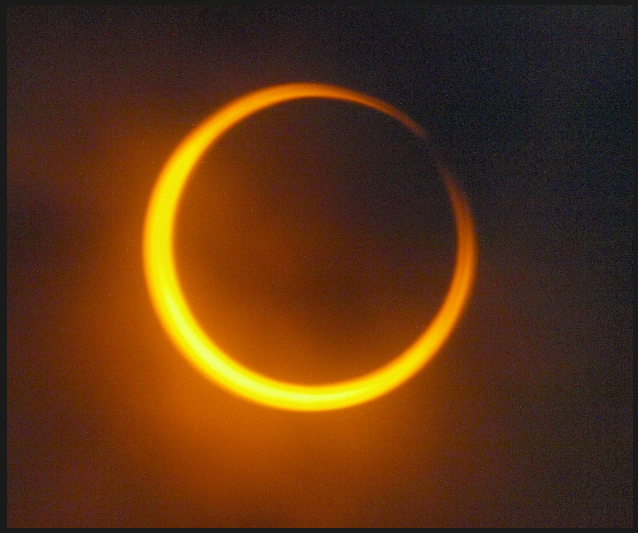

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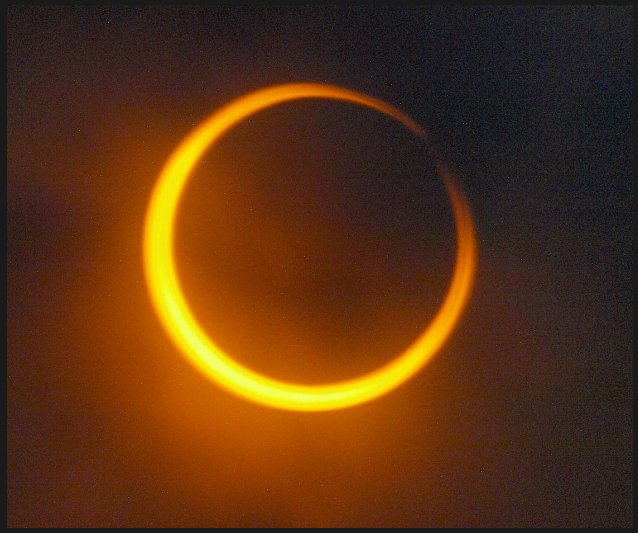

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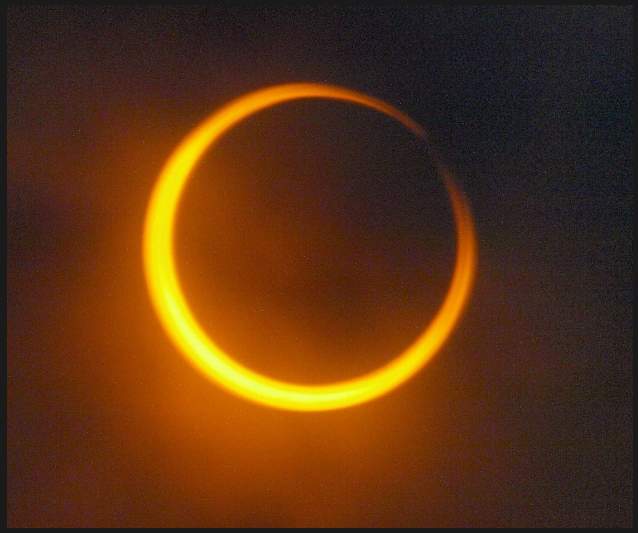

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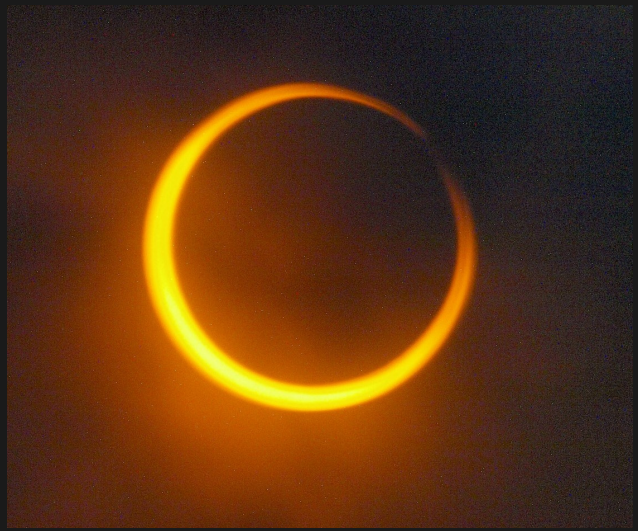

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https://www.timeanddate.com/eclipse/solar/2024-april-8

Sidebar: Living on the moon

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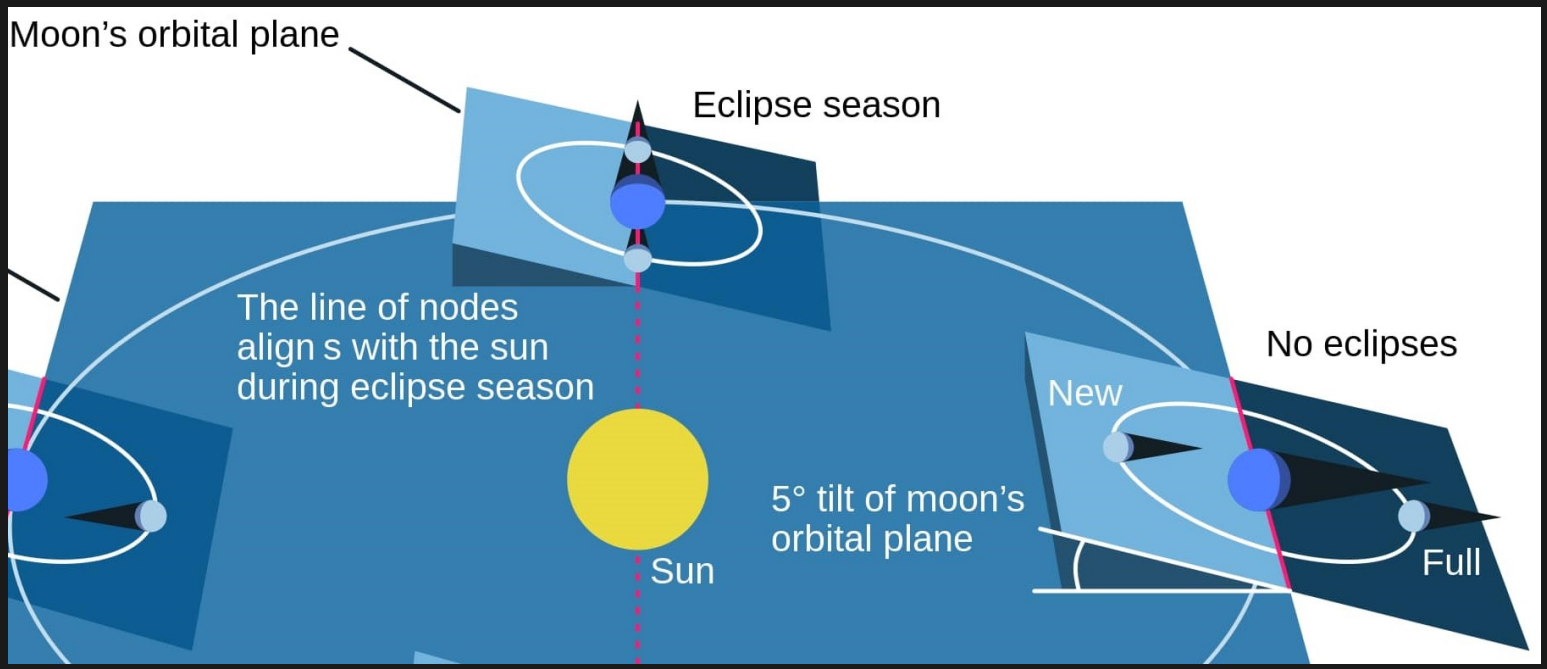
https://en.wikipedia.org/wiki/Solar_eclipses_on_the_Moon

Why isn't there an eclipse every month?



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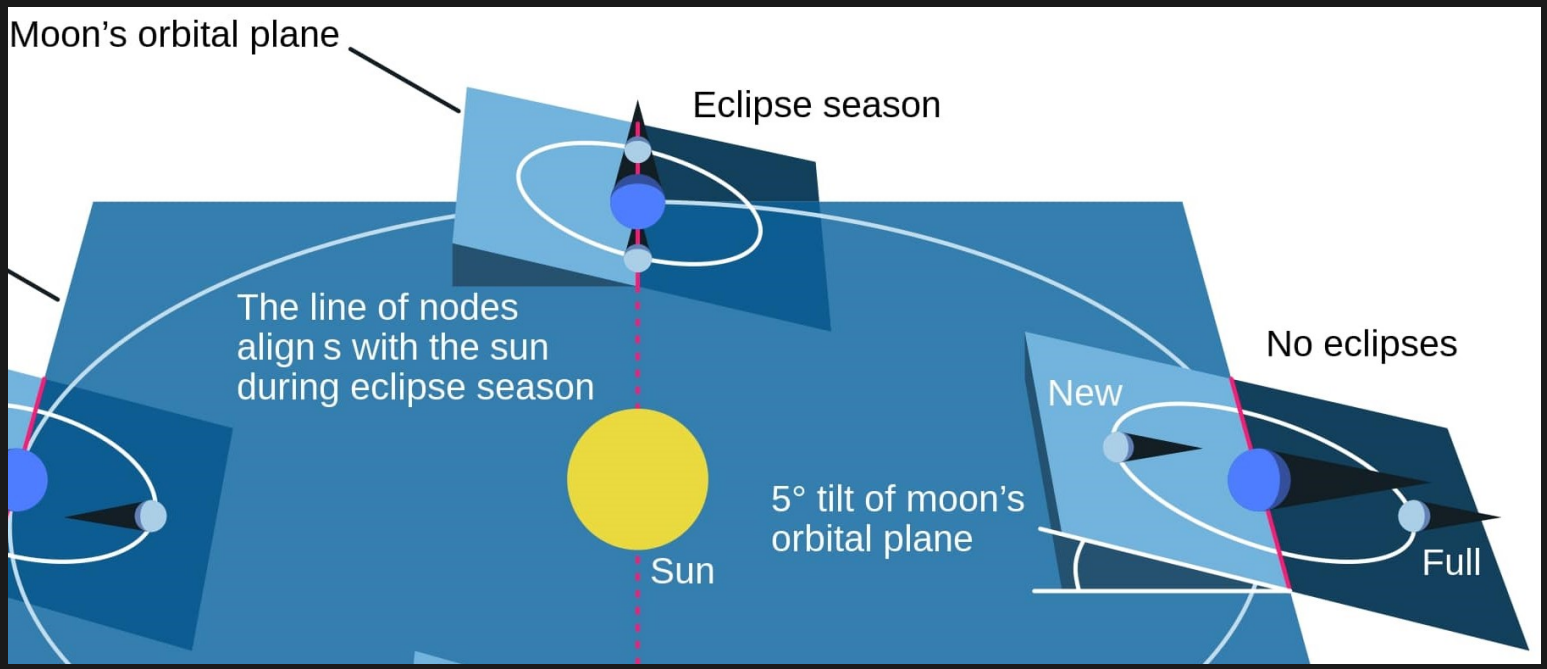

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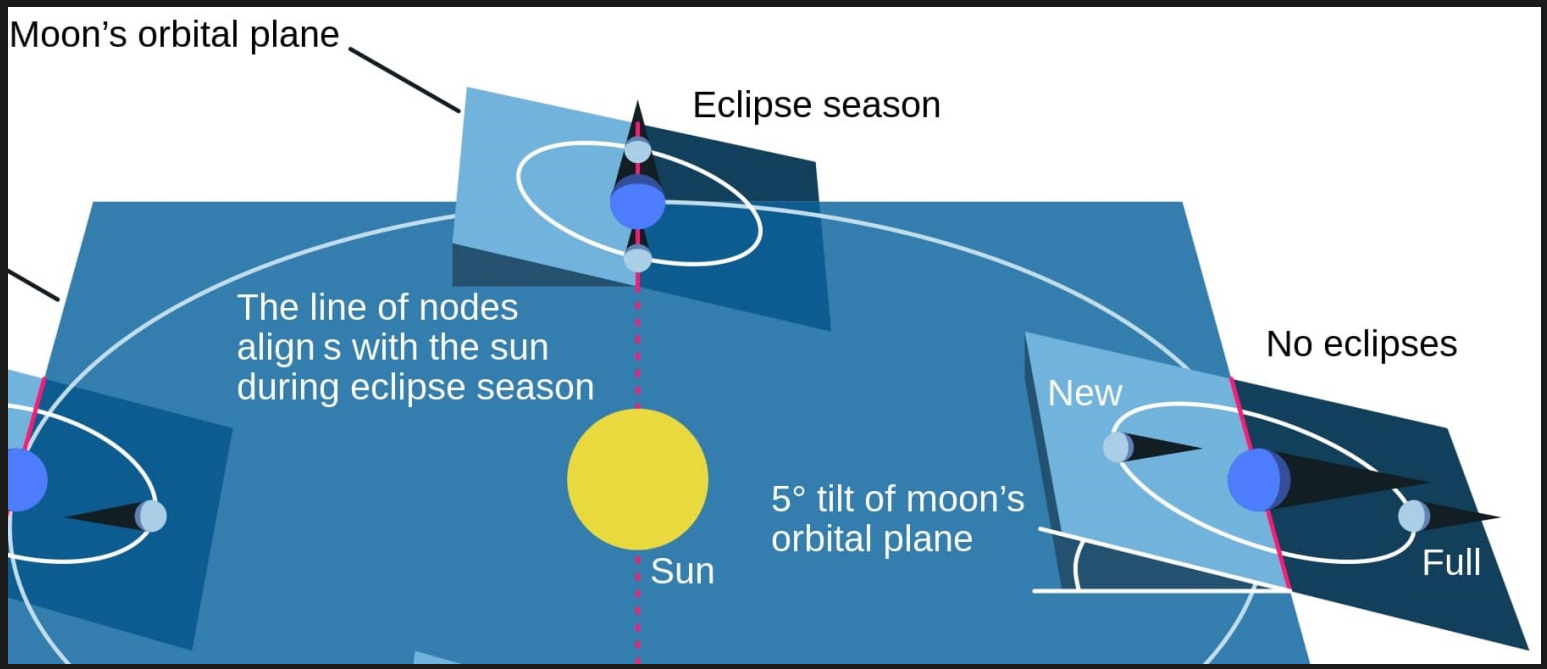

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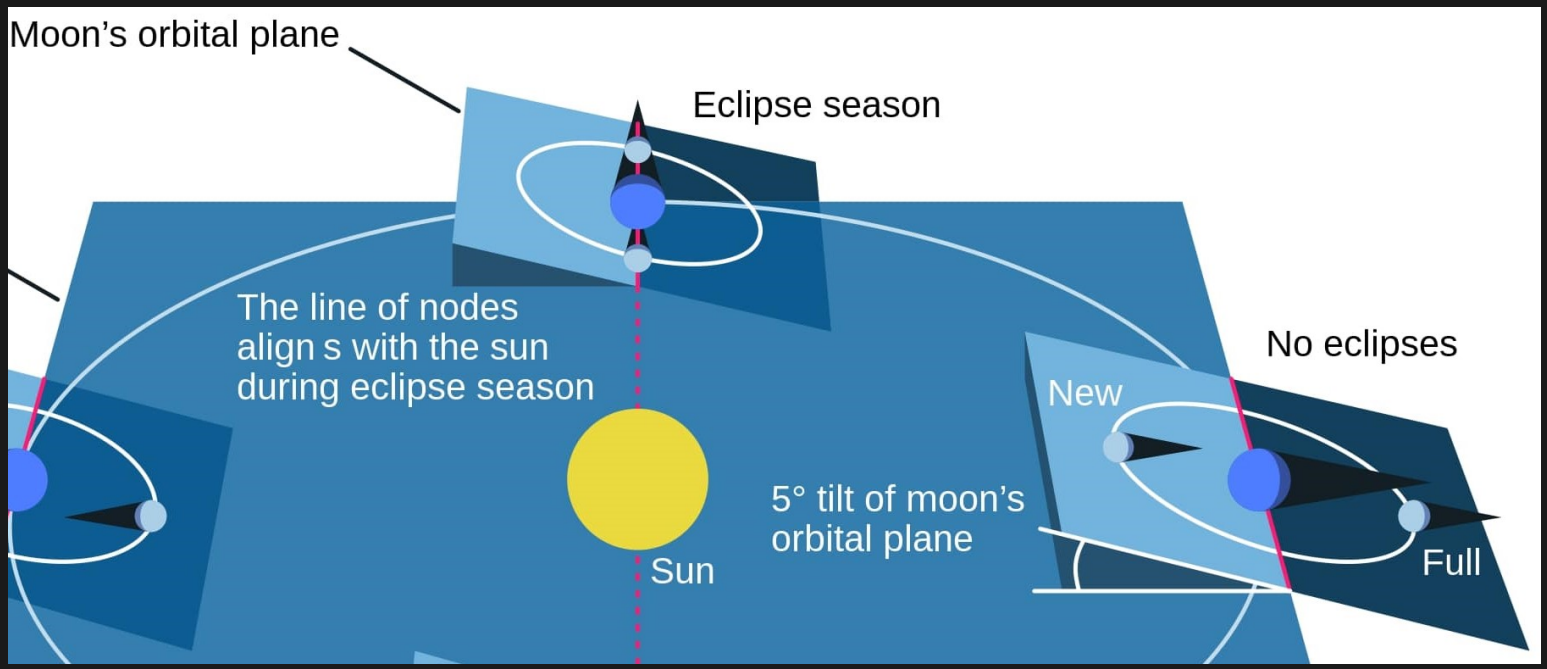

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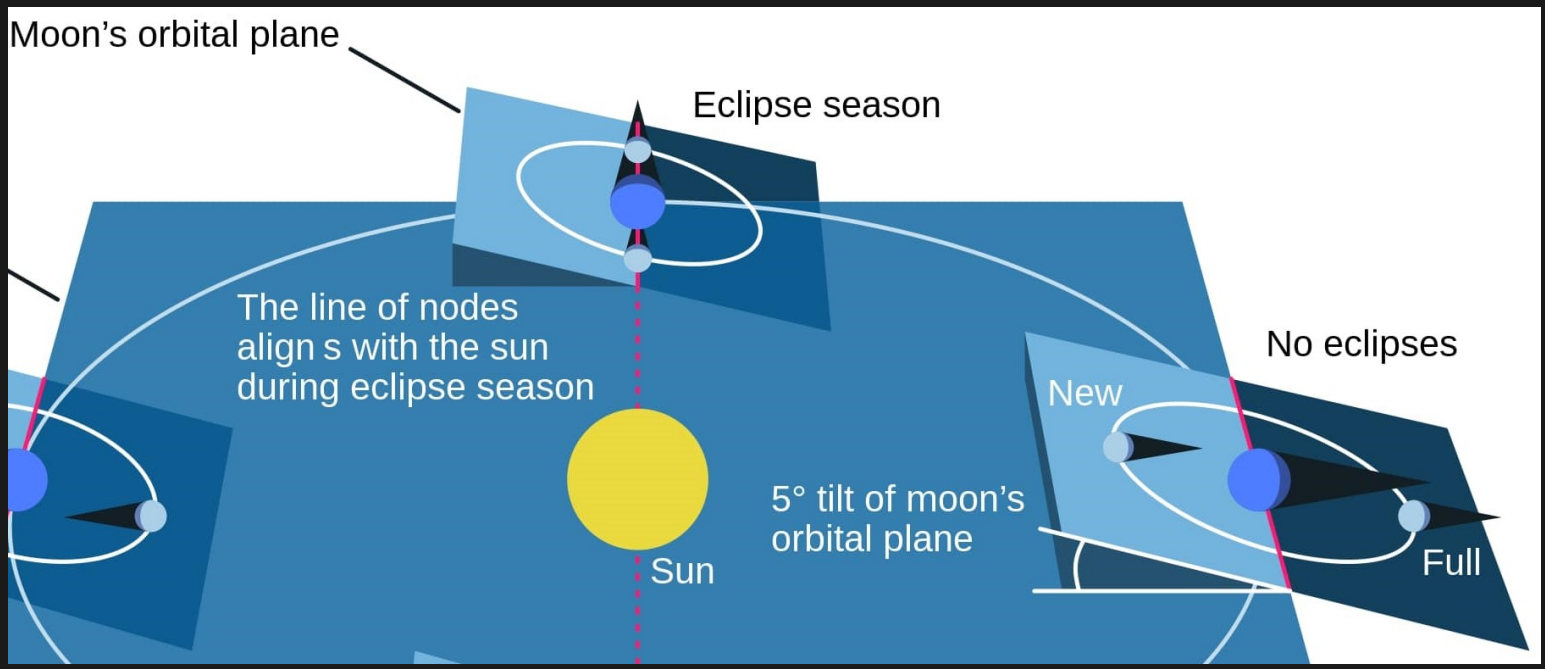

