The Solar Eclipse

John Matthews
Professor of Physics, U. of New Mexico

The Moon orbits the Earth.
Every month the Moon is between the Sun and the Earth.
Some months this causes a Solar eclipse.

It’s mostly about Sun, Moon, Earth alignment

(https://www.timeanddate.com/eclipse/solar/2019-december-26)

Solar eclipse evolves as the Earth turns and the Moon moves

Time when Moon is on part of the Sun is long, maybe 3 hours.

(https://www.skyandtelescope.com/astronomy-news/100-days-until-christmas-ring-of-fire-eclipse/ and https://www.omanobserver.om/sultanate-to-witness-annular-solar-eclipse-in-december/)

Image sequence of an annular eclipse

Time when Moon is totally within the Solar disk is short, a few minutes.

(https://www.skyandtelescope.com/astronomy-news/100-days-until-christmas-ring-of-fire-eclipse/ and https://www.omanobserver.om/sultanate-to-witness-annular-solar-eclipse-in-december/)

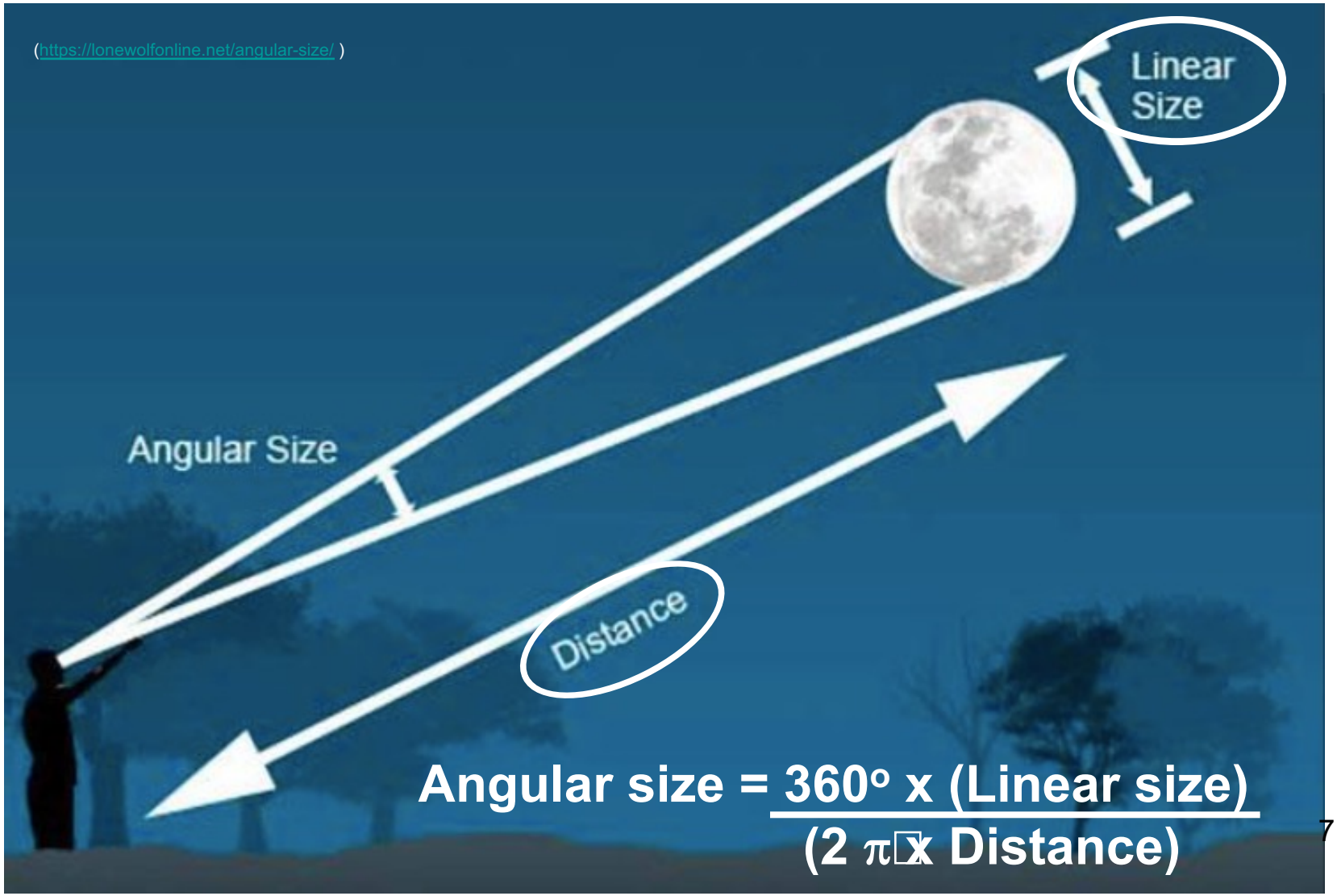
Annular eclipse when the Moon does not quite cover the Sun

Annular eclipse is when the Moon is a little “**too small**” to cover the Sun.