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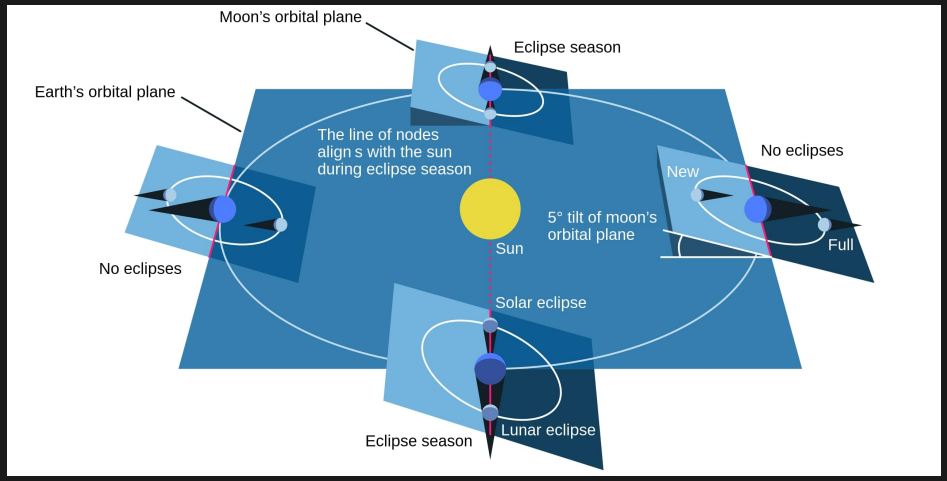

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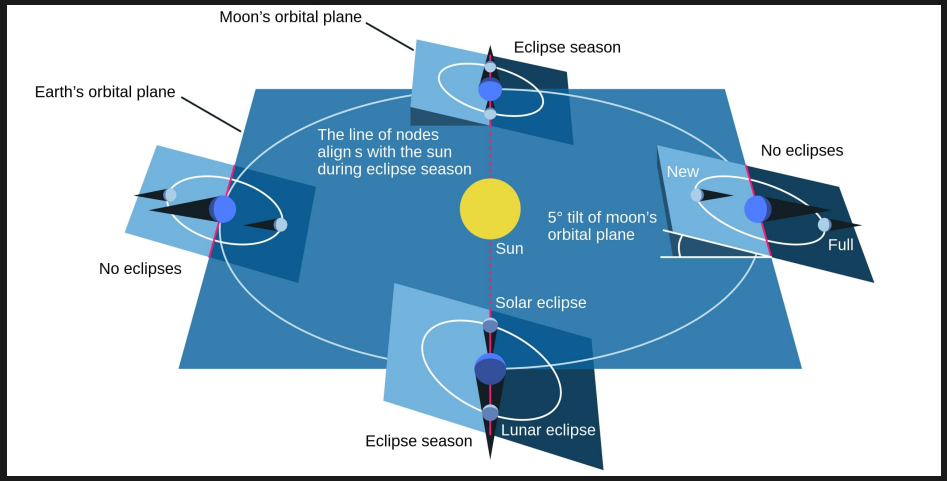

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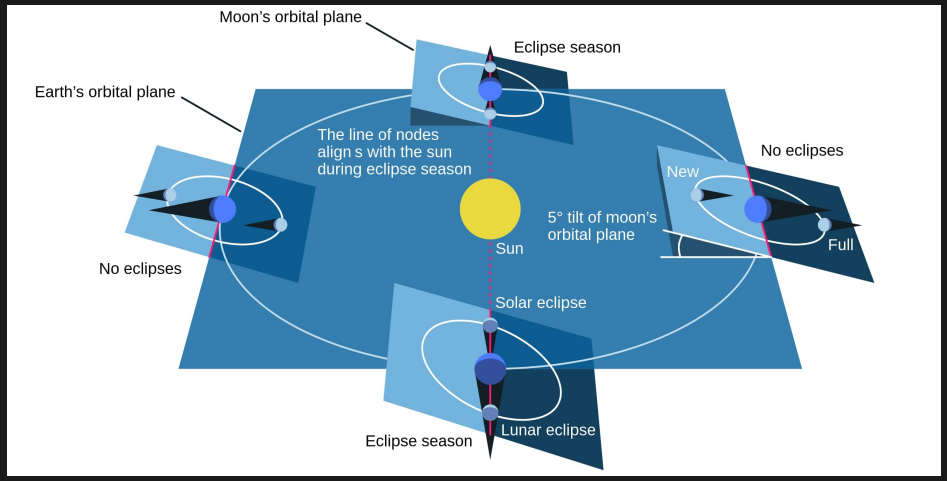

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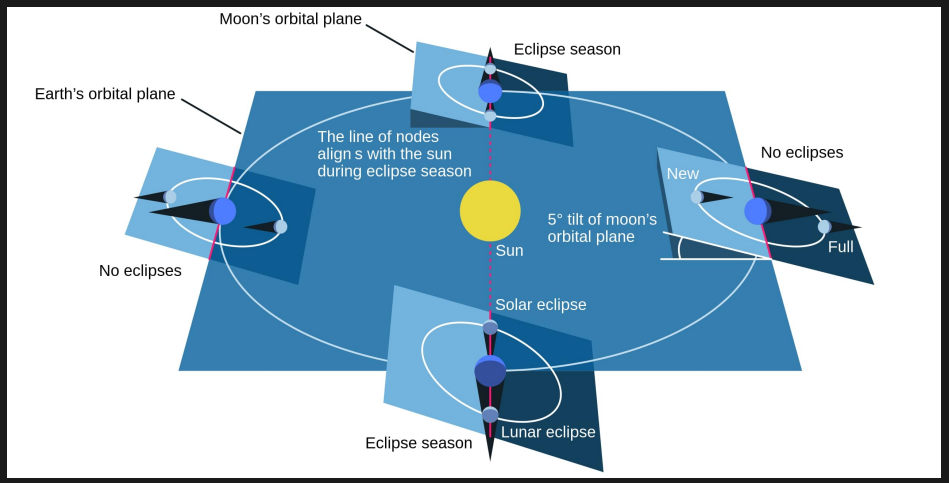

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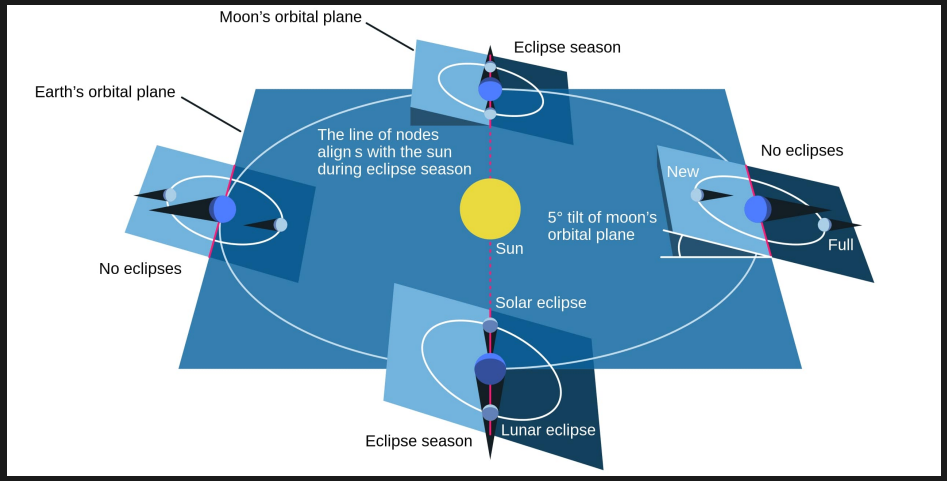

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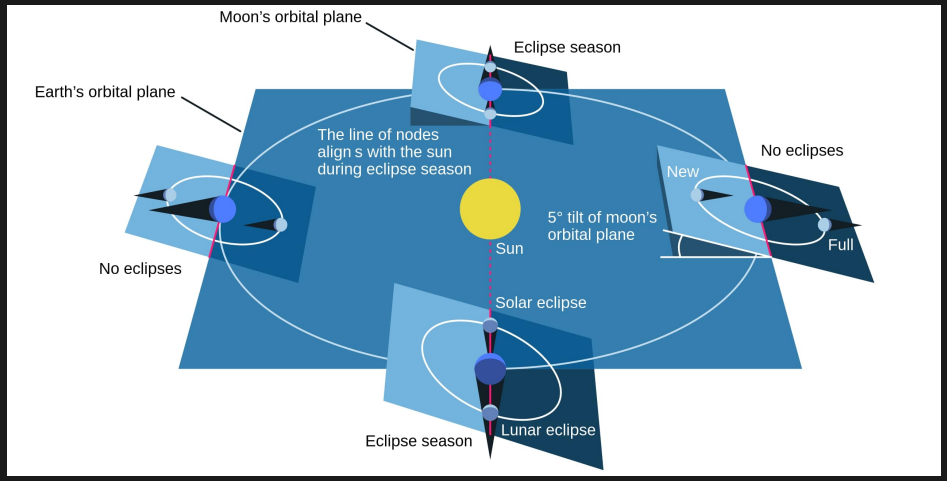
Meanwhile the line of nodes itself rotates clockwise roughly every 18.60 years. This means the time of the eclipse season changes gradually.

Why isn't there an eclipse every month? (continued)



Each red line in the picture is the line of nodes. Eclipses can occur only during the time of year when it is pointing toward the sun (within a few degrees), known as eclipse season. It occurs roughly twice each calendar year.

Meanwhile the line of nodes itself rotates clockwise roughly every 18.60 years. This means the time of the eclipse season changes gradually. It is April/October now but was August/February in 2017.

The Saros series

Over 2000 years ago Babylonian astronomers noticed that eclipses (both lunar and solar) occur in cycles of roughly 18 years.

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A solar/lunar eclipse is almost always followed by a lunar/solar eclipse half a saros or sar (roughly 9 years) later.

I will explain later why this happens. First we will look at three examples of solar eclipses in the same Saros series.

Doug Ravenel

Example 1: Saros series 139

Three Saros periods back from April 8, 2024, gets us to March 7, 1970,

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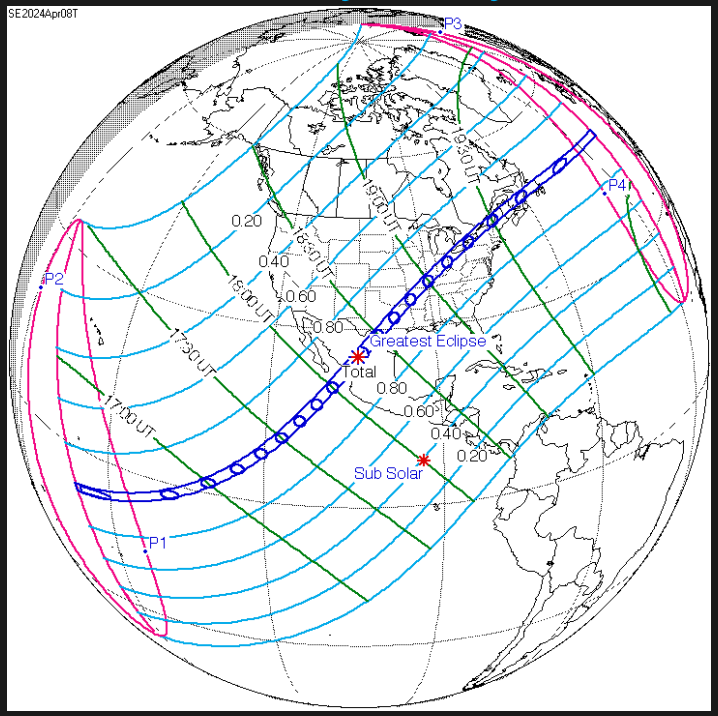
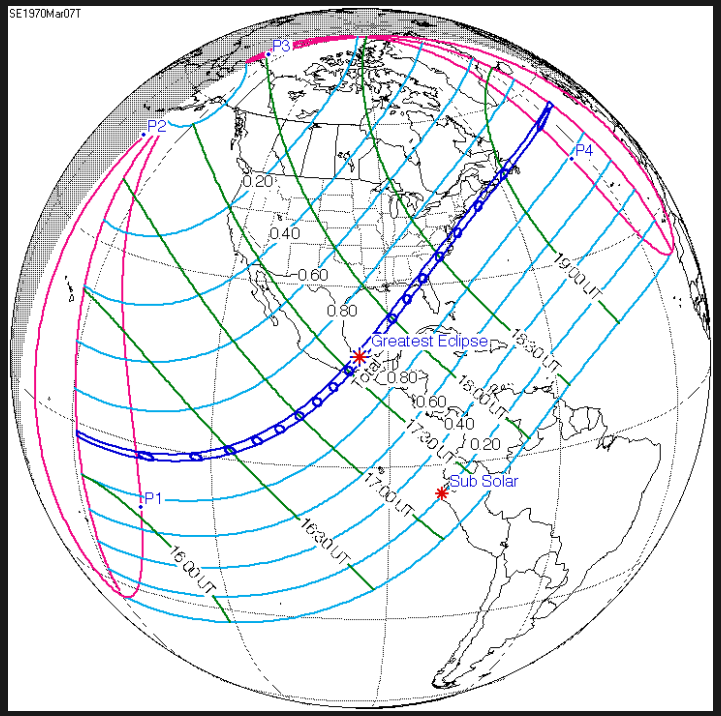


April 8, 2024



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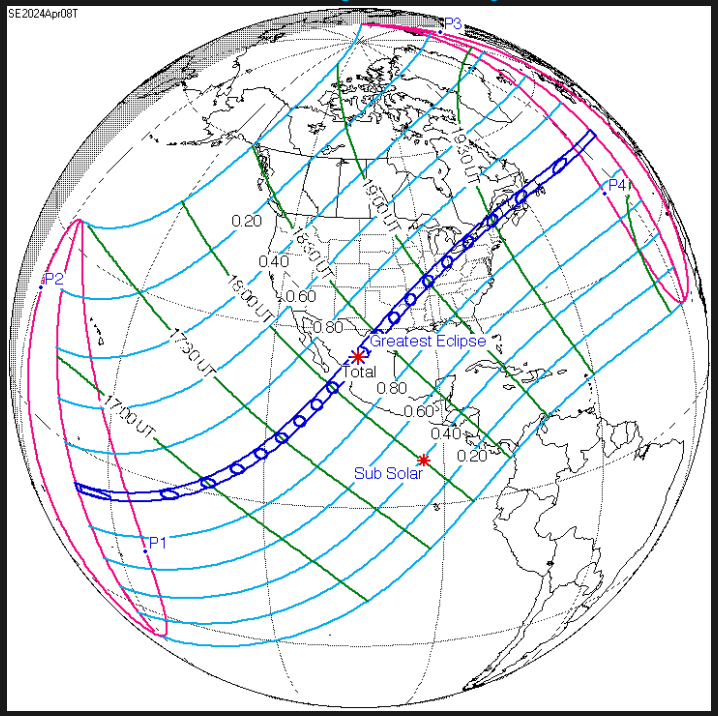

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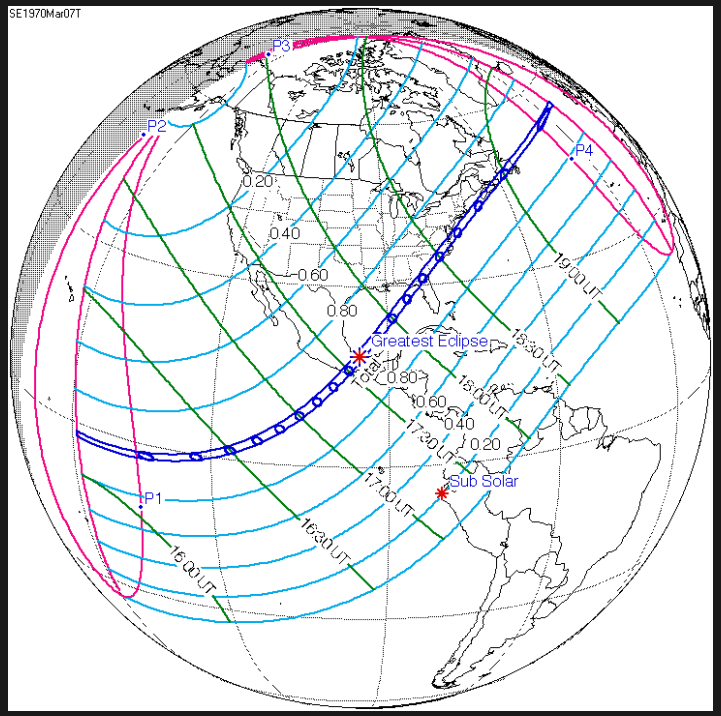

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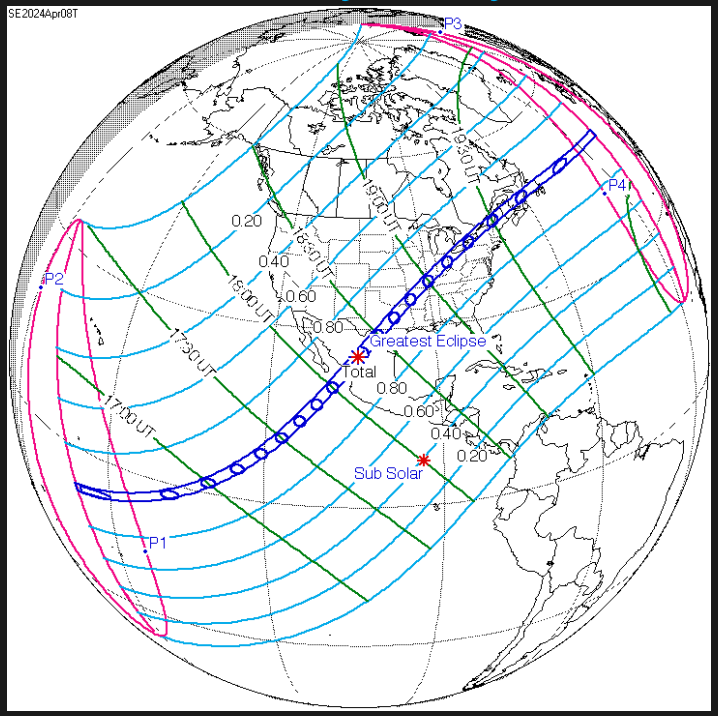

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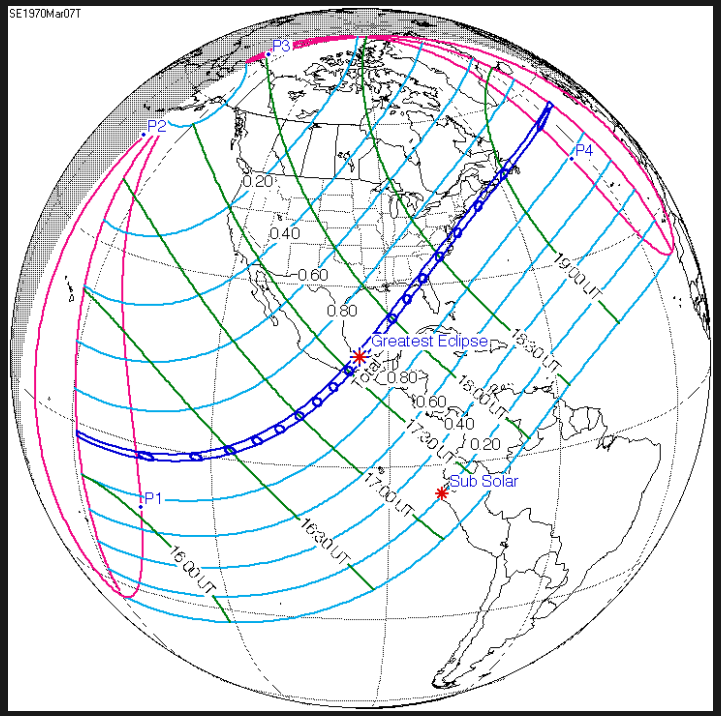