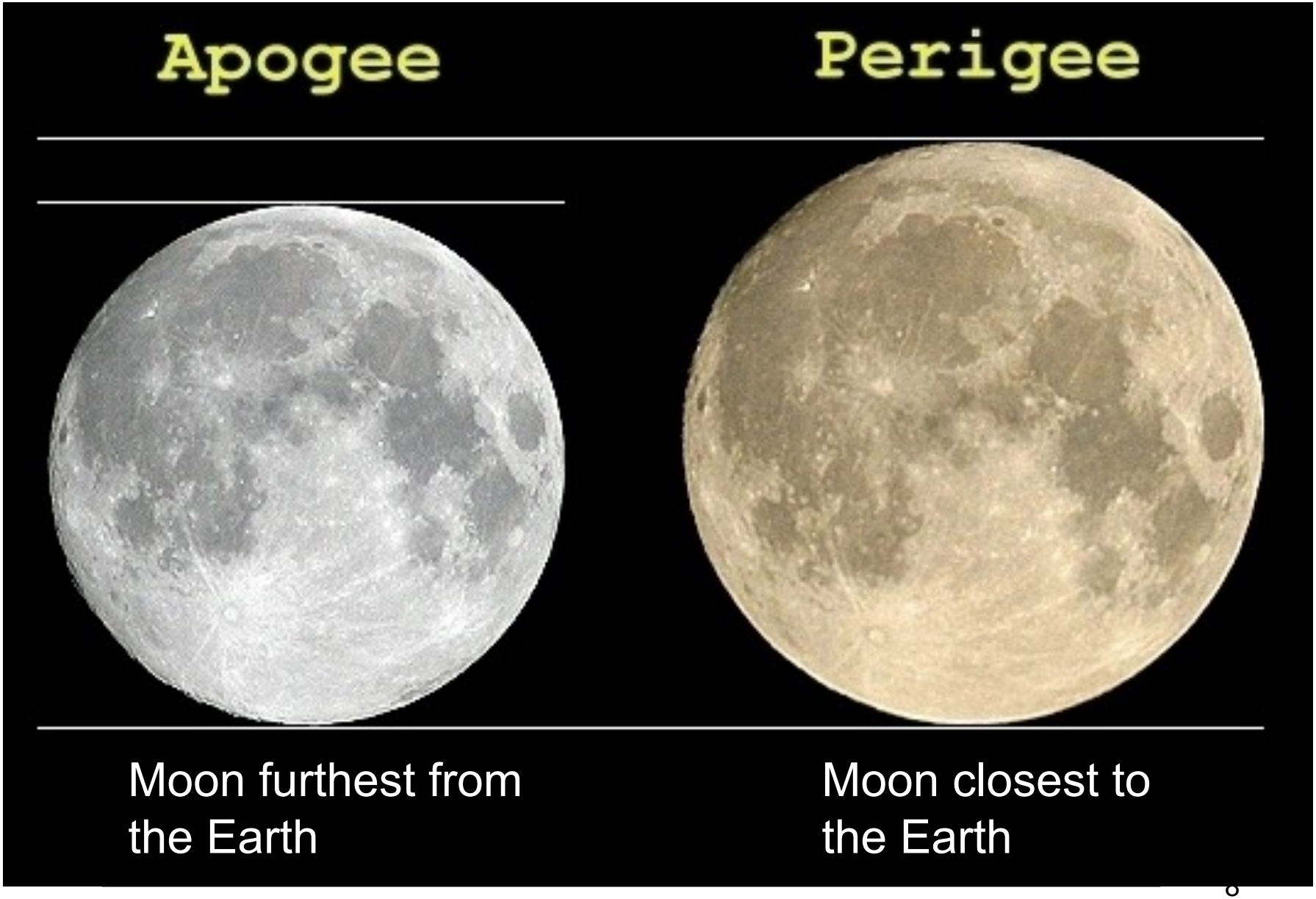
(https://www.skyandtelescope.com/astronomy-news/100-days-until-christmas-ring-of-fire-eclipse/ and https://www.omanobserver.om/sultanate-to-witness-annular-solar-eclipse-in-december/)

“Too small” is about the relative Moon / Sun angular sizes

The **angular size** of an object depends on its actual (linear) size and its distance from the Earth.



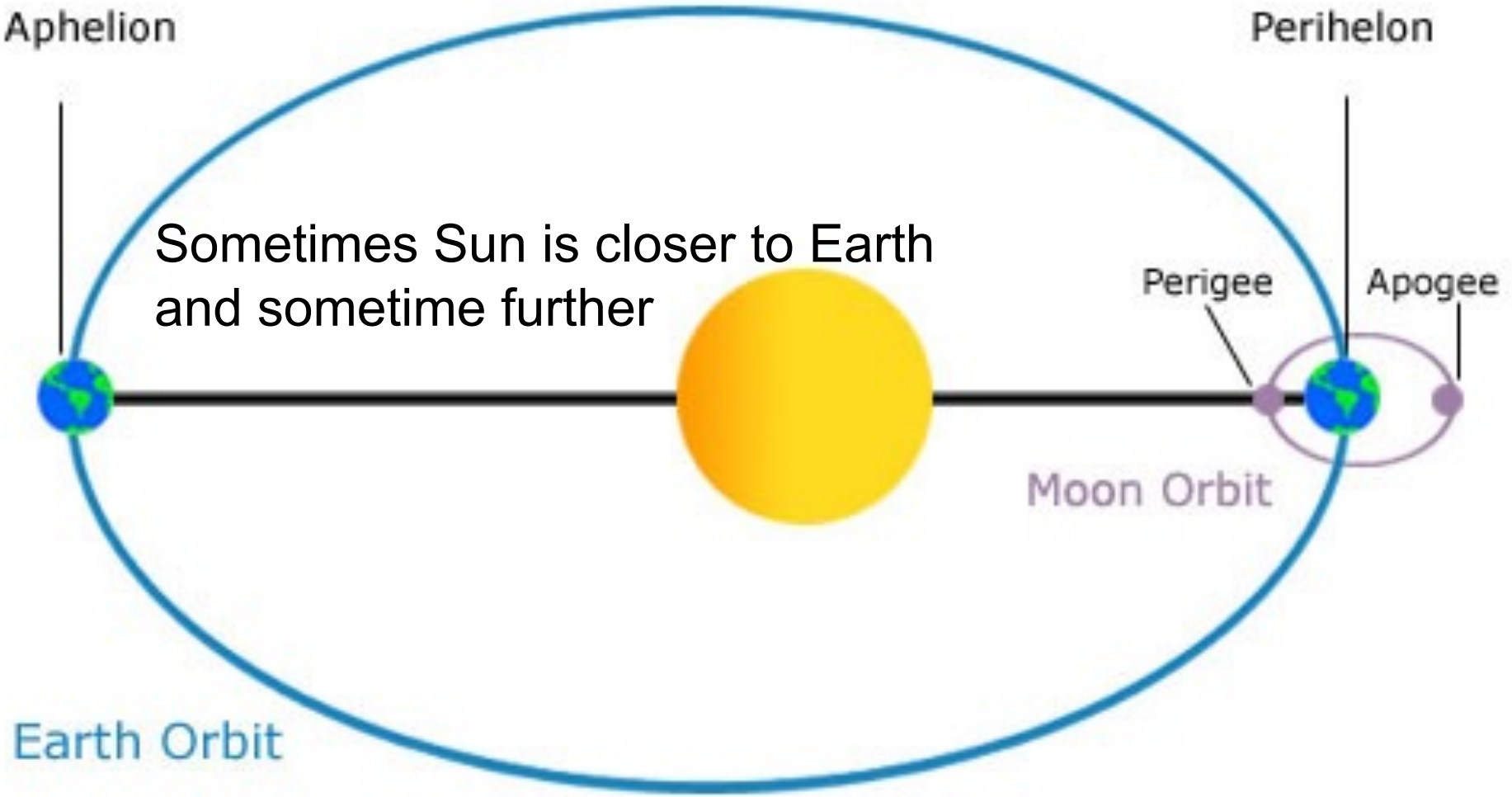
When Moon is farther from the Earth it appears “smaller”



(http://homepages.wmich.edu/~korista/moon-illus.html)

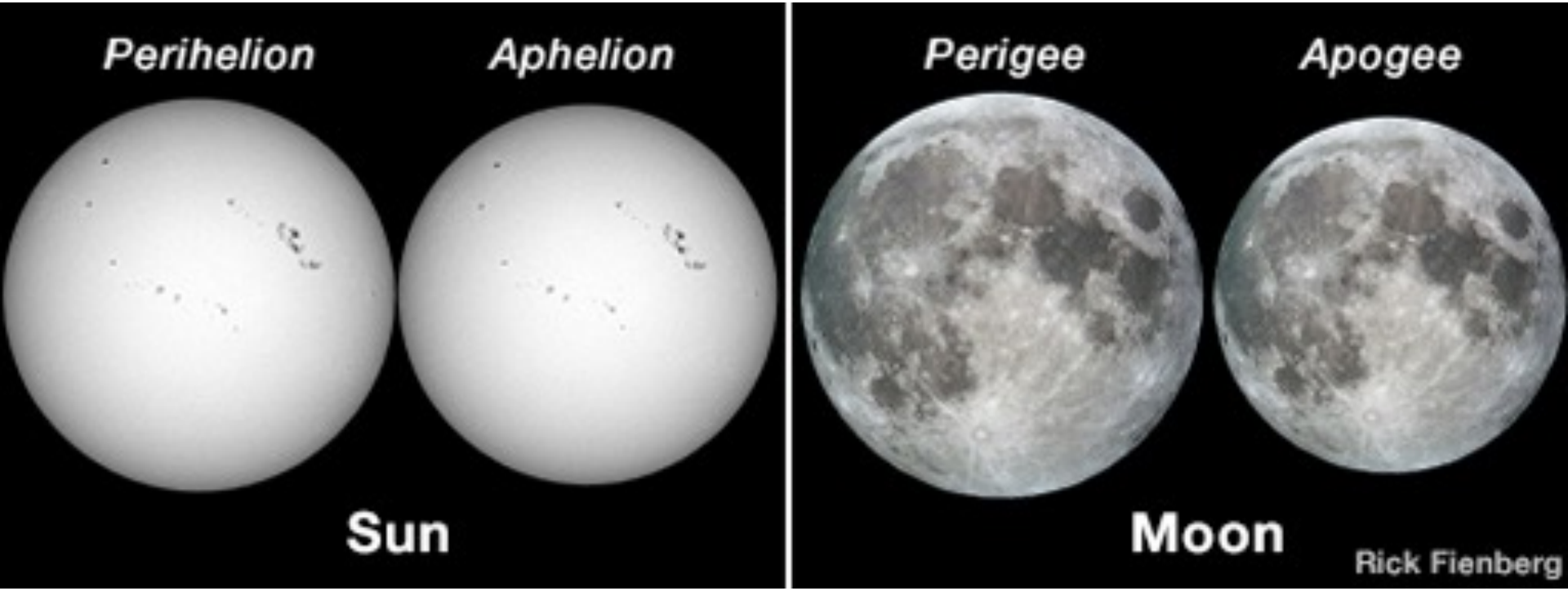
Eclipses are Total, or Annular, because orbits are ellipses

Sometimes Moon is closer to Earth and sometime further



(https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-orbit-58.html)