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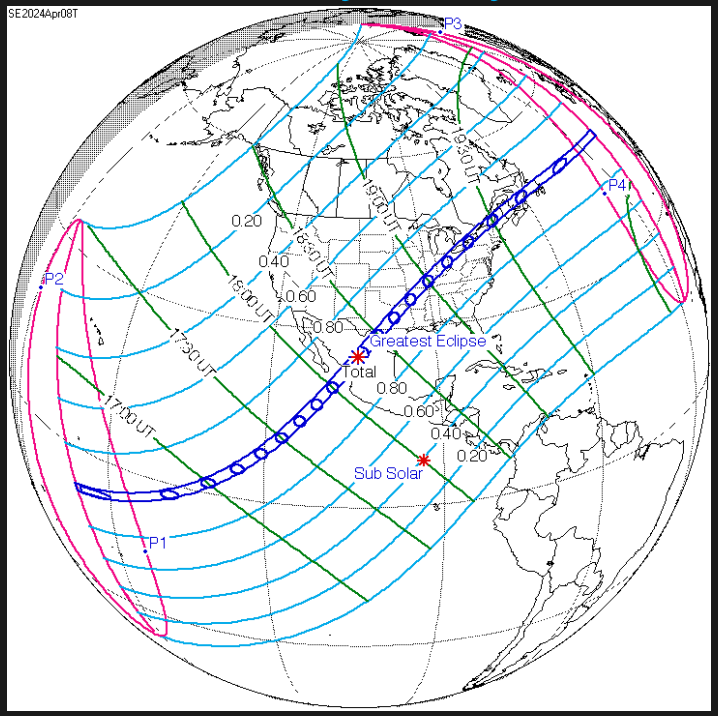

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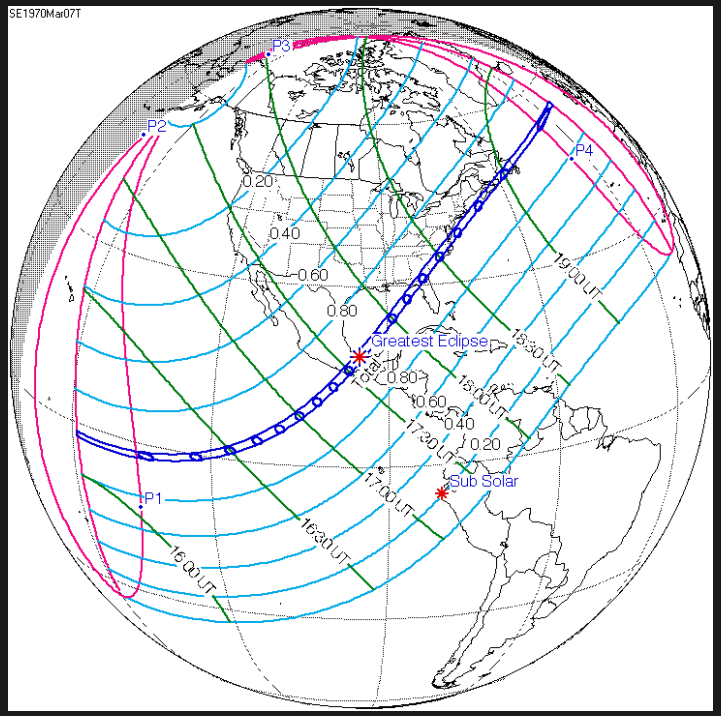

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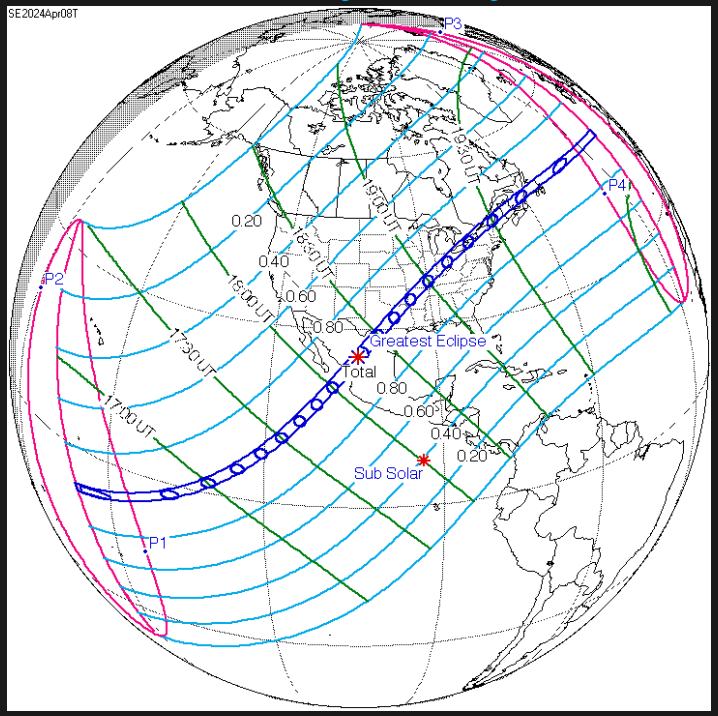

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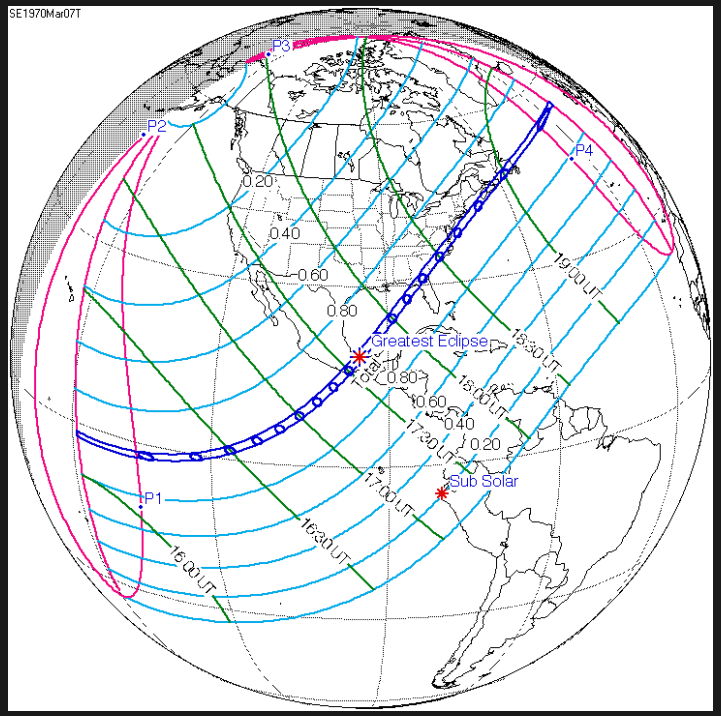

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A nice thing about this Saros series is that the eclipses in it are getting longer. The one next month will last longer than the one I saw 54 years ago. The length of totality will peak in 2186 (9 cycles away) at 7 minutes 29 seconds, making it the longest one in 10,000 years!

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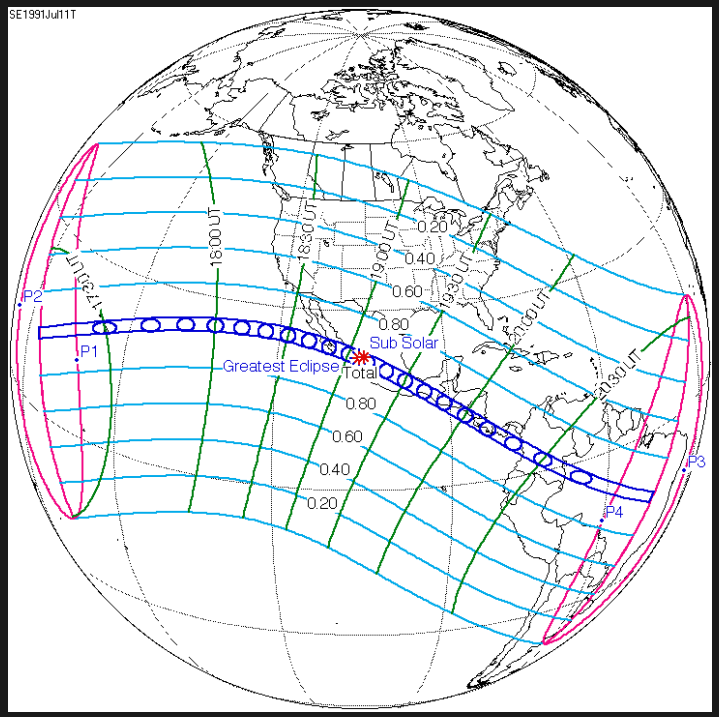

July 11, 1991

In 1991 there was a solar eclipse visible in Hawaii and Mexico.

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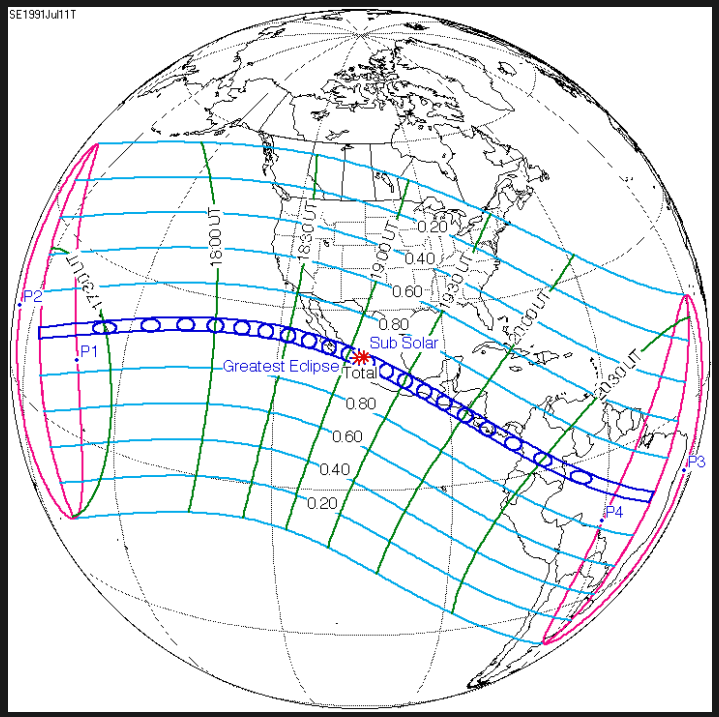

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In 1991 there was a solar eclipse visible in Hawaii and Mexico. The Keck observatory atop Mauna Kea on the big island was in its path, and skies were clear there

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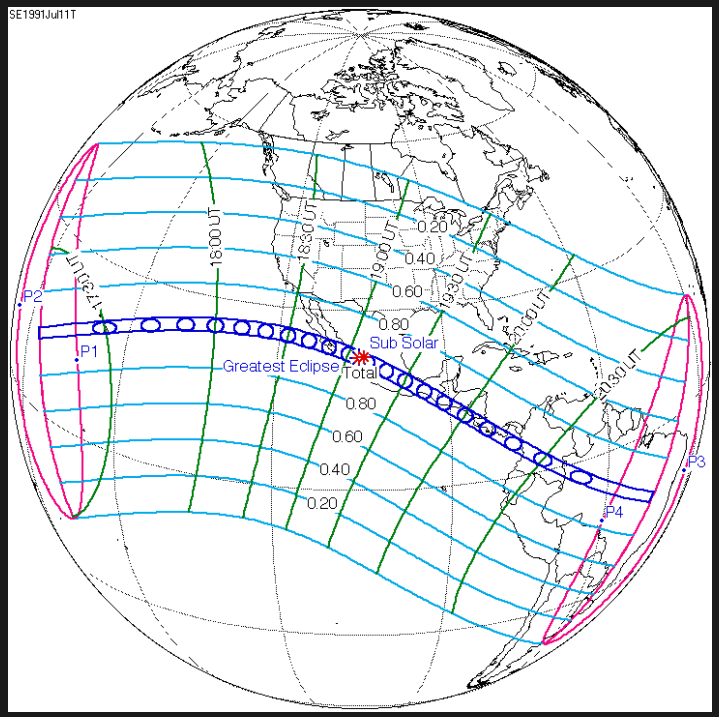

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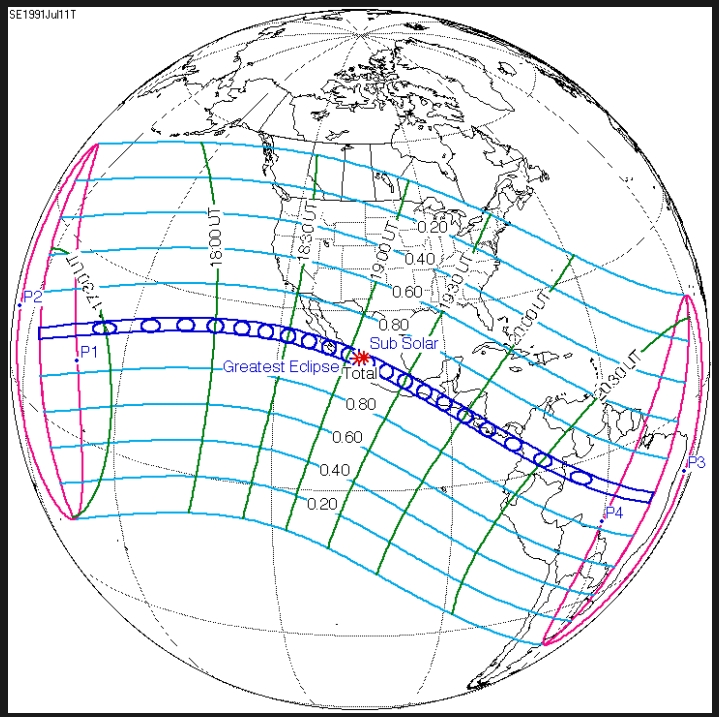
In 1991 there was a solar eclipse visible in Hawaii and Mexico. The Keck observatory atop Mauna Kea on the big island was in its path, and skies were clear there but some beaches on the island were clouded out.

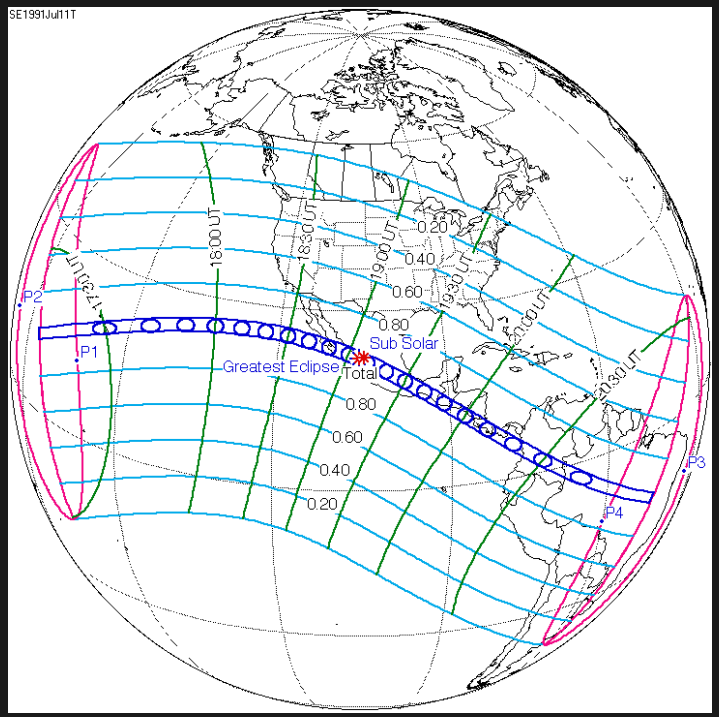
Example 2: Saros series 136 (continued)



July 11, 1991

There was an algebraic topology conference in Mexico organized around the eclipse at a site south of Mexico City.

Example 2: Saros series 136 (continued)



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There was an algebraic topology conference in Mexico organized around the eclipse at a site south of Mexico City. We had clear skies, after several days of clouds.

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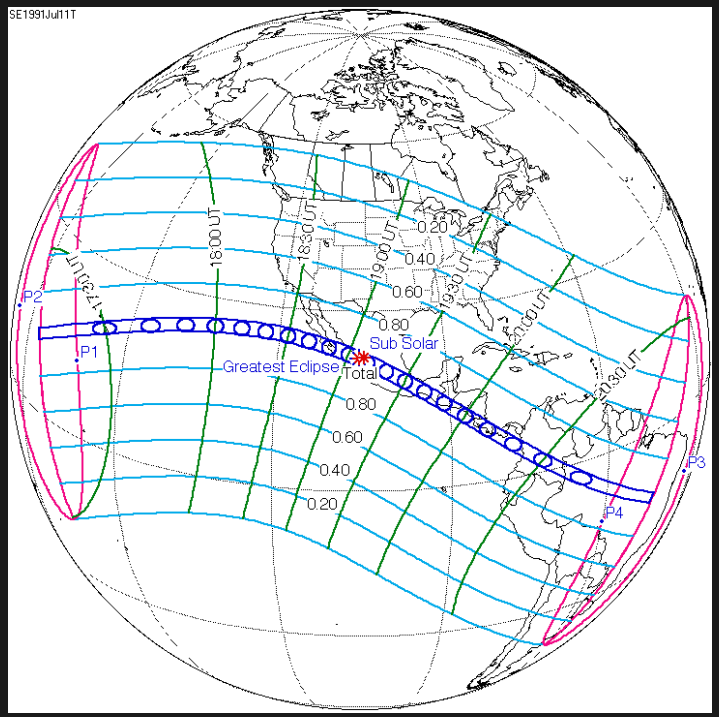

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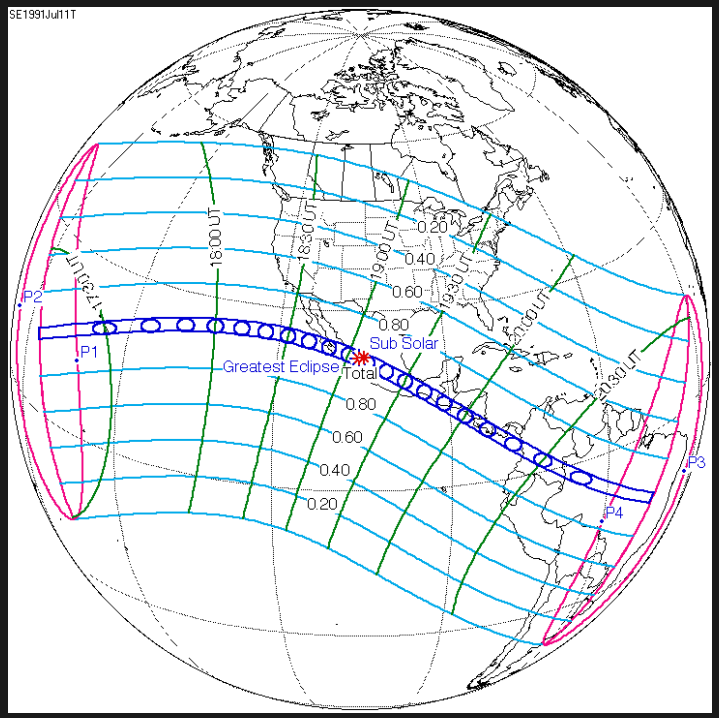
Teotihuacan is a spectacular archeaological site north of Mexico City.

Example 2: Saros series 136 (continued)



July 11, 1991

Teotihuacan is a spectacular archeaological site north of Mexico City. Ten thousand people gathered there to watch the eclipse.

Example 2: Saros series 136 (continued)

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Those ten thousand tourists were not only clouded out,

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Example 2: Saros series 136 (continued)

Those ten thousand tourists were not only clouded out, the eclipse made it rain on them!

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Those ten thousand tourists were not only clouded out, the eclipse made it rain on them! Totality causes a small temperature drop.

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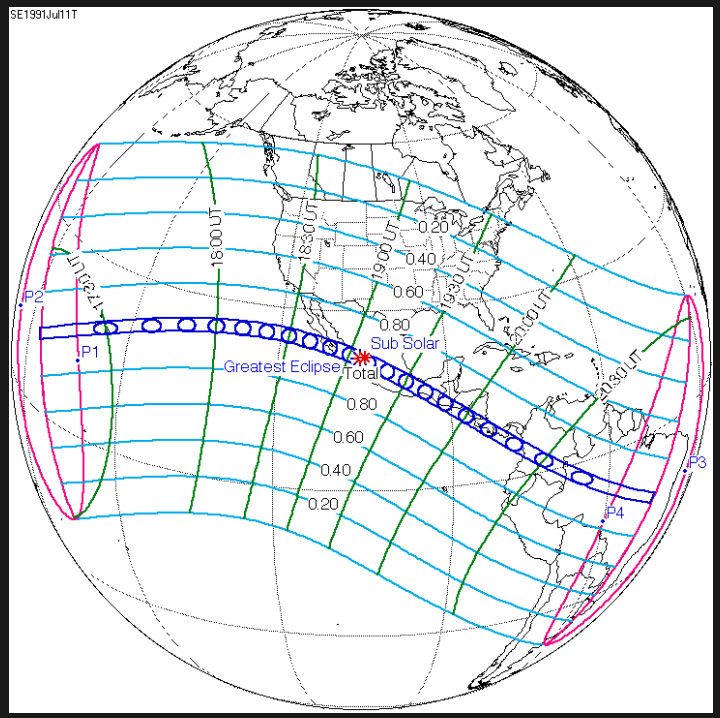

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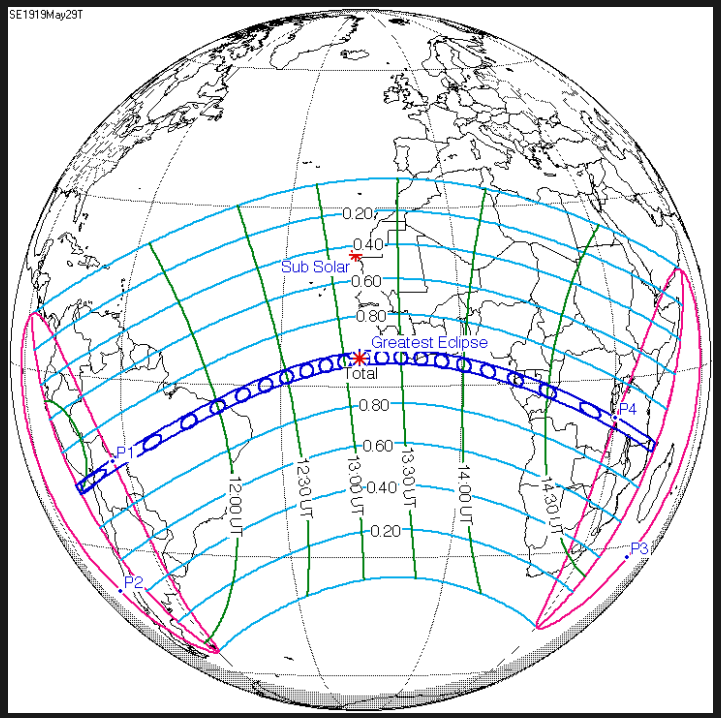
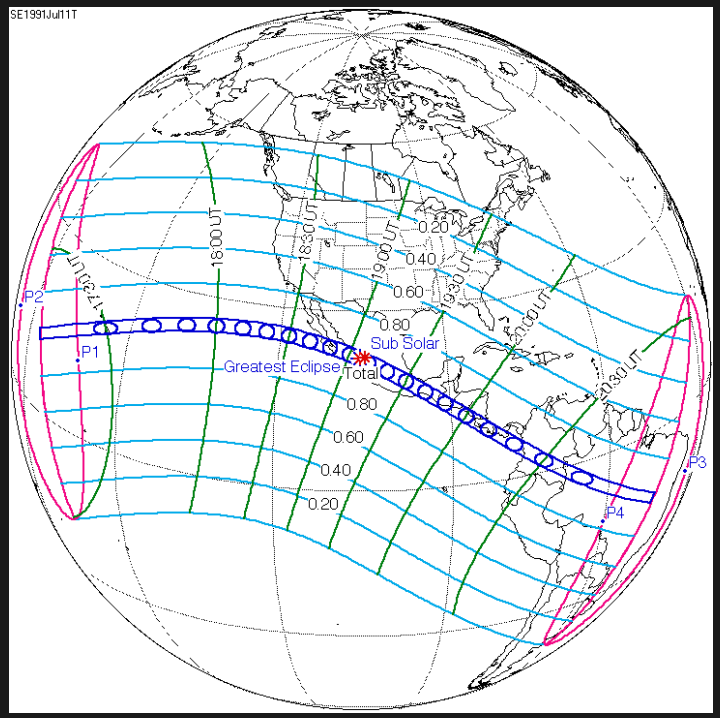


May 29, 1919

Four saros periods back from the 1991 eclipse gets us to May 29, 1919,

Example 2: Saros series 136 (continued)



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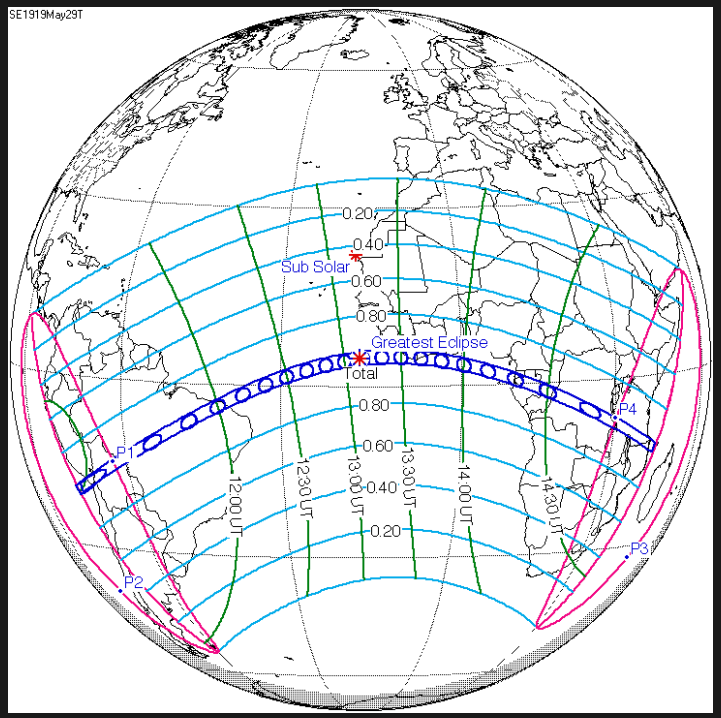

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Four saros periods back from the 1991 eclipse gets us to May 29, 1919, the day of the Eddington-Einstein eclipse,

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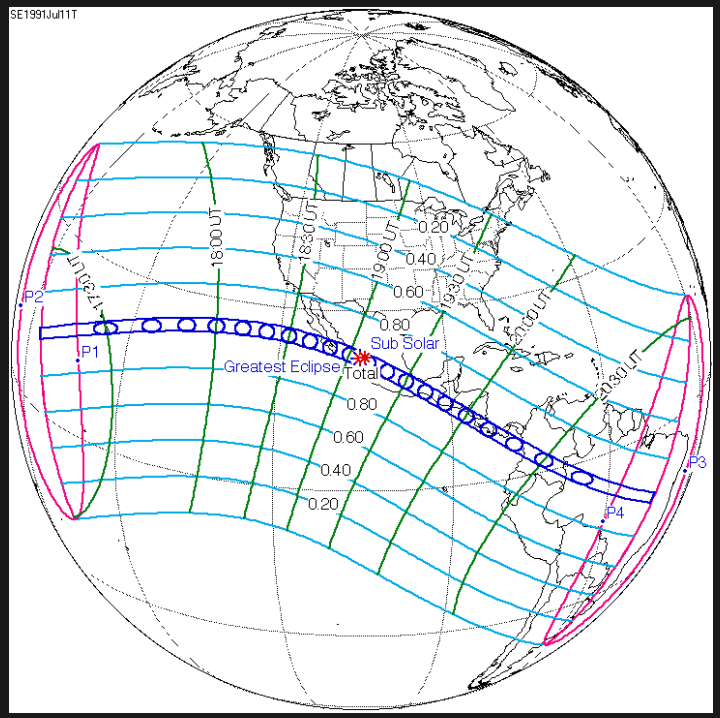

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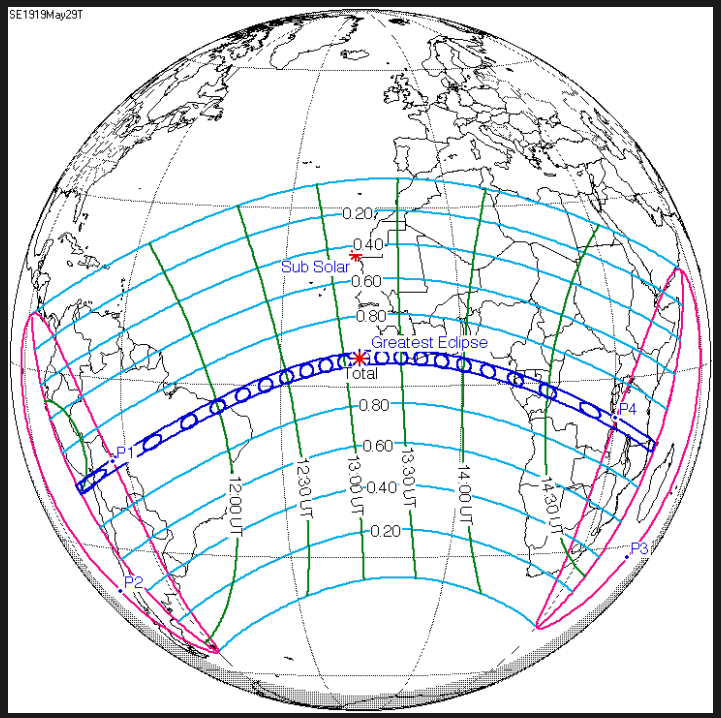

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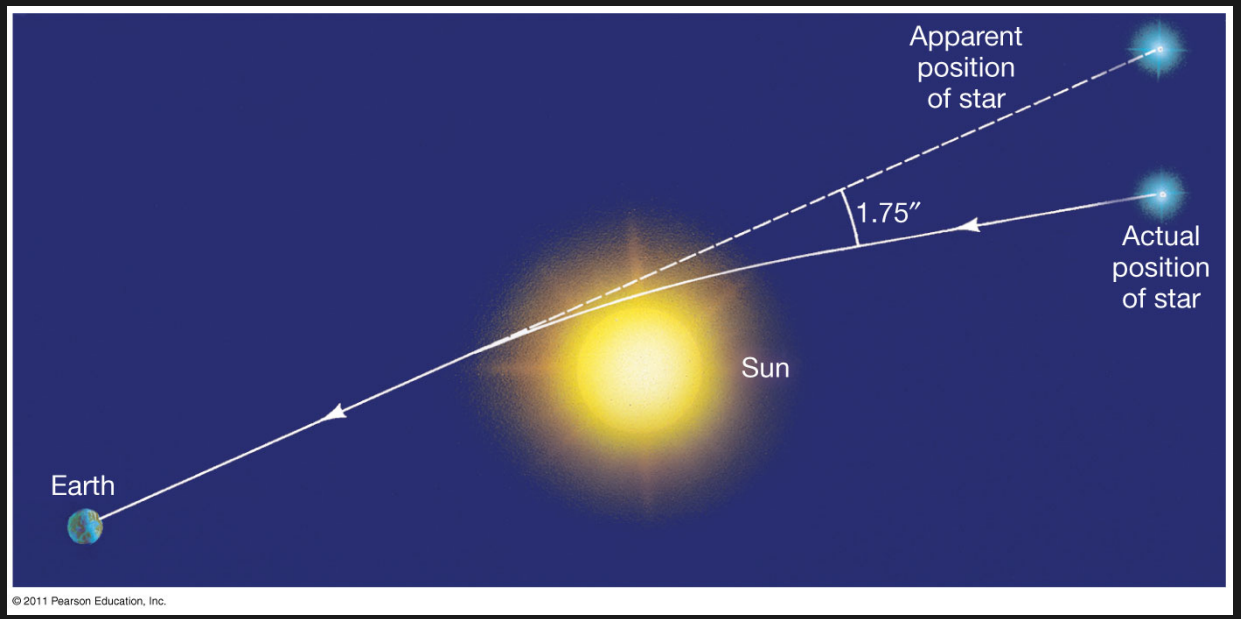
Four saros periods back from the 1991 eclipse gets us to May 29, 1919, the day of the Eddington-Einstein eclipse, possibly the most famous one in the history of science.

Example 2: Saros series 136 (continued)



In his 1915 paper on general relativity, Einstein predicted that light from a distant star passing very near the sun would be bent by the sun's gravity.

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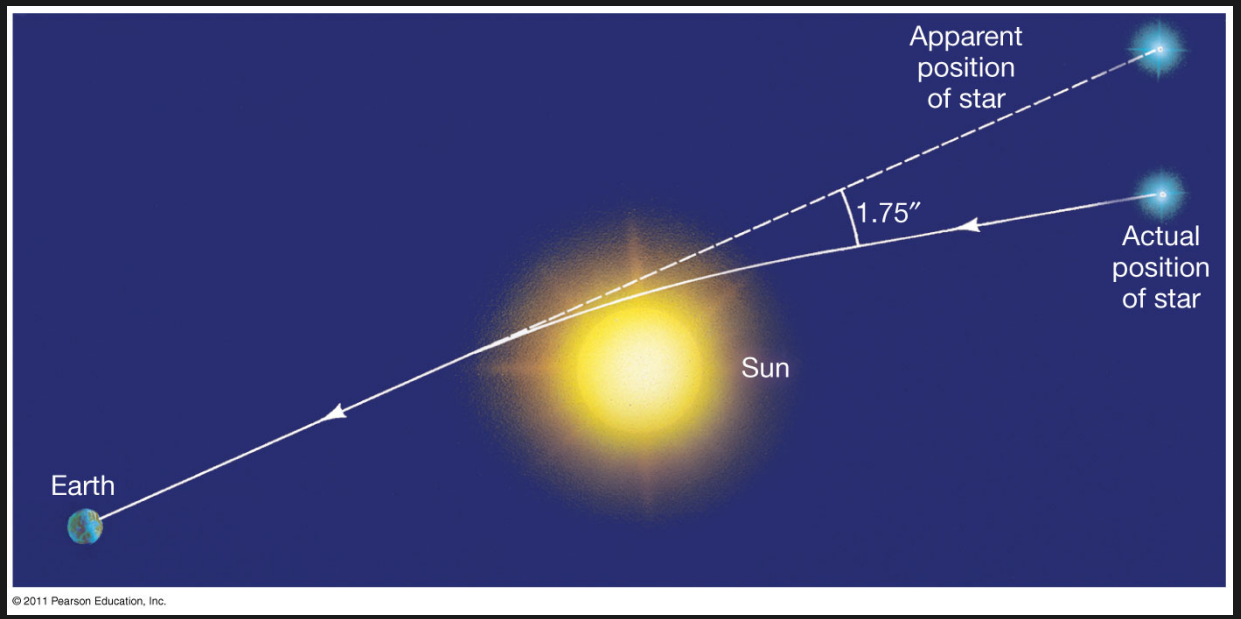

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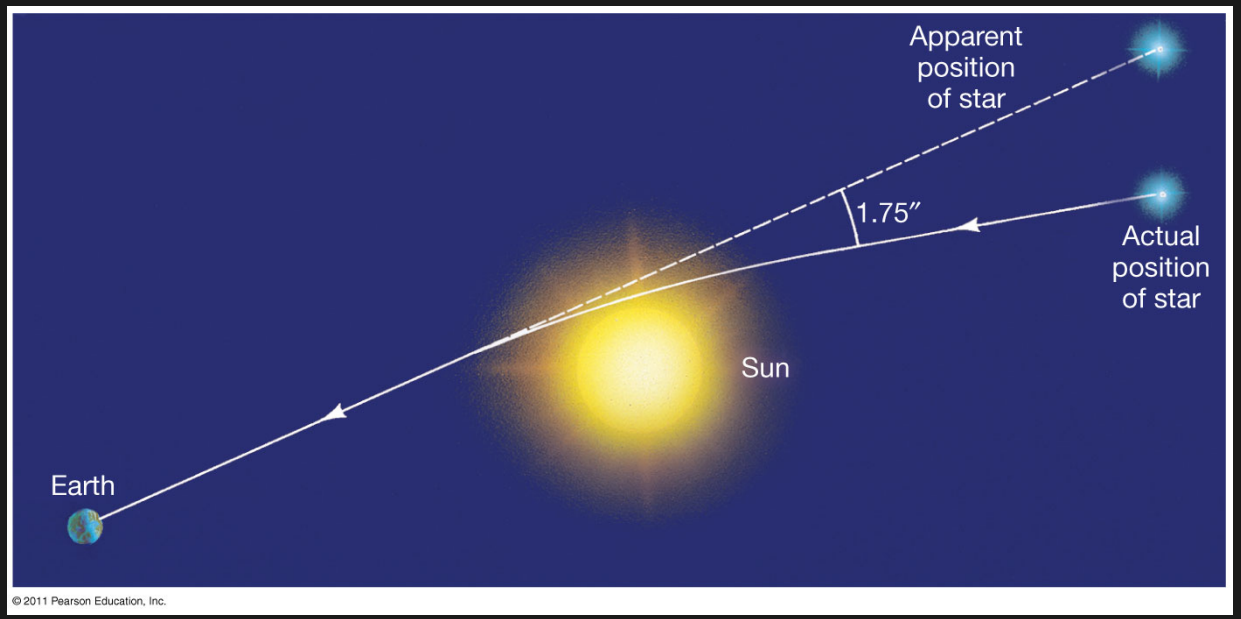

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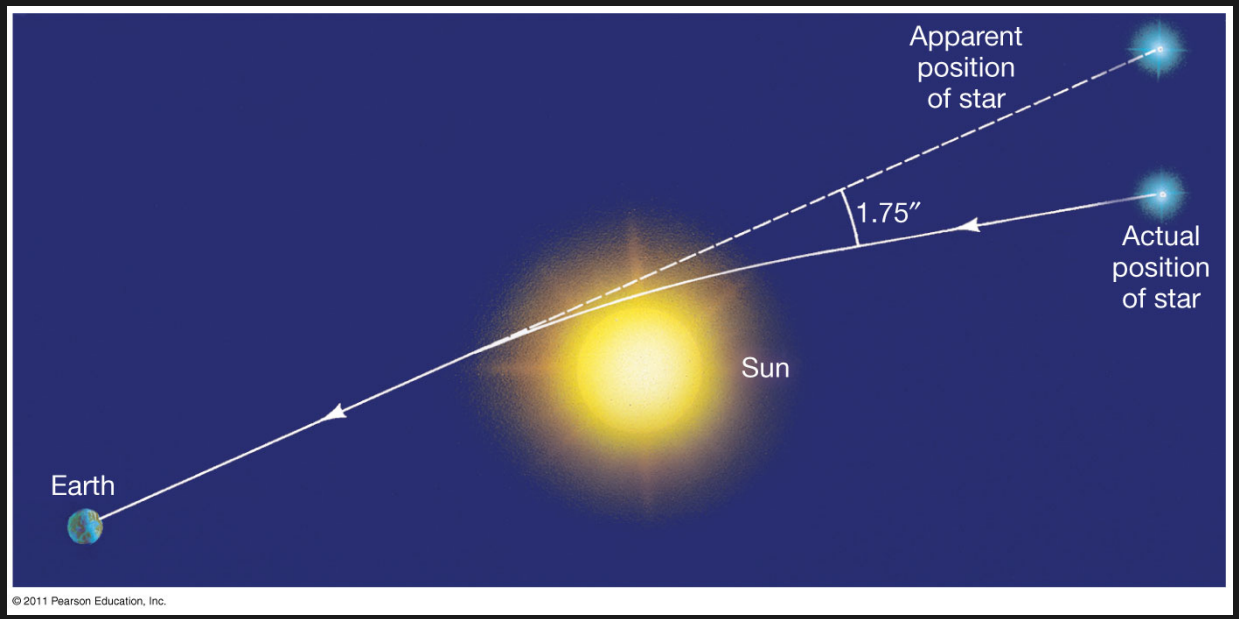

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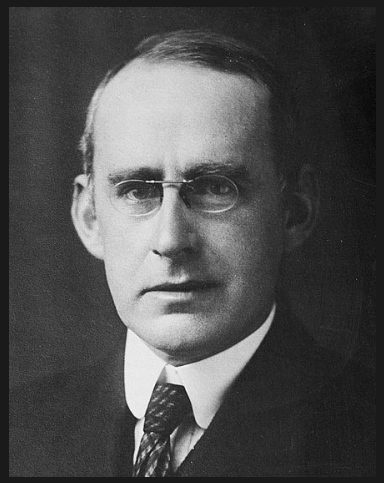
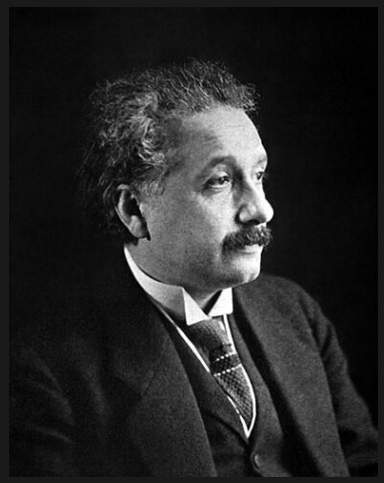


Arthur Eddington
1882-1944



Albert Einstein
1879-1955

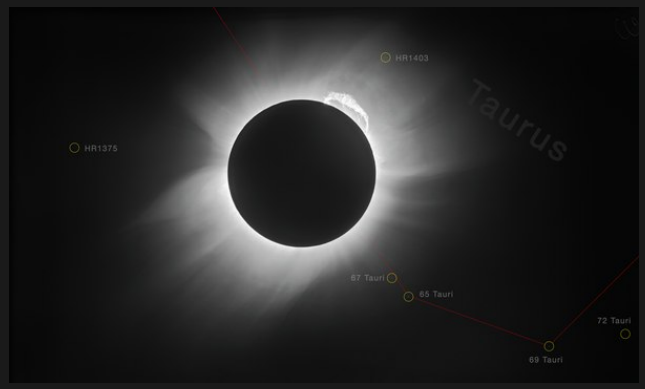
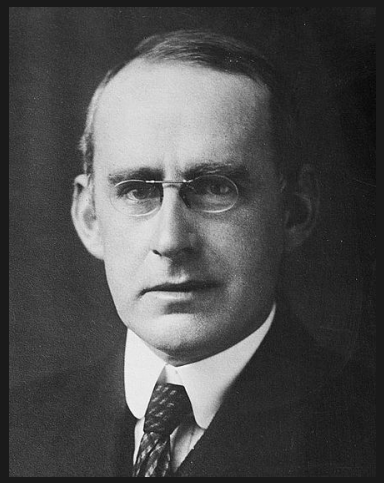


Photo by Eddington

The British physicist Arthur Eddington used the 1919 eclipse to make such an observation from the island of Principé off the west coast of Africa.