Annular eclipse when Moon is “smaller” than the Sun



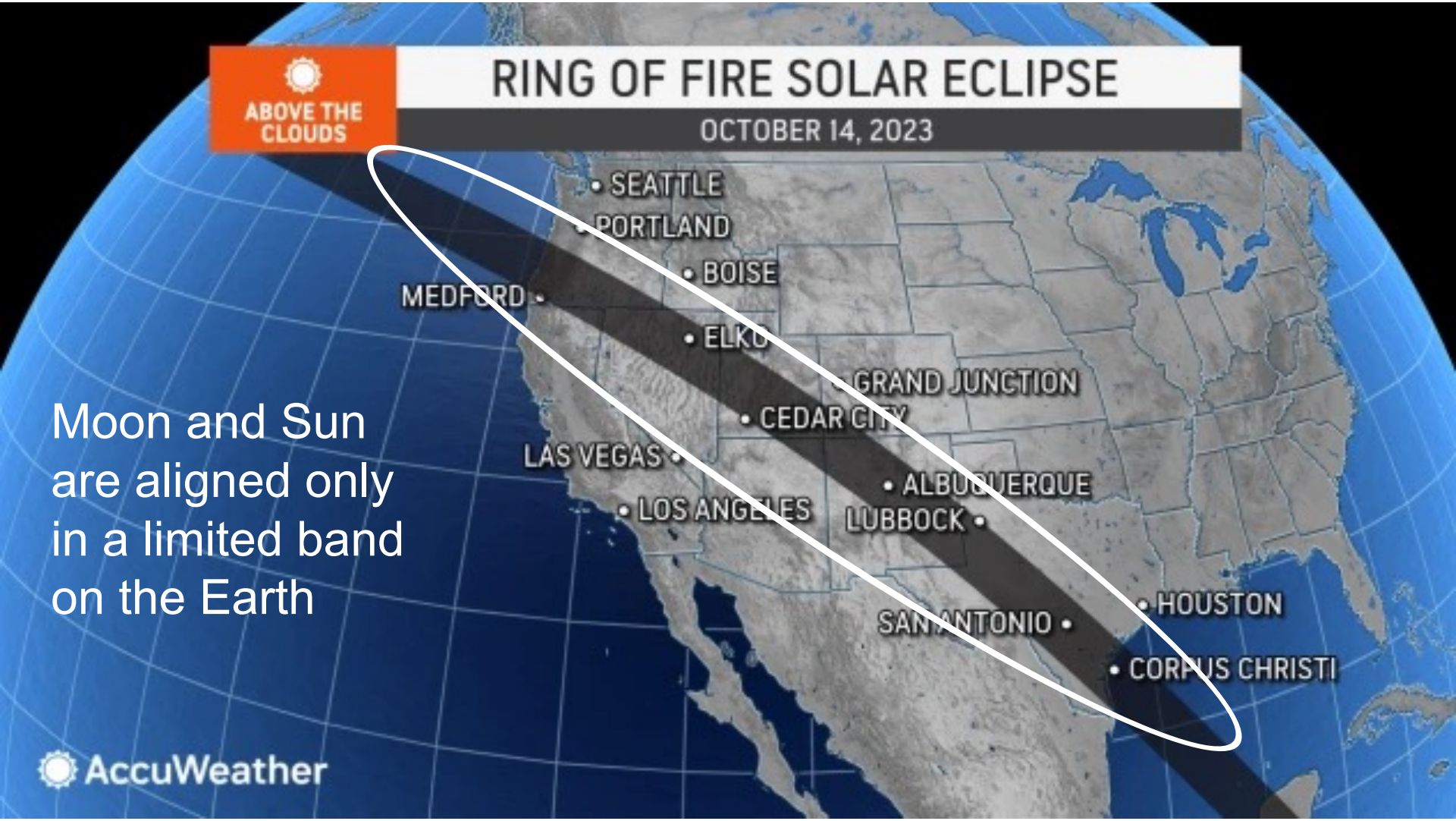
Annular eclipse favored when Earth is closest to the Sun (perihelion) and Moon is furthest from the Earth (Apogee)

For each eclipse which is “bigger”?

(https://bigthink.com/starts-with-a-bang/october-14-annular-eclipse-consequences/)

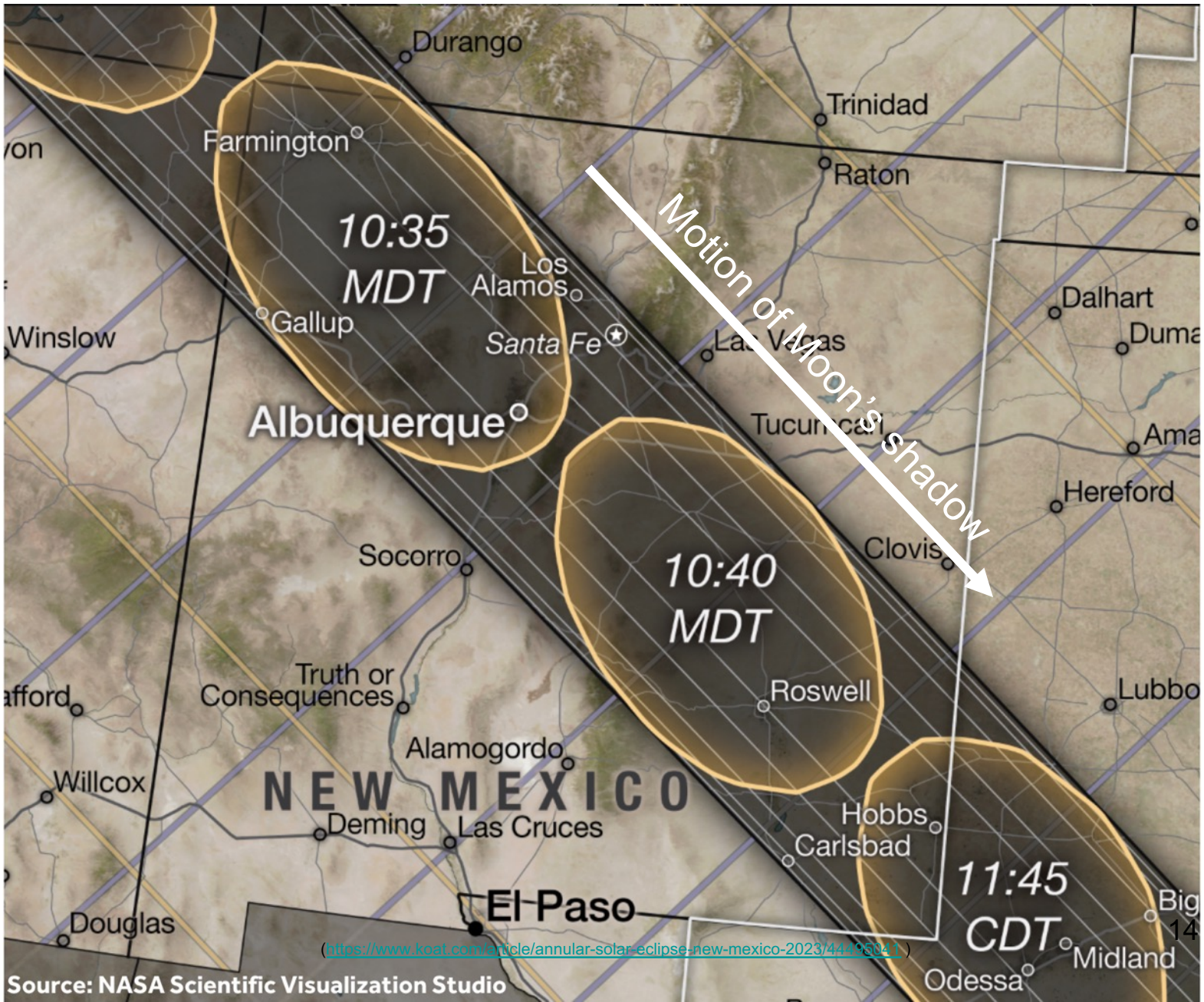
Viewing point on the Earth is also critical