Example 2: Saros series 136 (continued)



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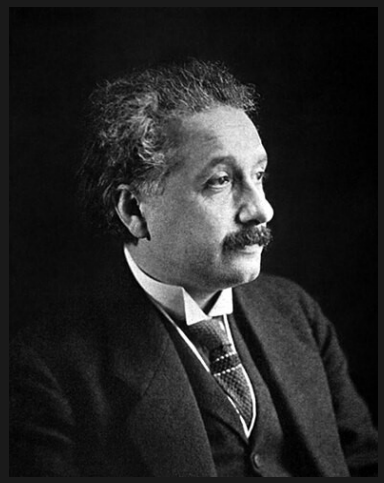

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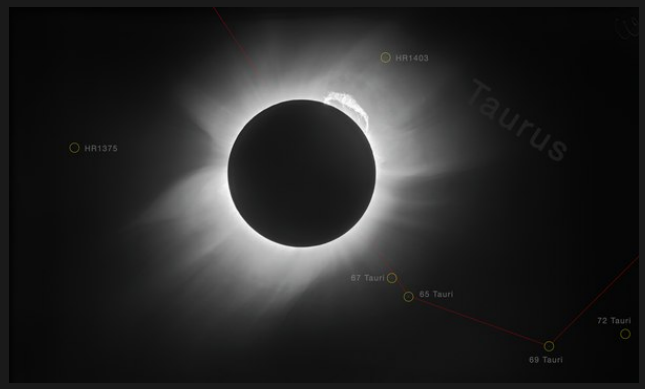

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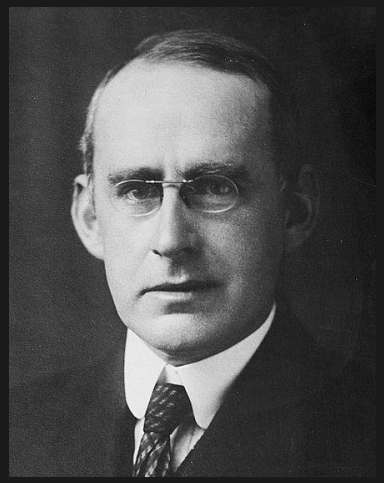
The British physicist Arthur Eddington used the 1919 eclipse to make such an observation from the island of Principé off the west coast of Africa. Just six months after the end of World War I, a British scientist travelled to the ends of the earth to confirm the theory of a German one.

Example 2: Saros series 136 (continued)



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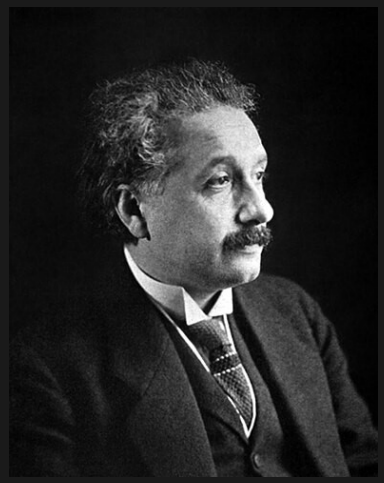

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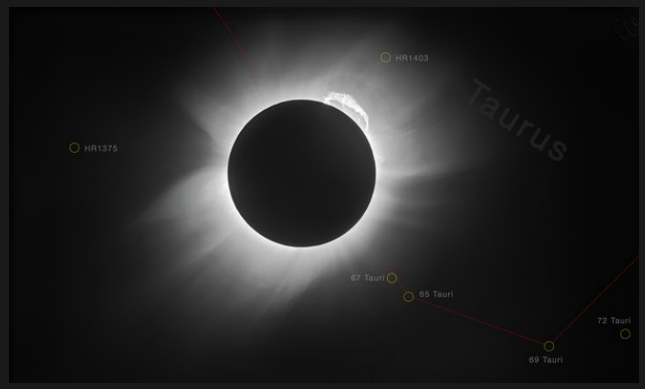

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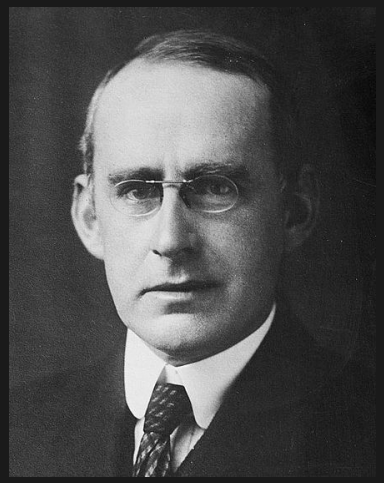

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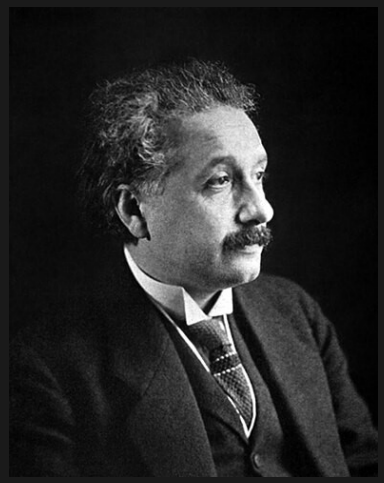


Albert Einstein
1879-1955

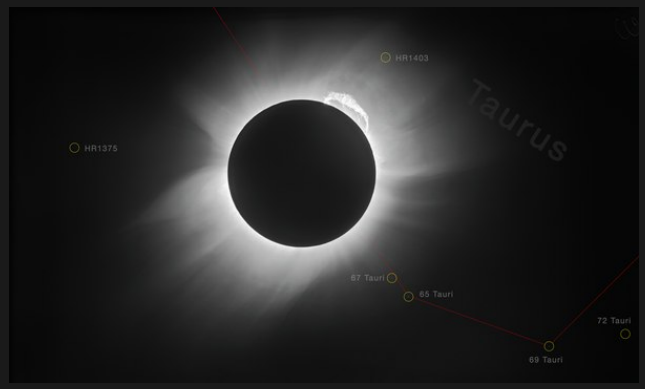
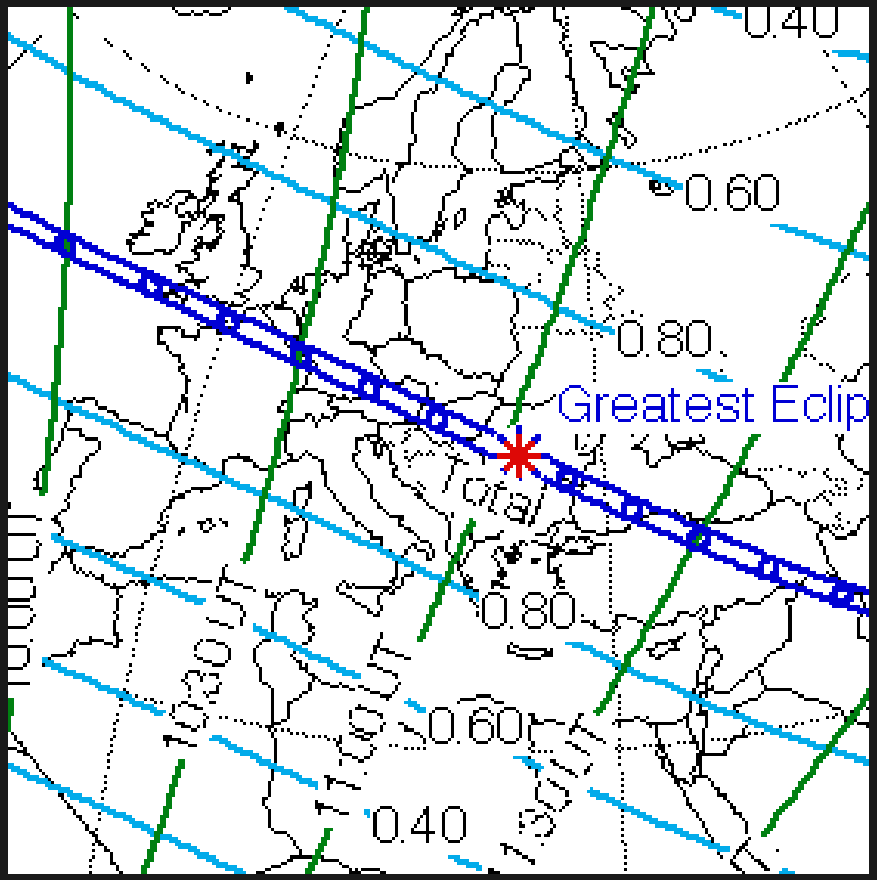


Photo by Eddington

The British physicist Arthur Eddington used the 1919 eclipse to make such an observation from the island of Principé off the west coast of Africa. Just six months after the end of World War I, a British scientist travelled to the ends of the earth to confirm the theory of a German one. The measurement was as Einstein had predicted. The ensuing headlines made him the most famous scientist in the world.

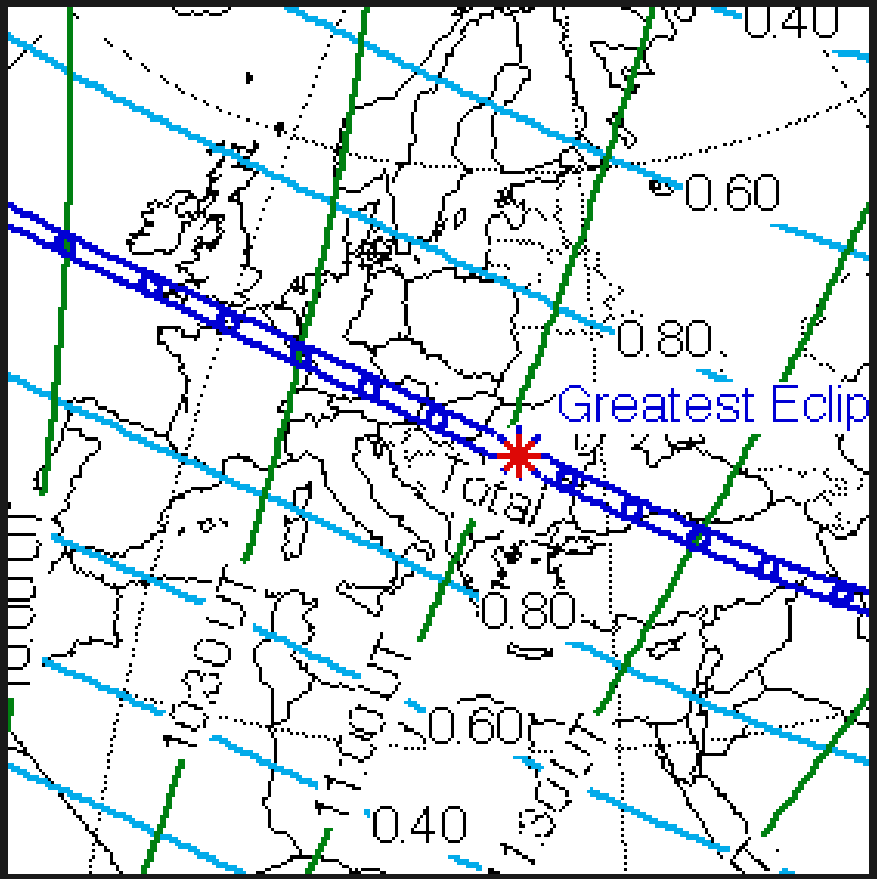
Example 3: Saros series 145



August 11, 1999

Doug Ravenel

Example 3: Saros series 145



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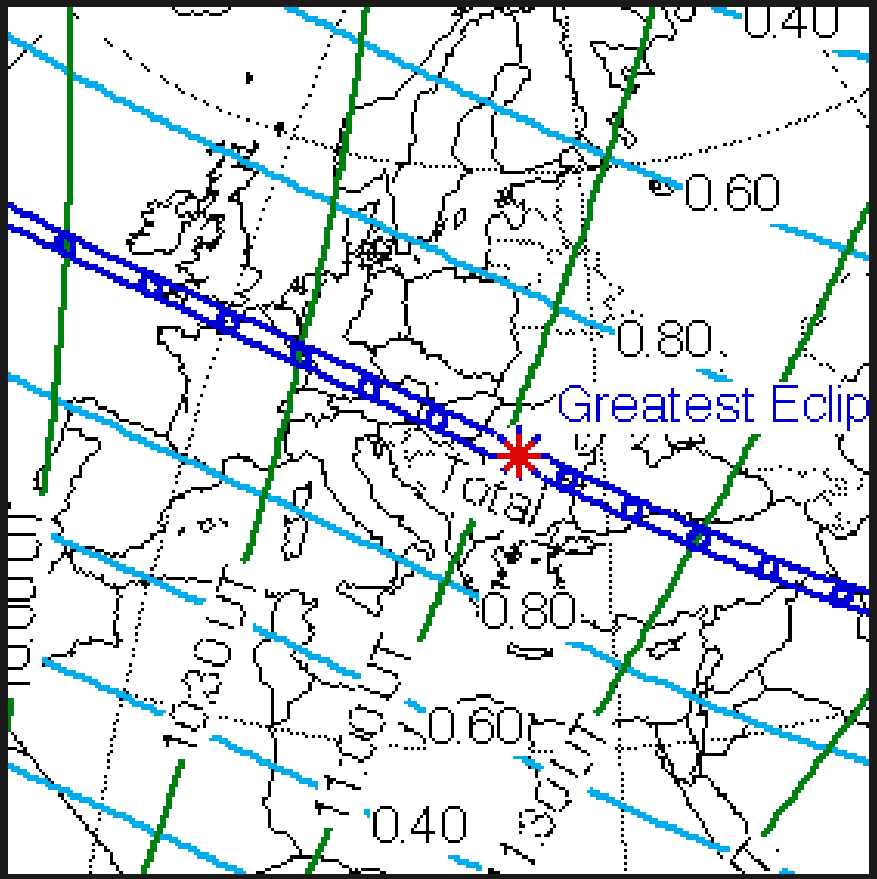

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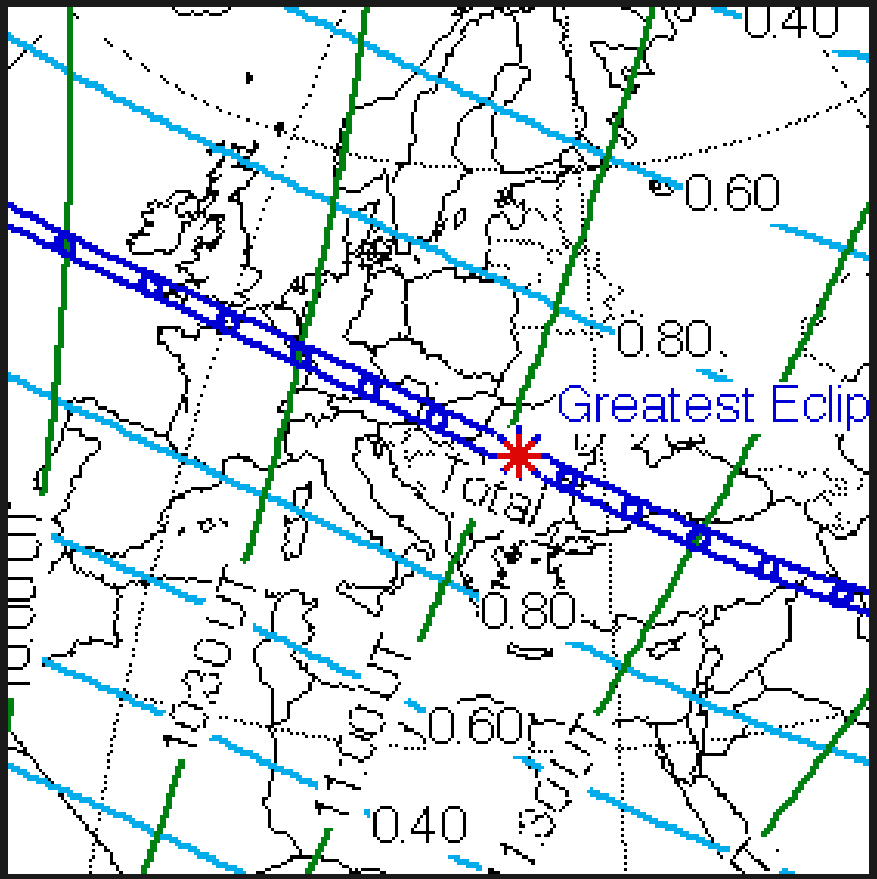

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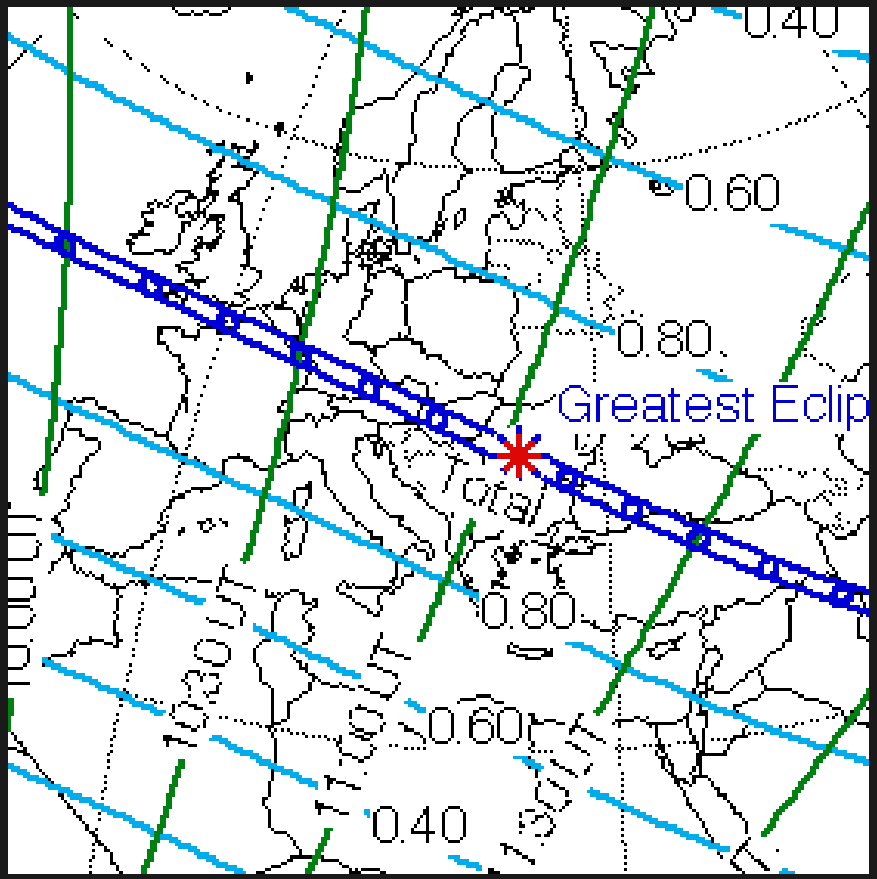

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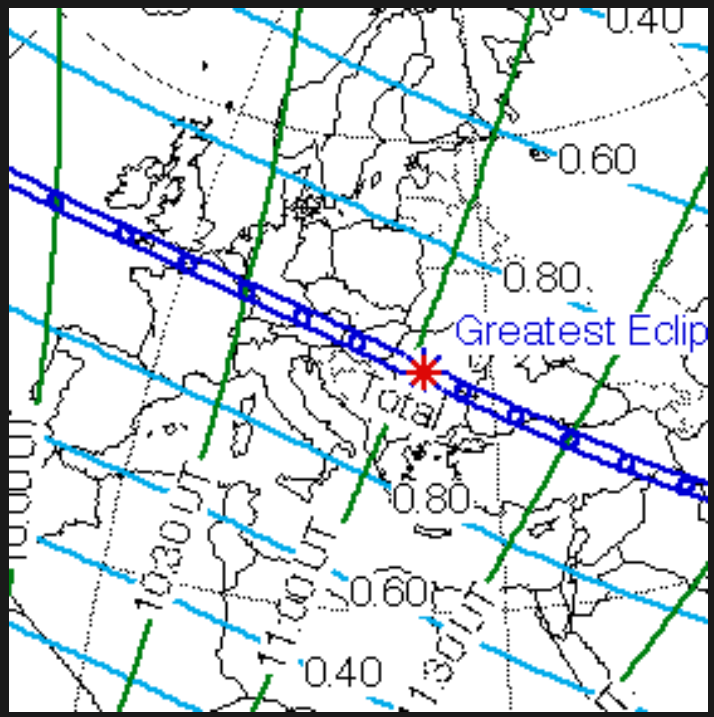
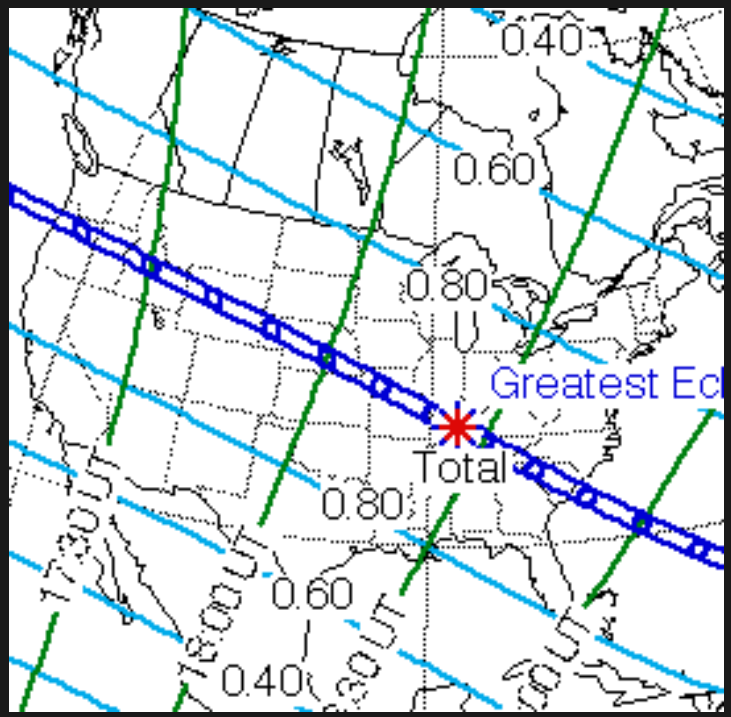
Most of western Europe was cloudy that day. One exception was Bucharest, where the skies were clear.