Moon’s shadow falls only in a limited band on the Earth



(https://www.accuweather.com/en/space-news/best-places-to-travel-for-solar-eclipse-oct-14-2023/1261158)

Fortunately many good sites to view the eclipse in NM



(https://www.koat.com/article/annular-solar-eclipse-new-mexico-2023/44495041)

Moon is centered on the Sun along the green line

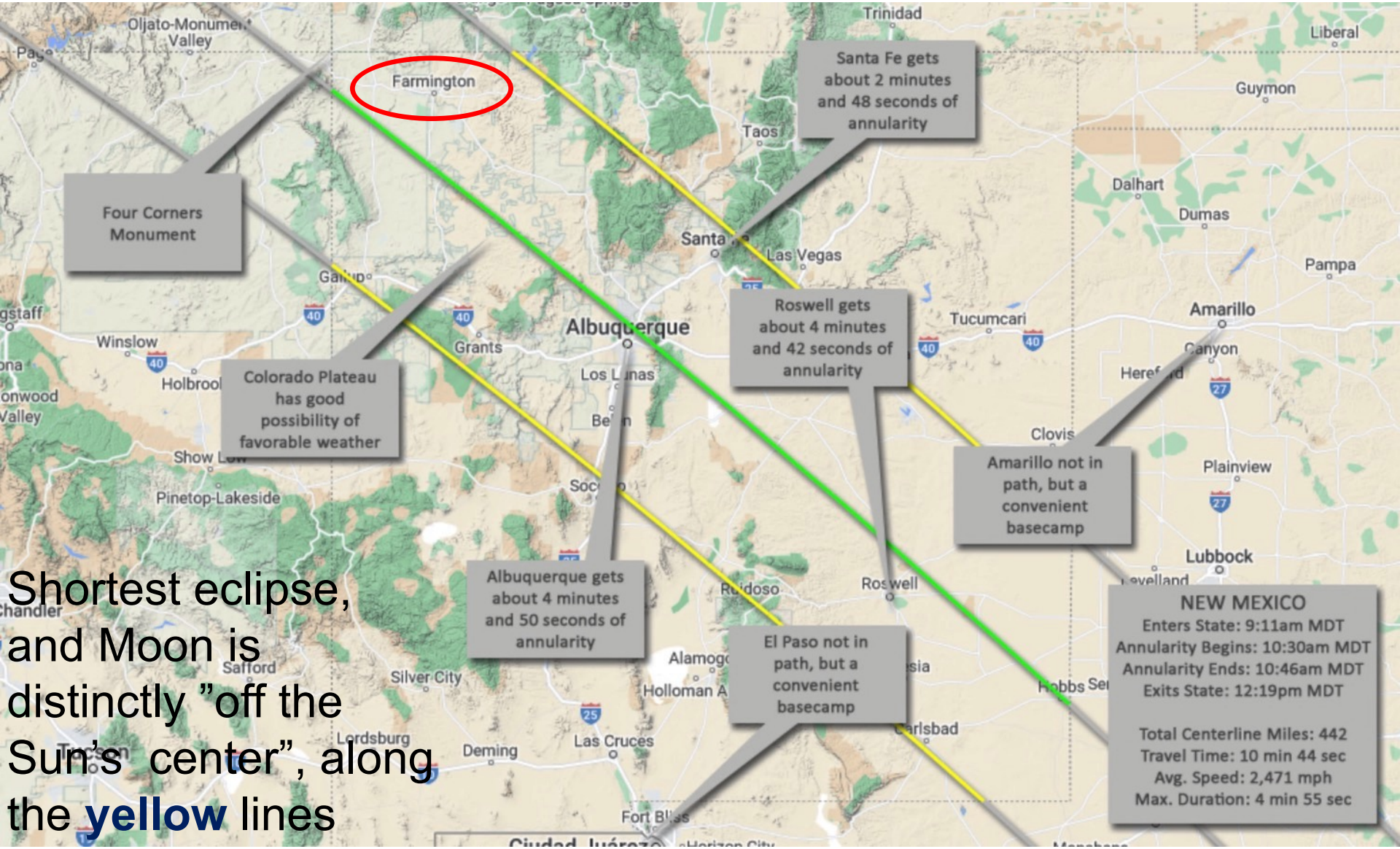
Longest eclipse, and Moon is "centered on the Sun", along the **green** line