Example 3: Saros series 145 (continued)



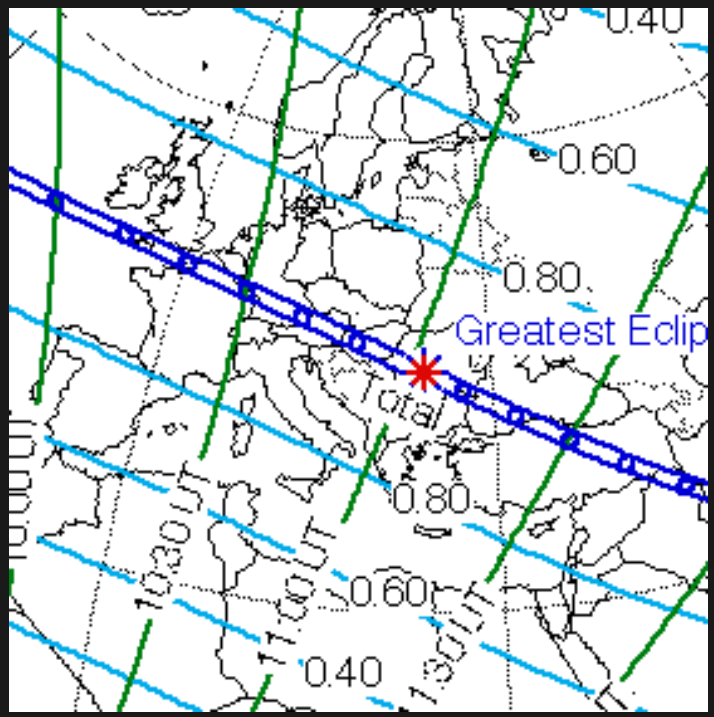
August 11, 1999



August 21, 2017

Doug Ravenel

Example 3: Saros series 145 (continued)



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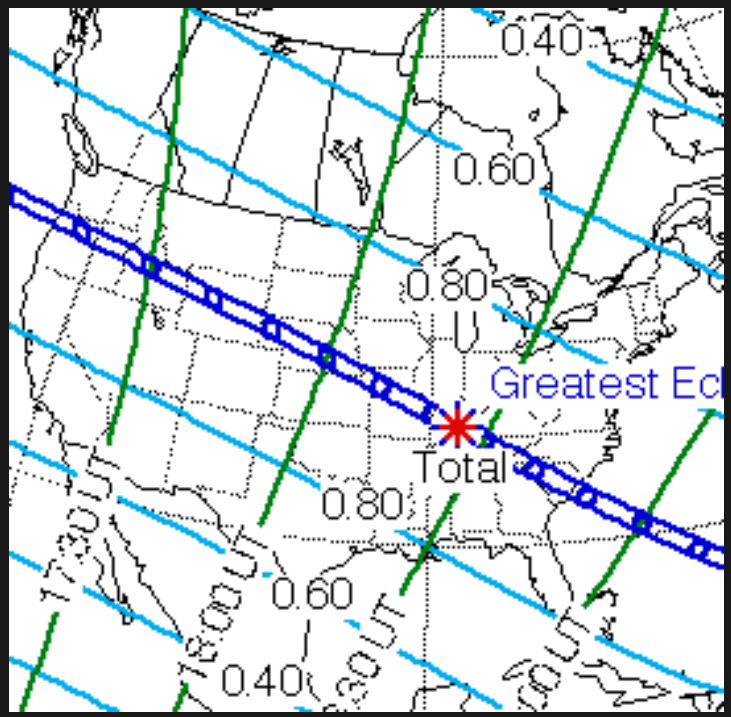

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The next eclipse in the series was visible across the United States from Oregon to South Carolina.

Doug Ravenel

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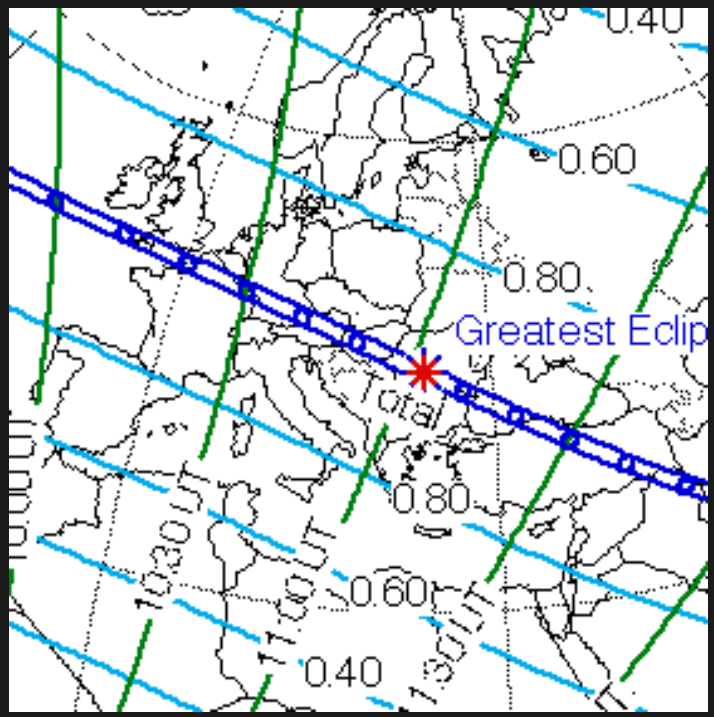

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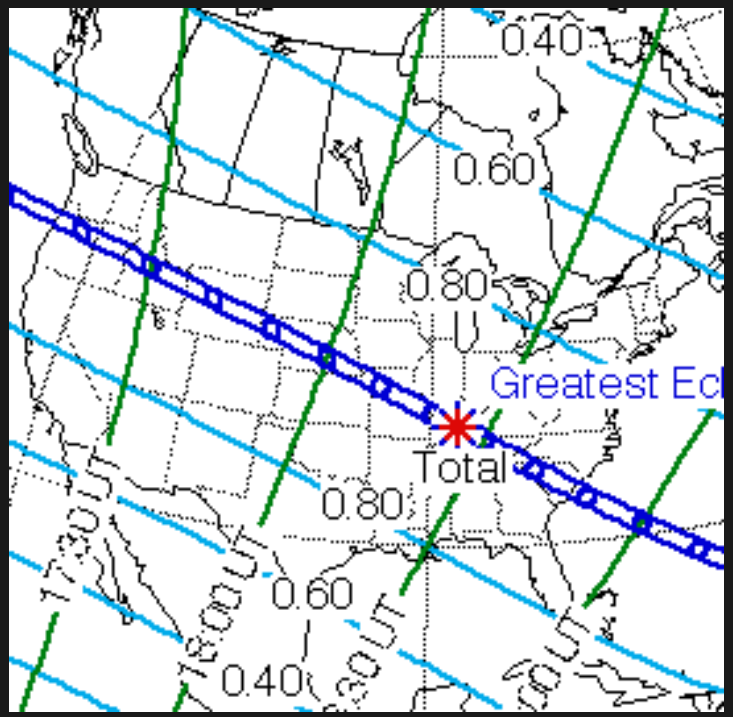
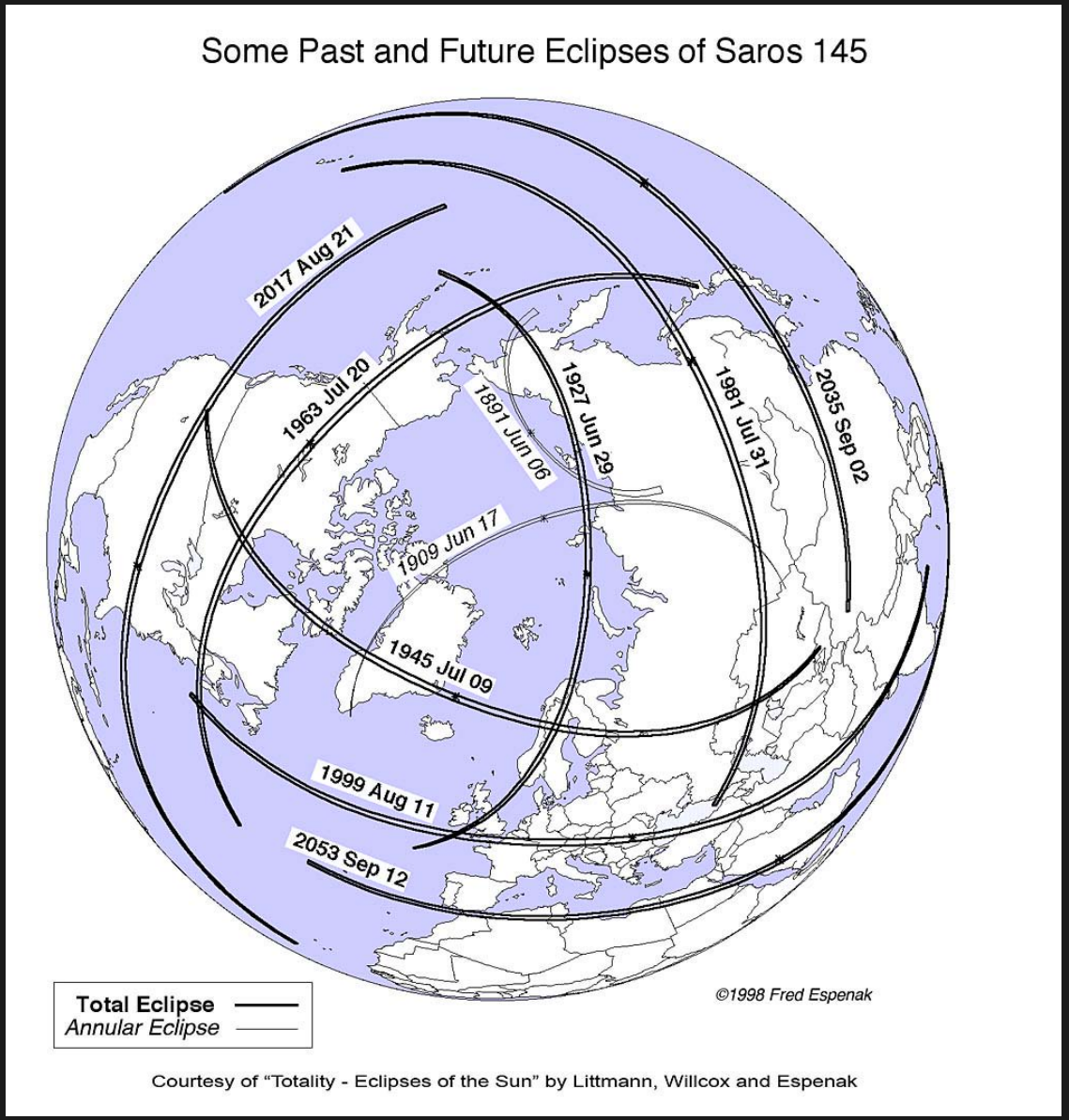


August 21, 2017

The next eclipse in the series was visible across the United States from Oregon to South Carolina. There was an another algebraic topology conference organized around it in Portland, and skies were clear.

Example 3: Saros series 145 (continued)



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WHY ARE THEY DIFFERENT?

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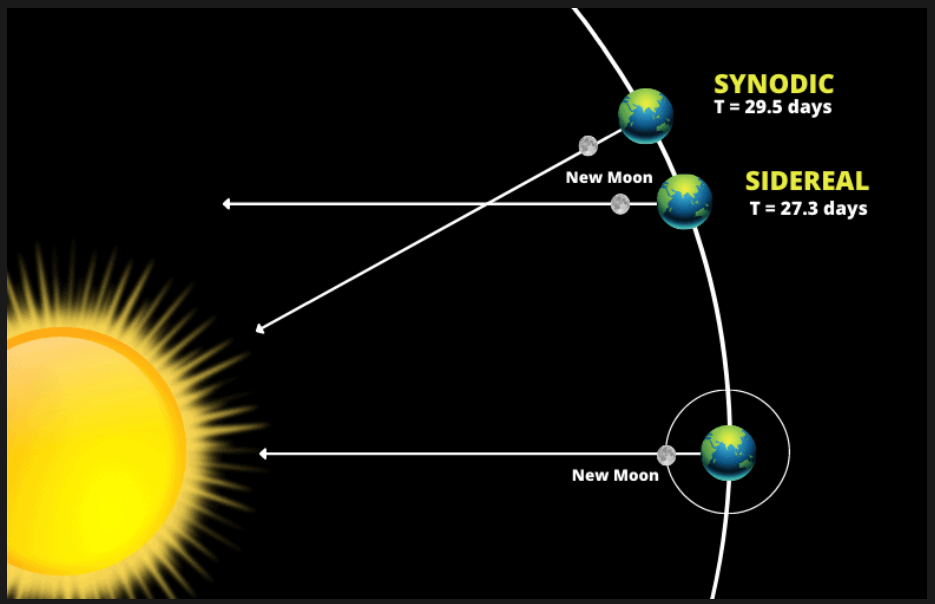

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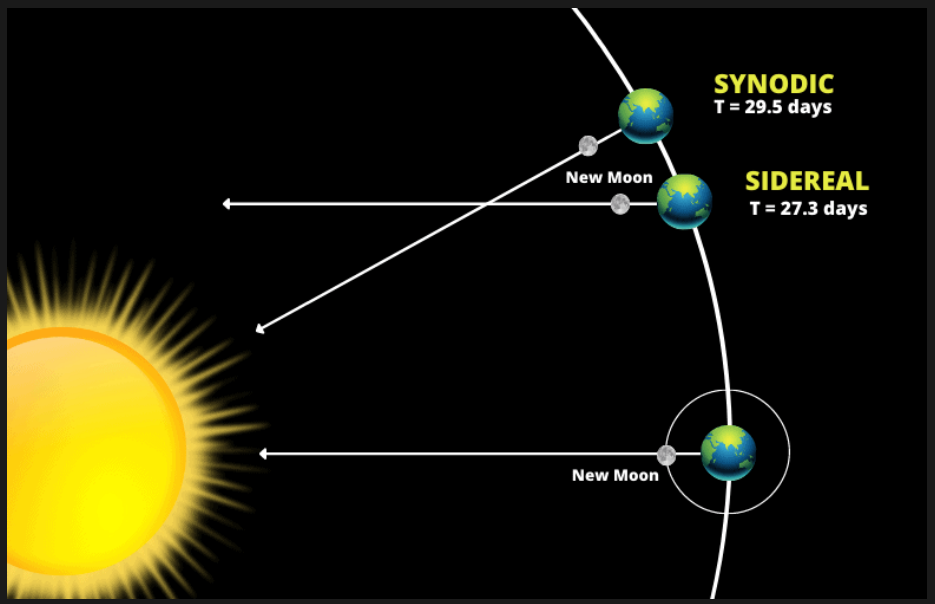

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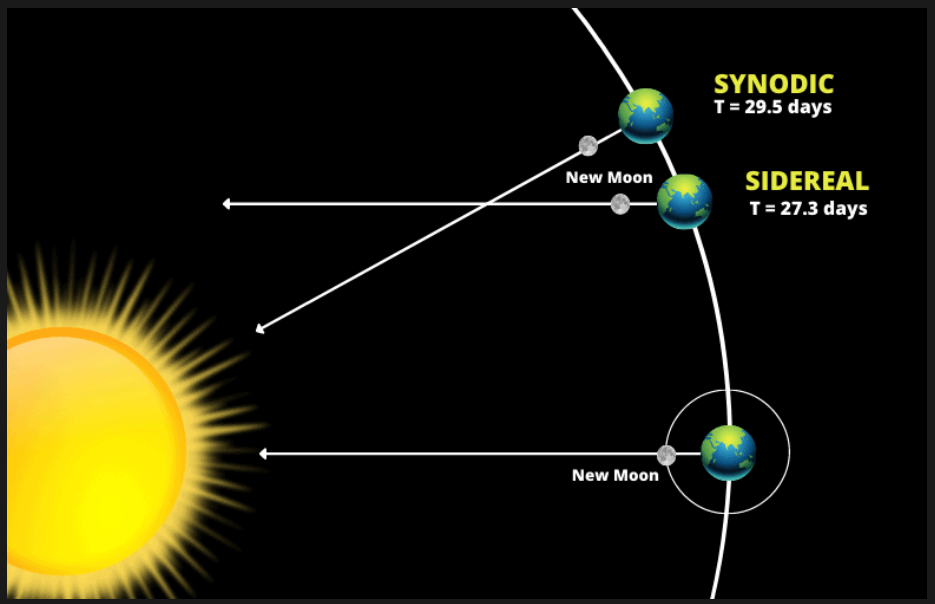

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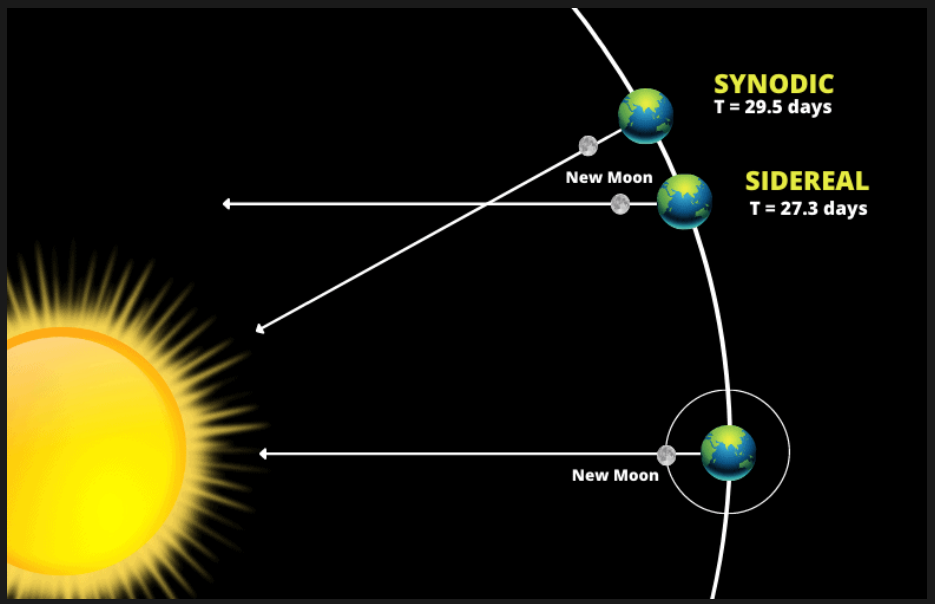

One sidereal month after a new moon, the moon is not yet new again because the earth has advanced in its orbit around the sun. It needs 2 more days to reach the new earth-sun line.