(https://nationaleclipse.com/overview_2023.html)

For most annular eclipse sites, the Moon is not centered

(https://katu.com/news/local/prepare-for-oregons-ring-of-fire-annular-solar-eclipse-next-month)

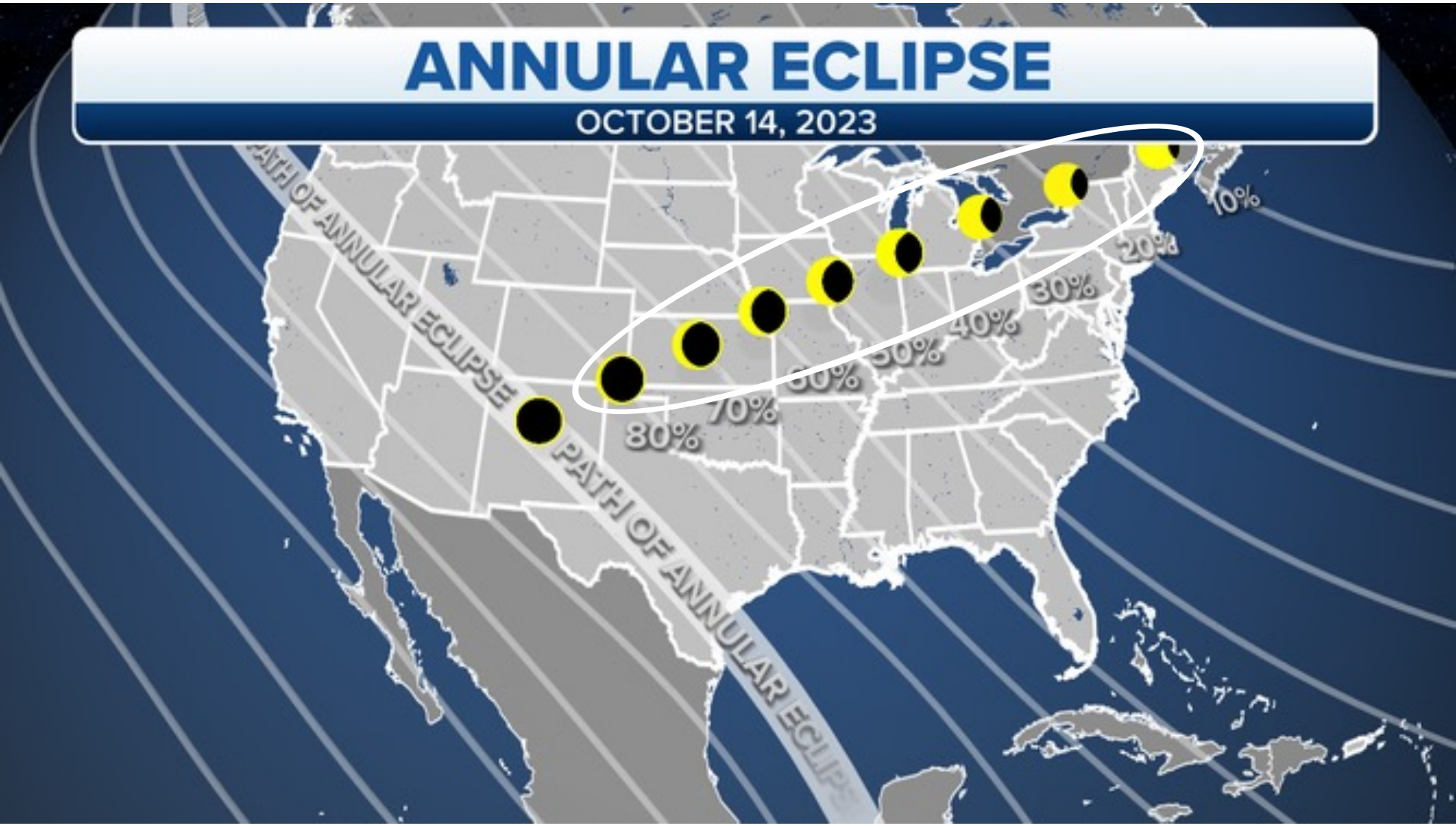
Moon is “on the Sun”, but is most off-center, at the yellow lines



Shortest eclipse, and Moon is distinctly ”off the Sun’s center”, along the **yellow** lines

(https://nationaleclipse.com/overview_2023.html)