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Doug Ravenel

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Why the Saros cycle? (continued)

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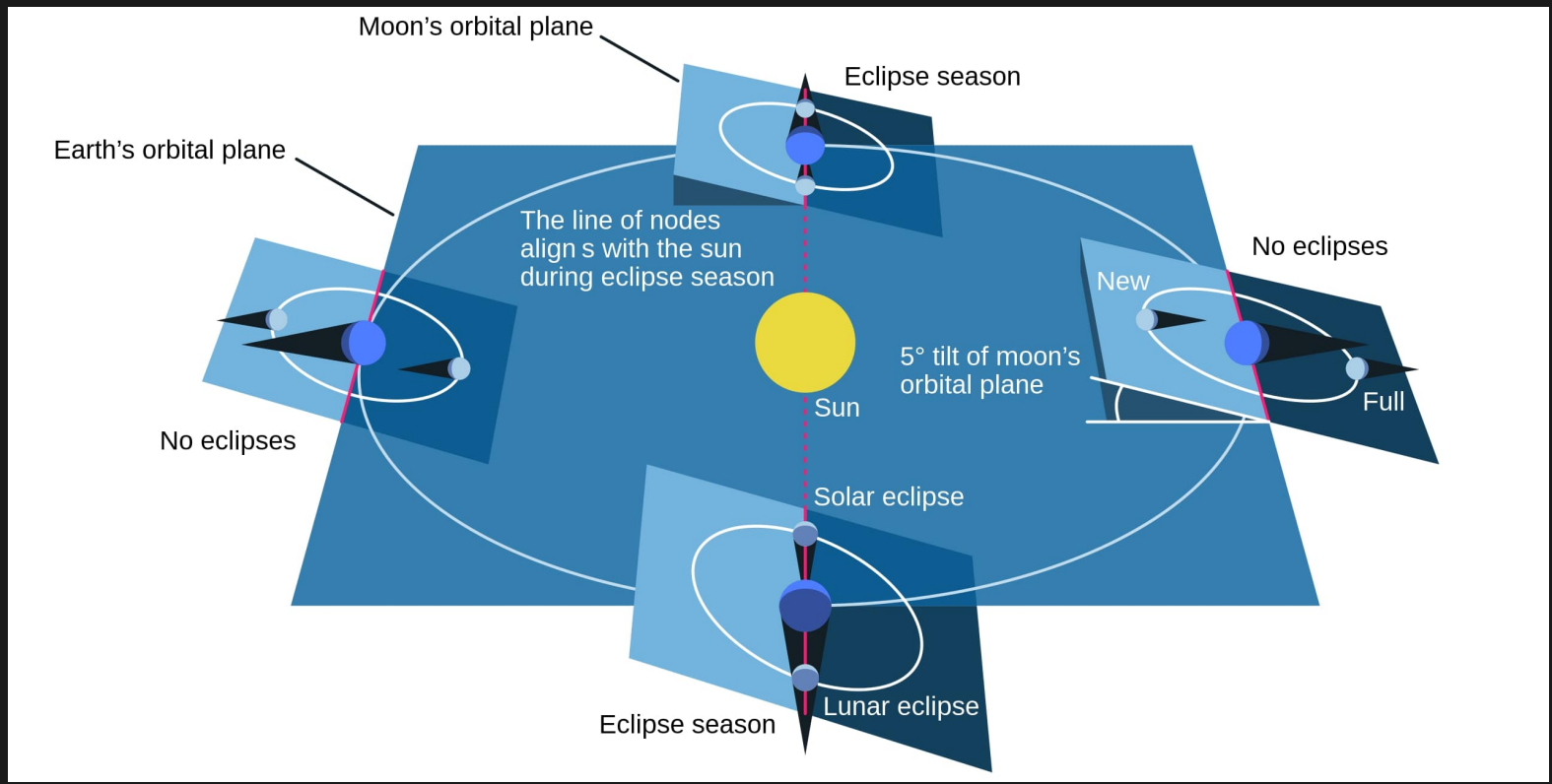

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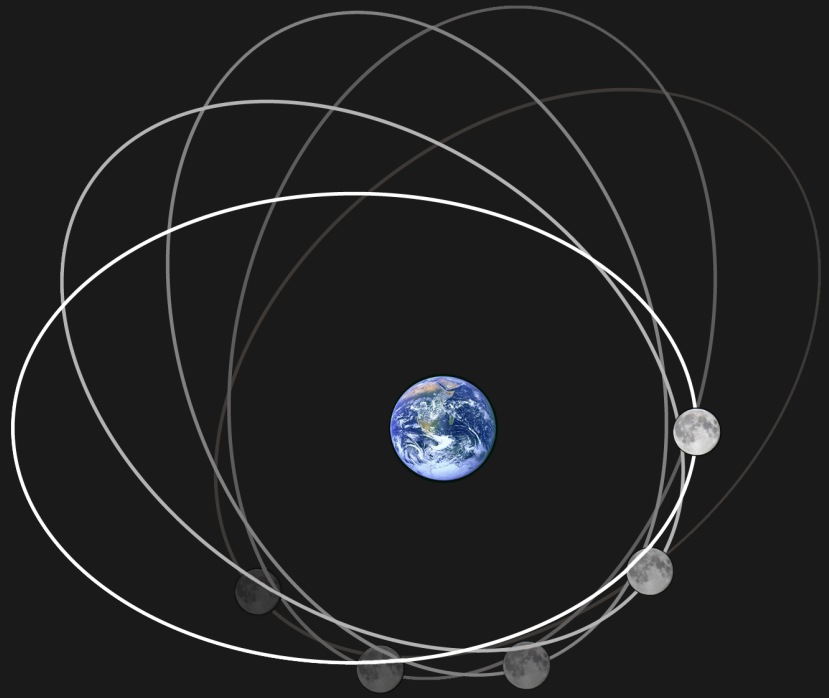

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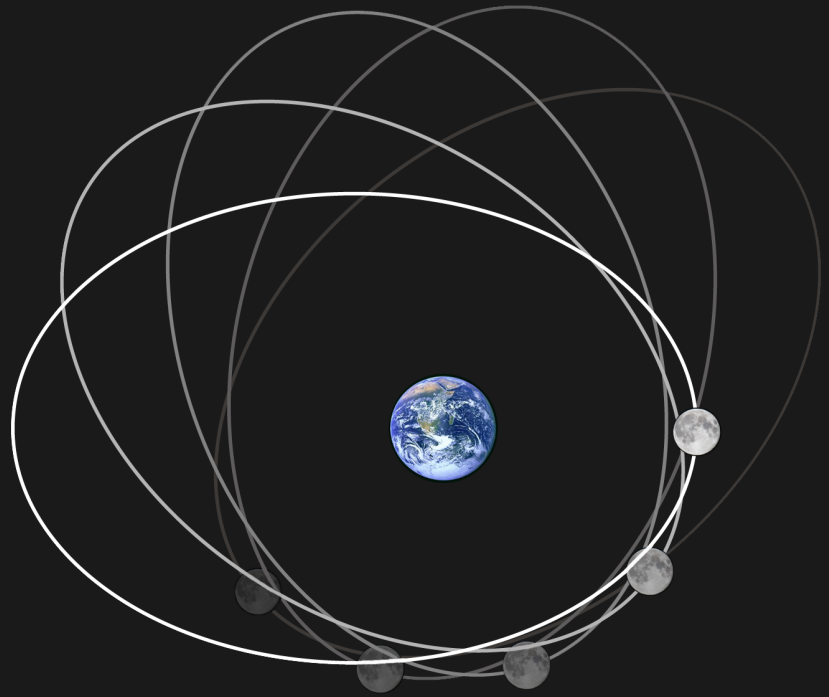

The rotation is called apsidal precession.

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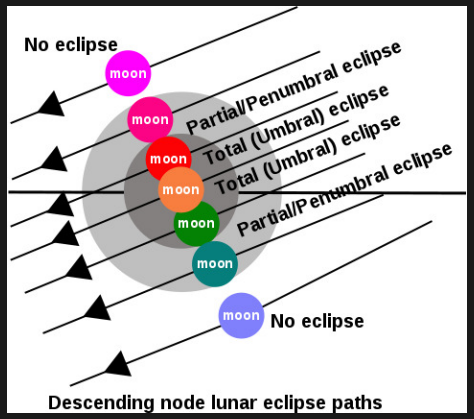
Doug Ravenel

Why the Saros cycle? (continued)



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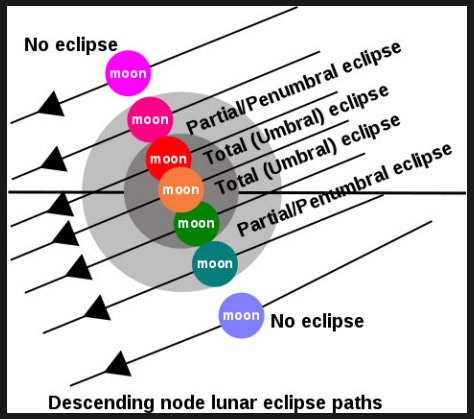

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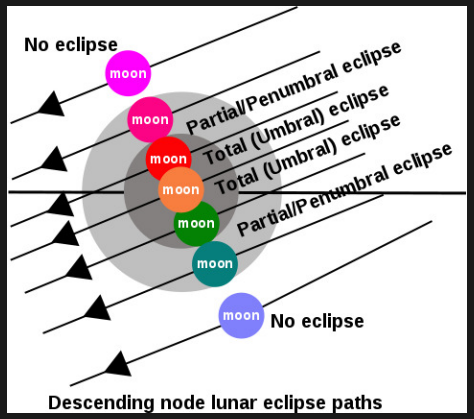

In a series of lunar eclipses where the moon is near ♌, the first one (which is only partial) occurs when the moon as passed ♌ and crosses the southern edge of the earth's shadow.

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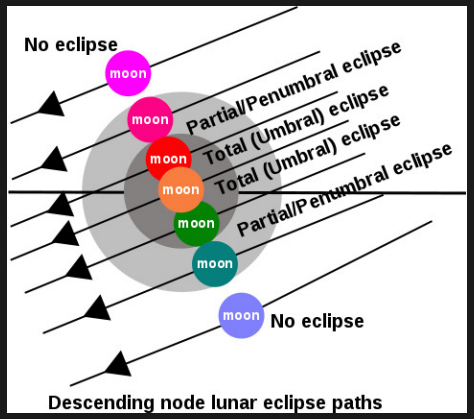

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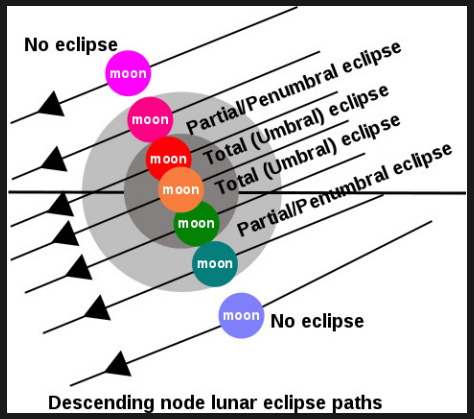

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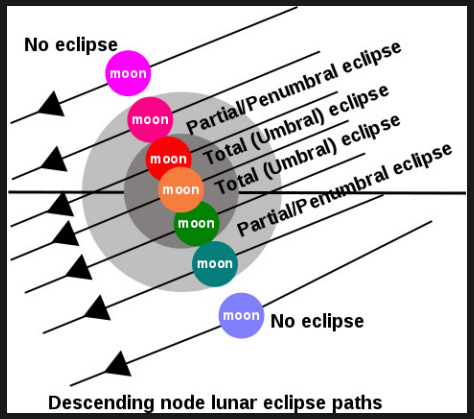

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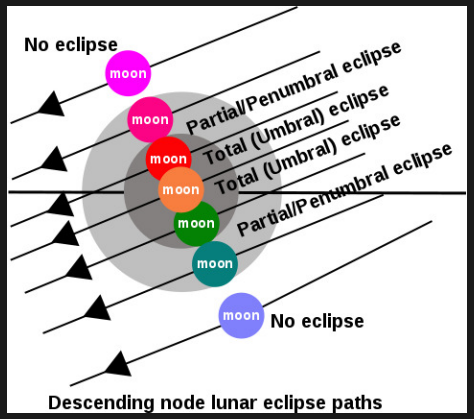

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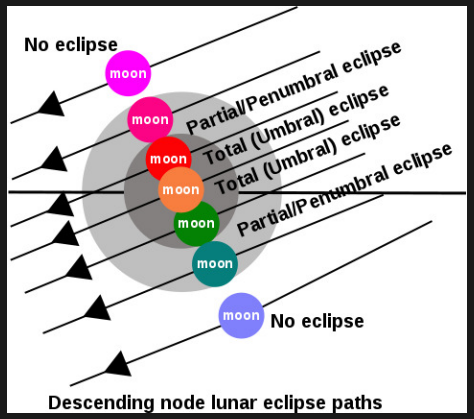

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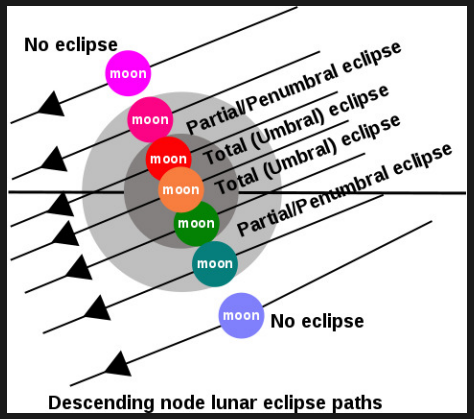

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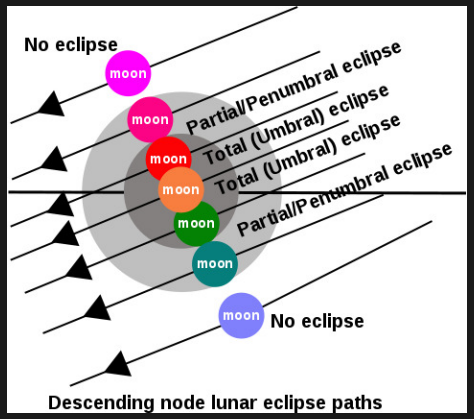

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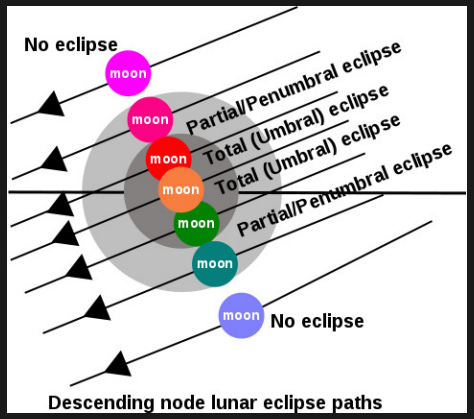

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A typical Saros series has 71 eclipses and lasts 1262 years.

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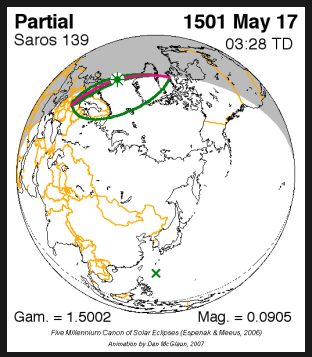

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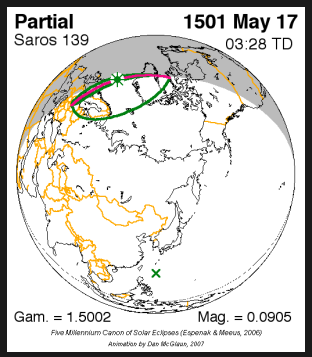

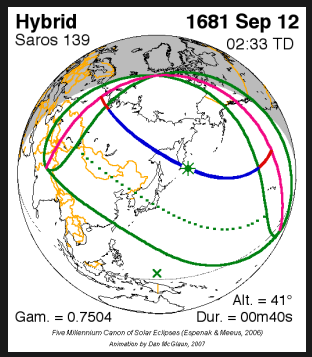

Doug Ravenel

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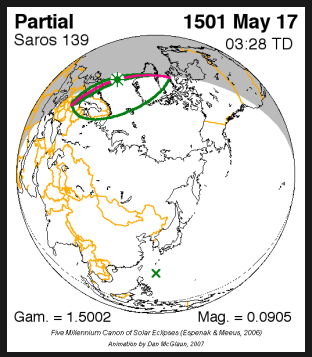

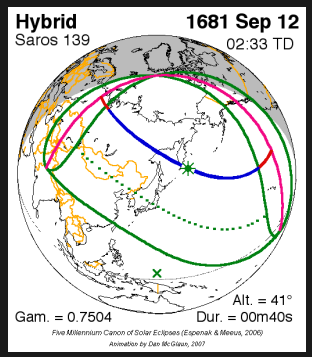

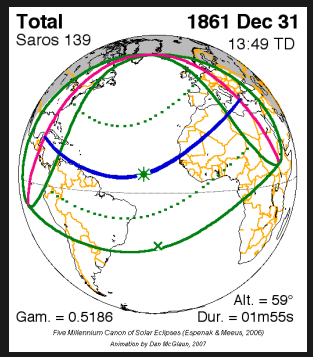

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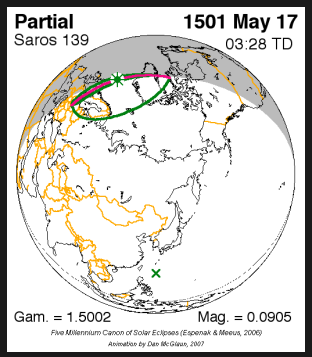

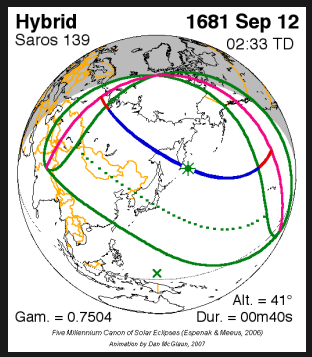

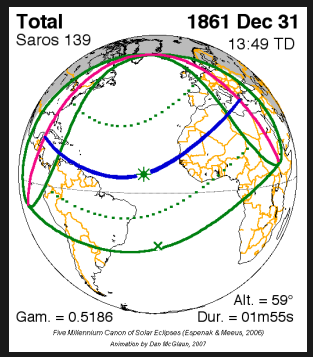

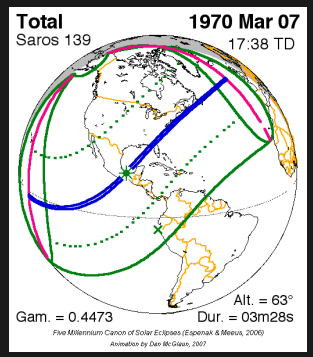

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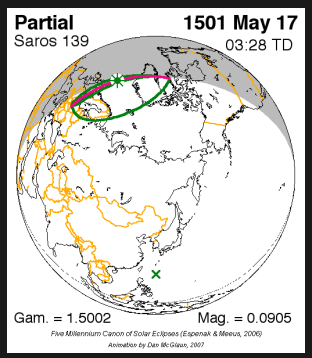

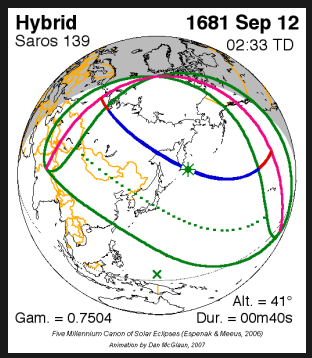

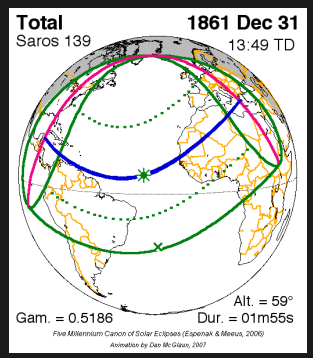

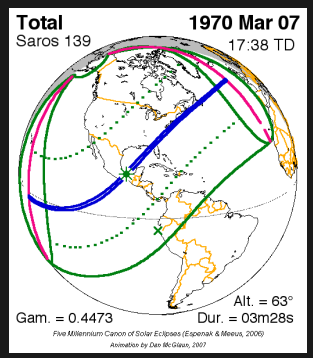

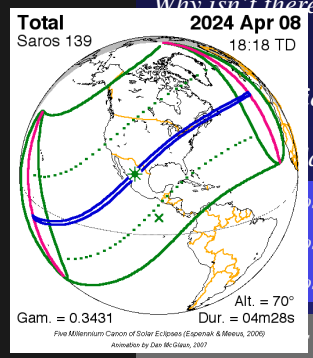

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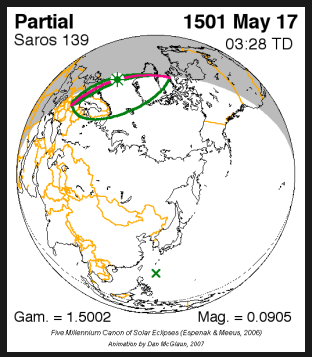

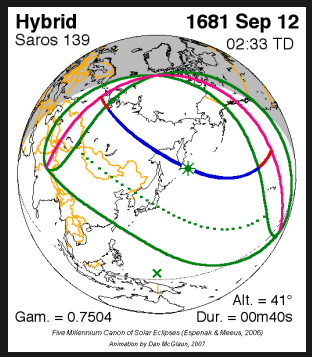

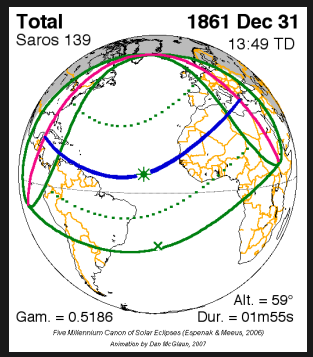

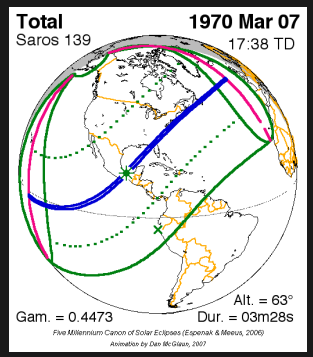

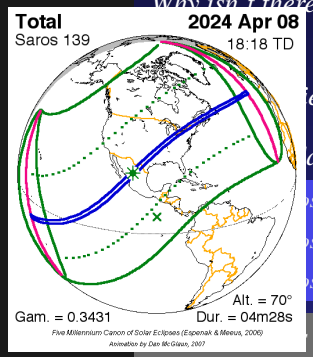

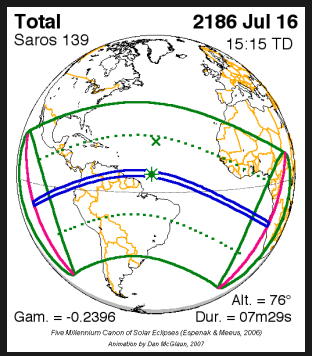

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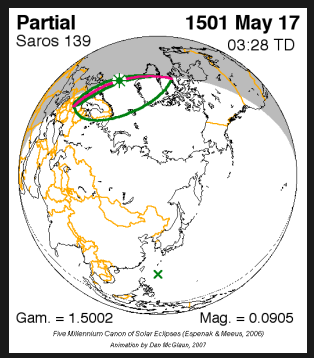

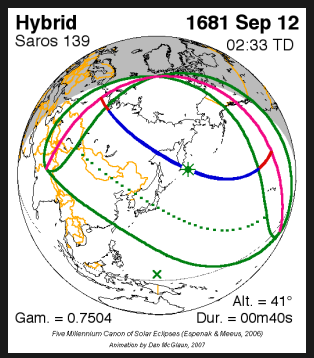

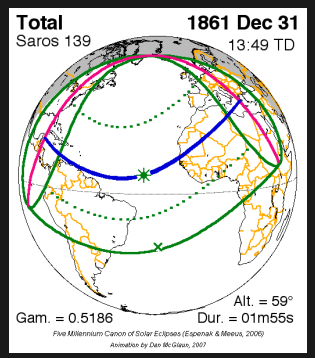

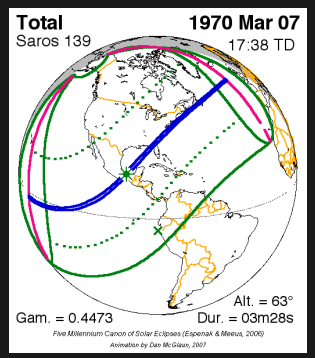

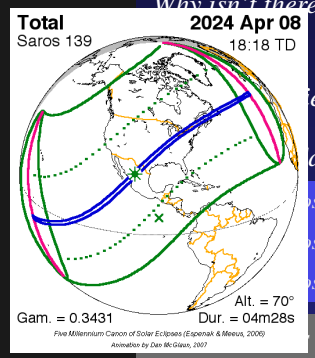

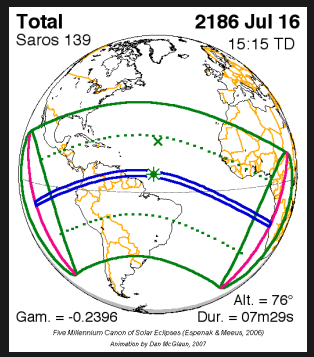

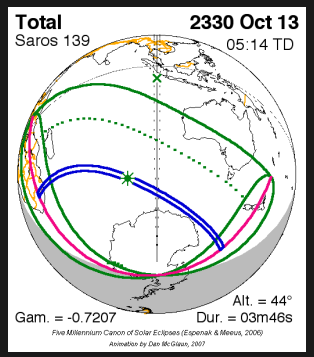

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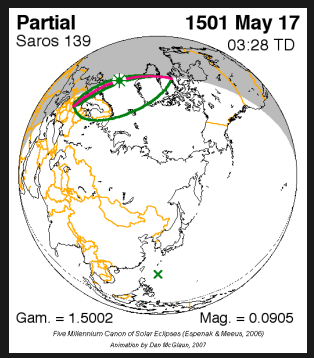

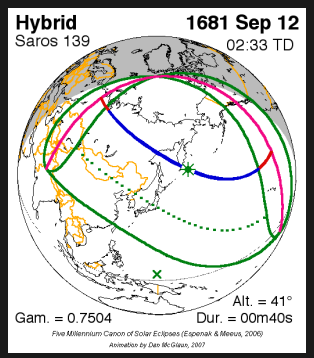

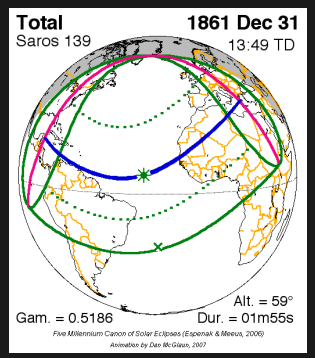

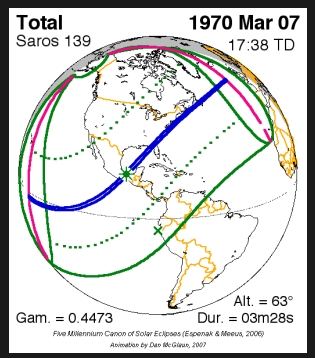

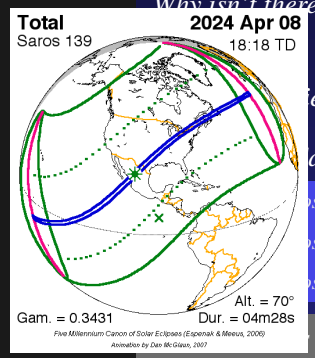

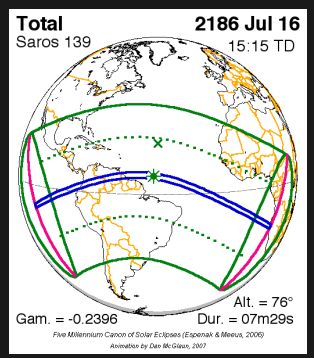

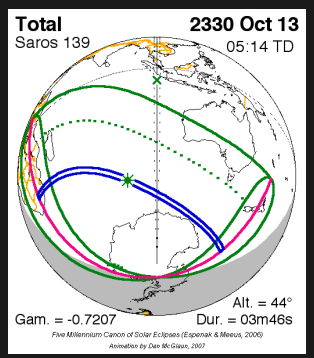

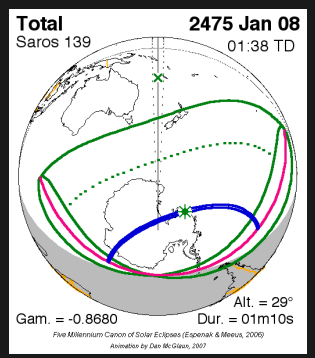

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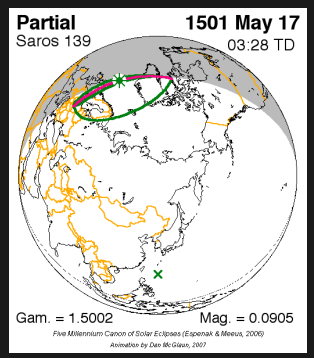
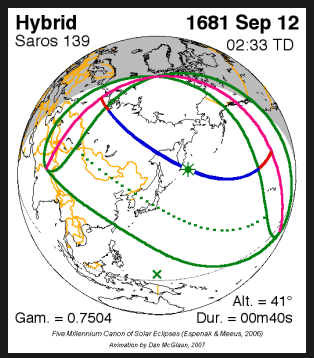
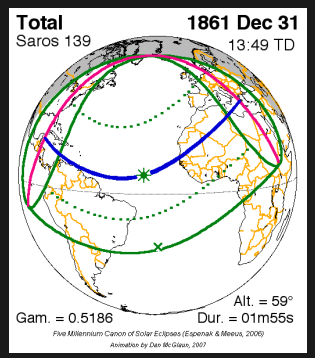
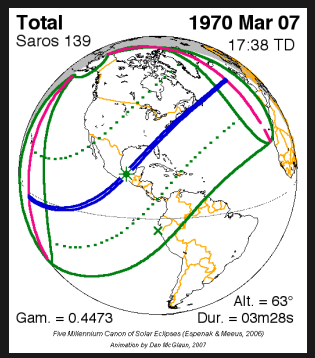
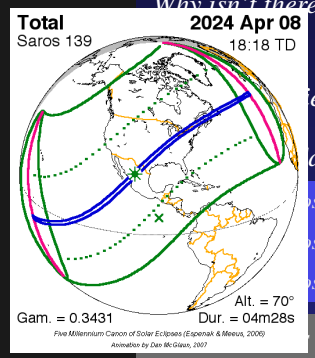
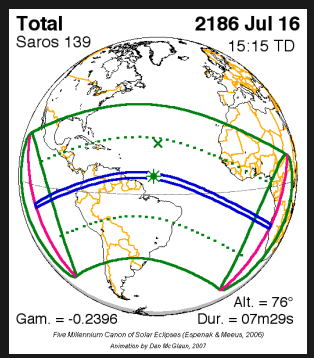


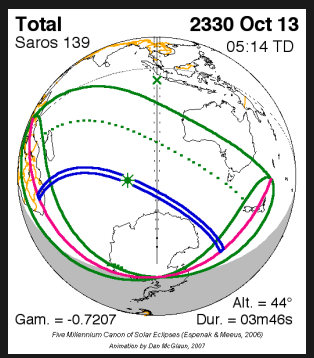


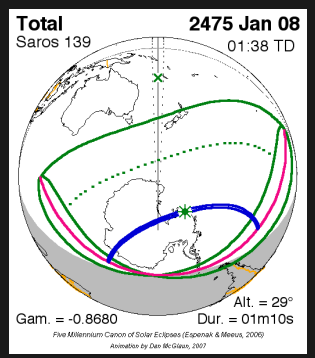


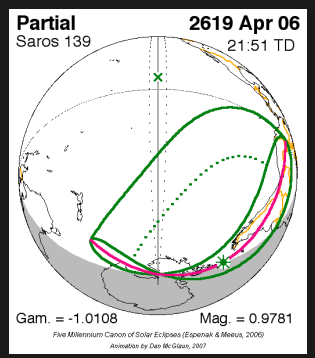






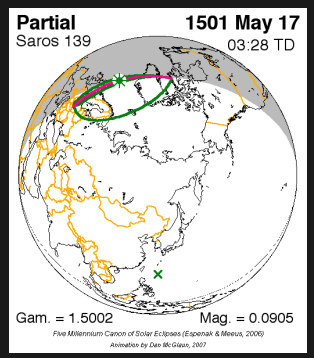


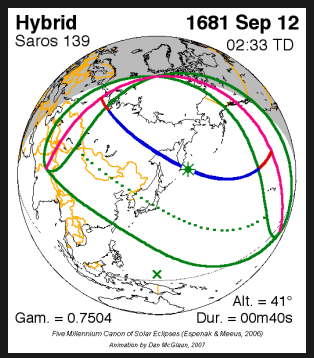


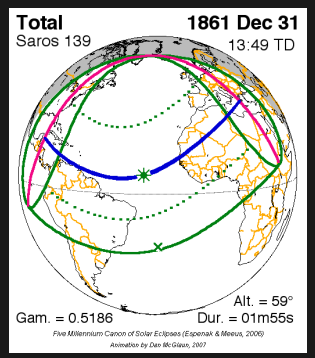


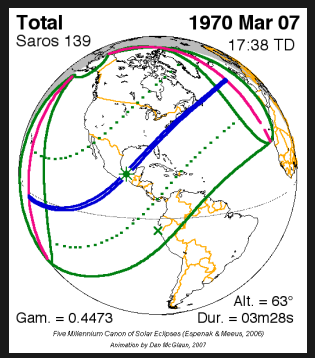
Why the Saros cycle? (continued)

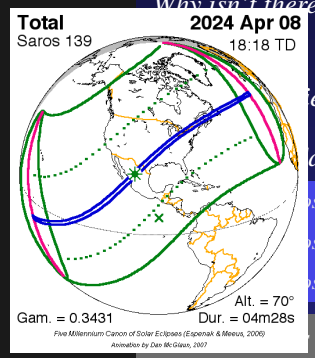
Here are some eclipses in Saros series 139, which includes the ones of 1970 and 2024. It started in 1501 and will end in 2763.

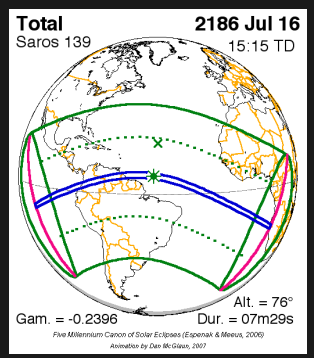


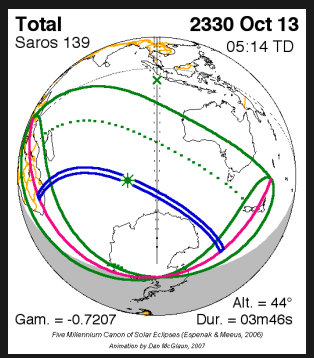


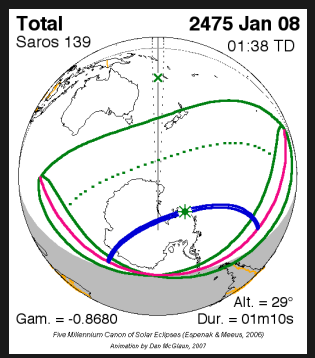


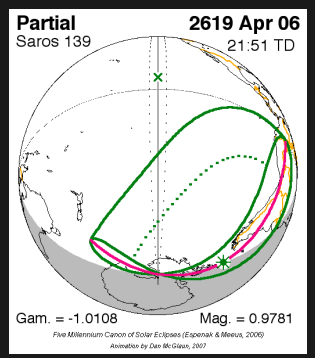


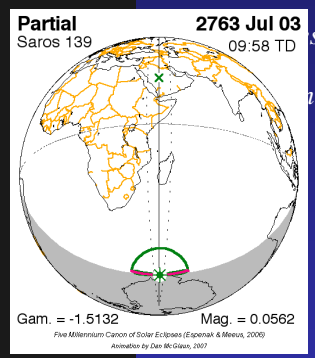




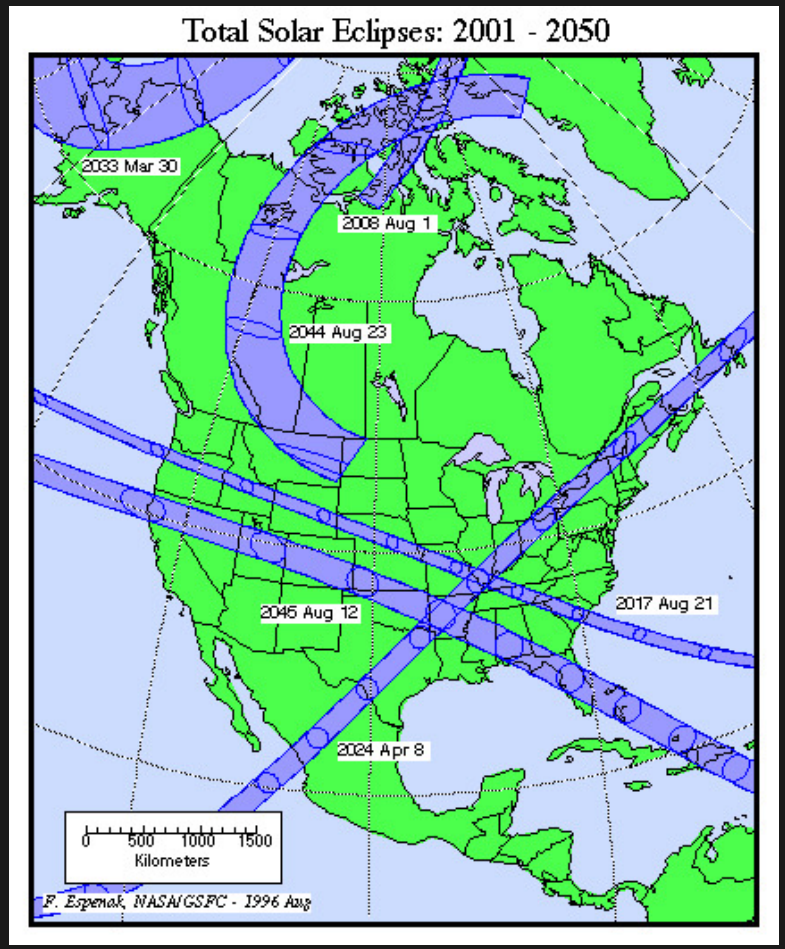




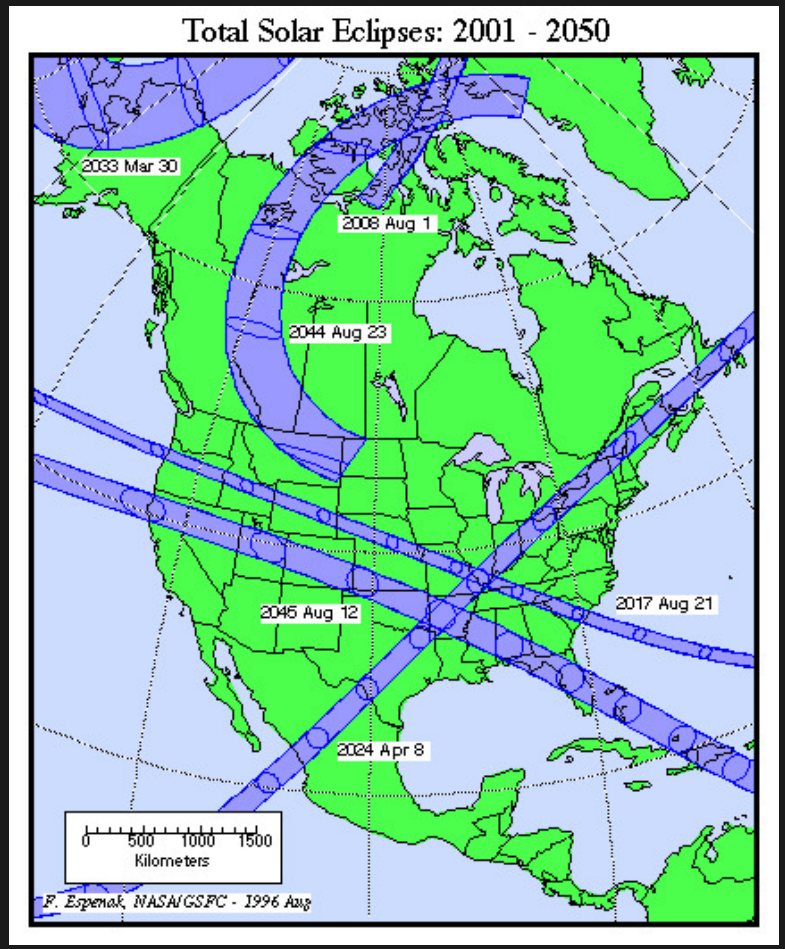




Future eclipses



Future eclipses



The eclipses of 2024, 2045 and 2017 are in the same Saros series as those of 1970, 1991 and 1999 respectively.

What we might see on April 8

What we might see on April 8

Planets and the comet during the coming eclipse.

What we might see on April 8

Planets and the comet during the coming eclipse.

THINK BLUE SKIES!

THANK YOU!