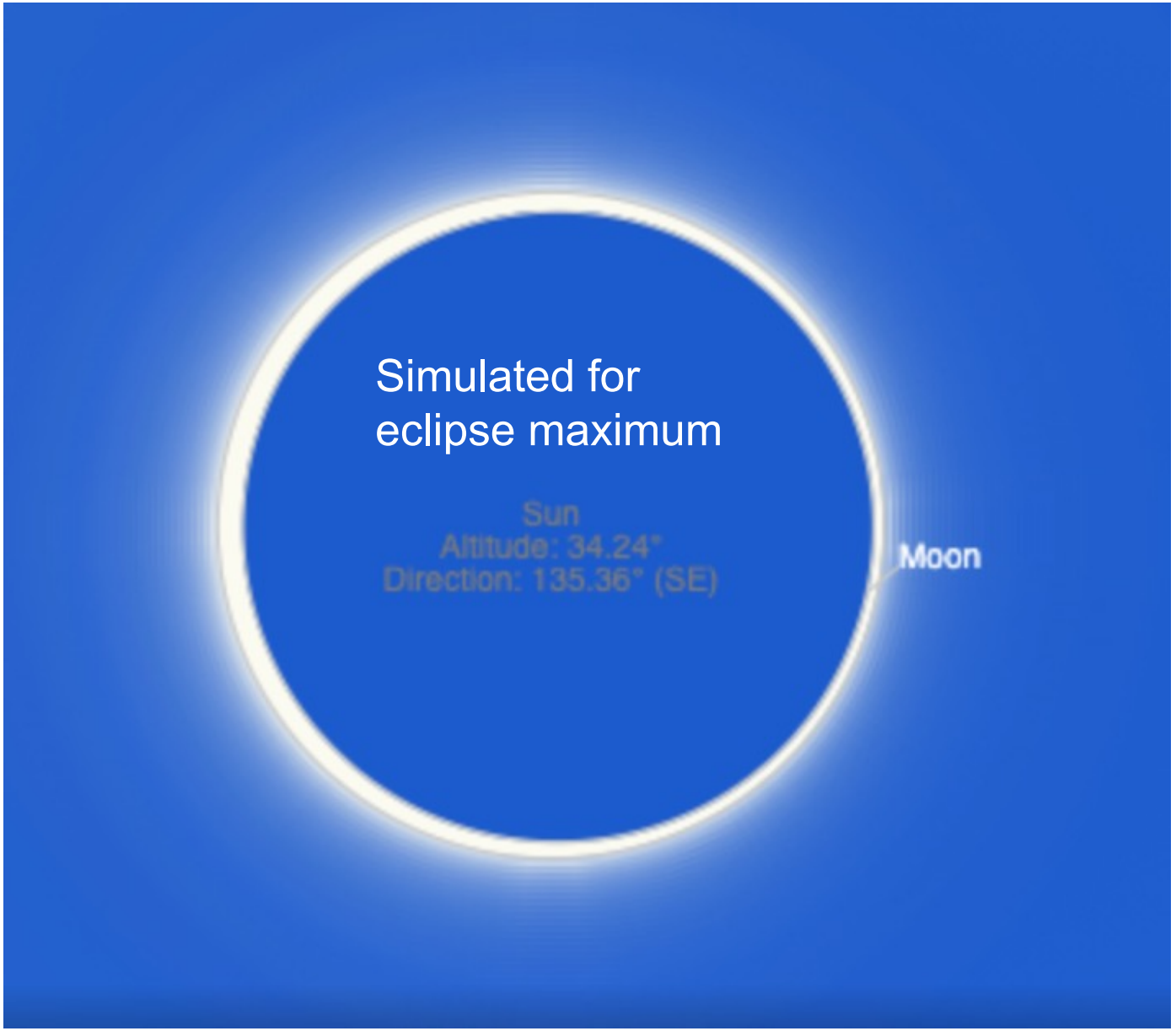
Outside the Eclipse Path, moon covers only part of the Sun



(https://www.foxweather.com/earth-space/ring-of-fire-solar-eclipse-to-dazzle-us-skies-in-2-years)

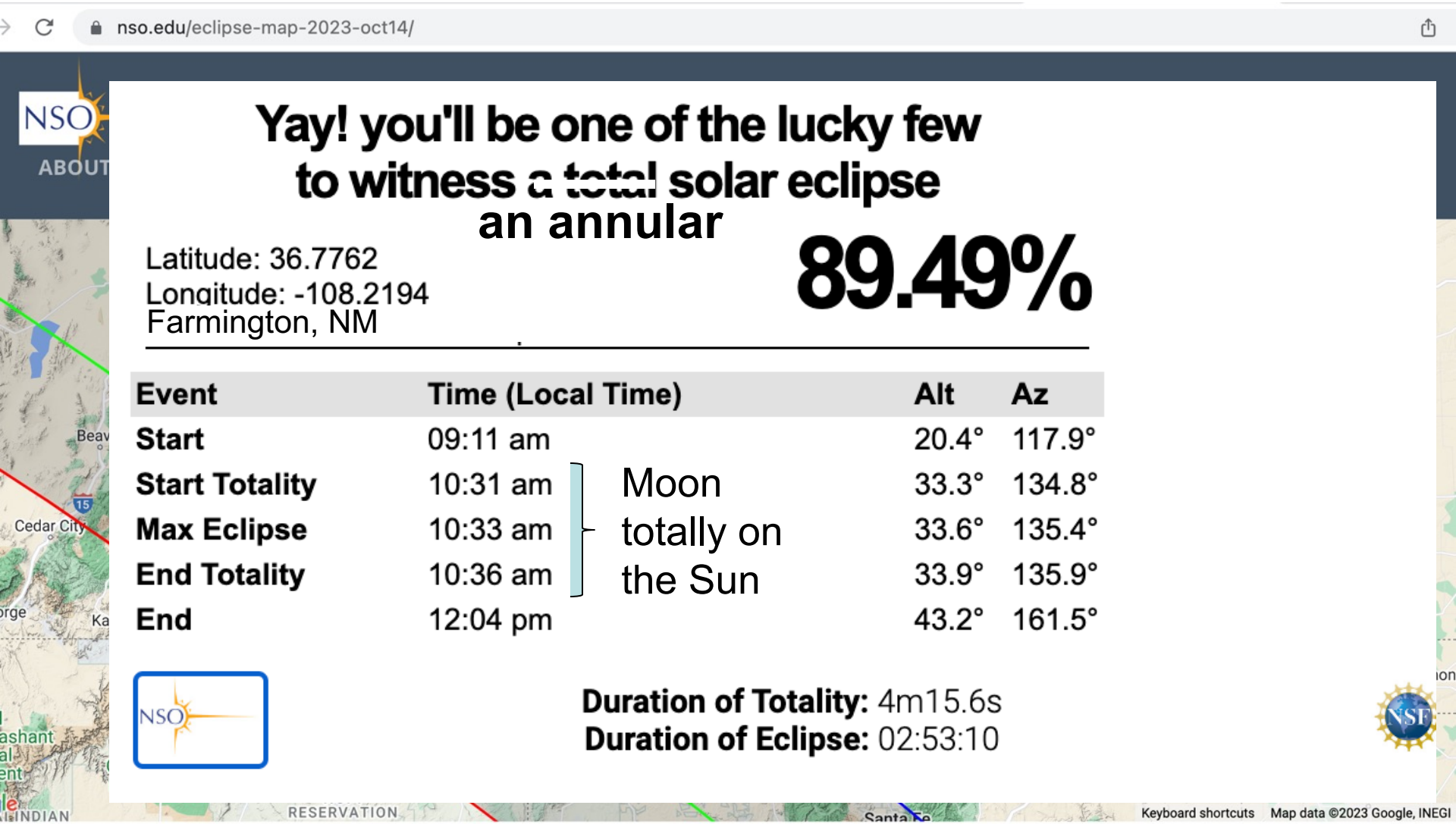
What will we see in Farmington?

Moon position on solar disk will be off-center for Farmington



(https://www.timeanddate.com/eclipse/in/@5467328?iso=20231014)

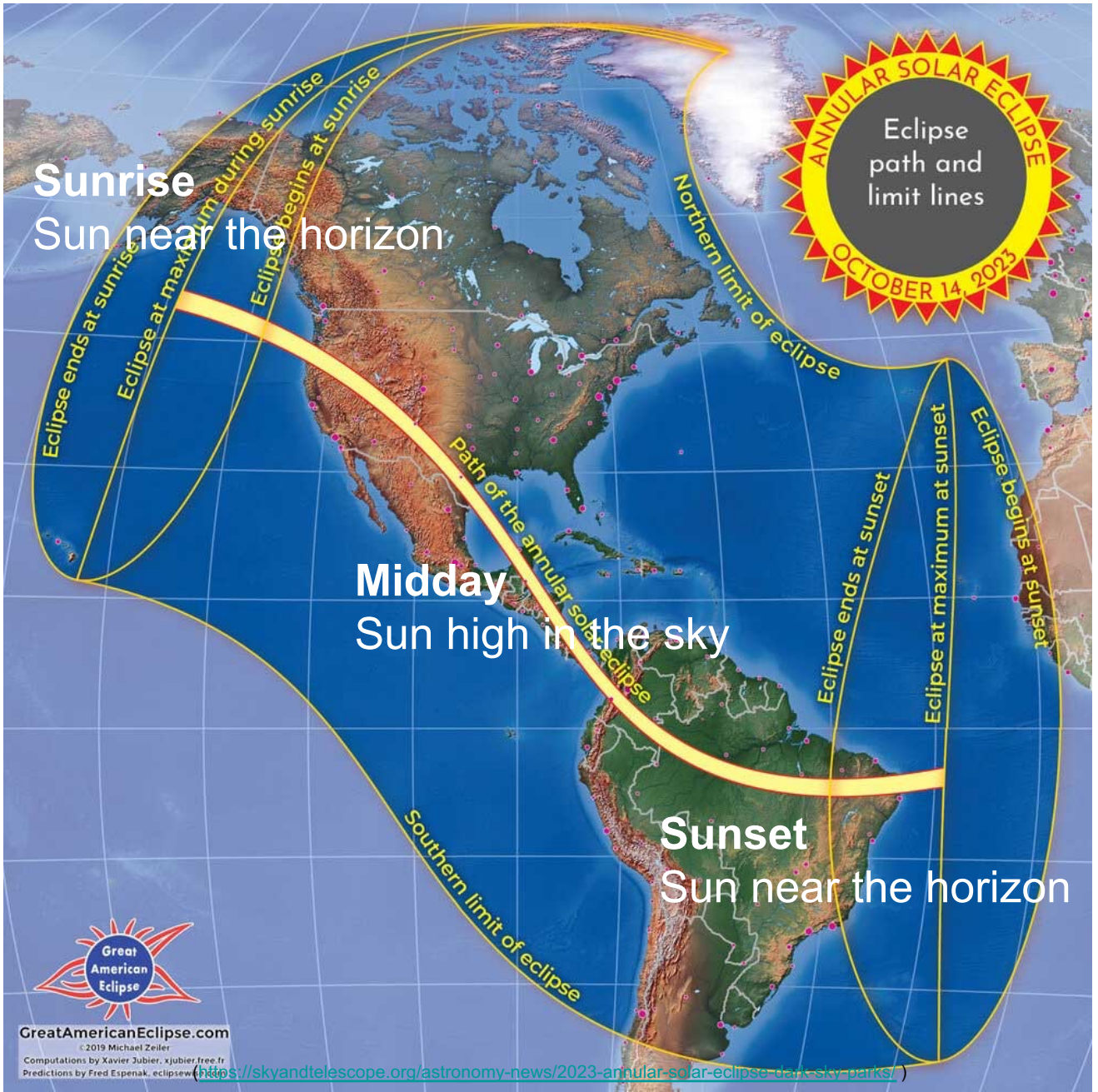
Moon is most “on the Sun” about 10:33am for Farmington



Credit: National Solar Observatory, AURA and National Science Foundation. Using NASA eclipse path data generated by Fred Espenak, Besselian Elements for October 14, 2023 eclipse. Specific eclipse data from the US Naval Observatory’s Astronomical Applications Department.

(https://www.skyandtelescope.com/astronomy-news/100-days-until-christmas-ring-of-fire-eclipse/)

Eclipse position in the sky also depends on viewing location



(https://skyandtelescope.org/astronomy-news/2023-annular-solar-eclipse-dark-sky-parks/)

Farmington guide to times and directions

The animation shows what the eclipse approximately looks like in Farmington. Stages and times of the eclipse are outlined below. All times are local time (MDT) for Farmington.

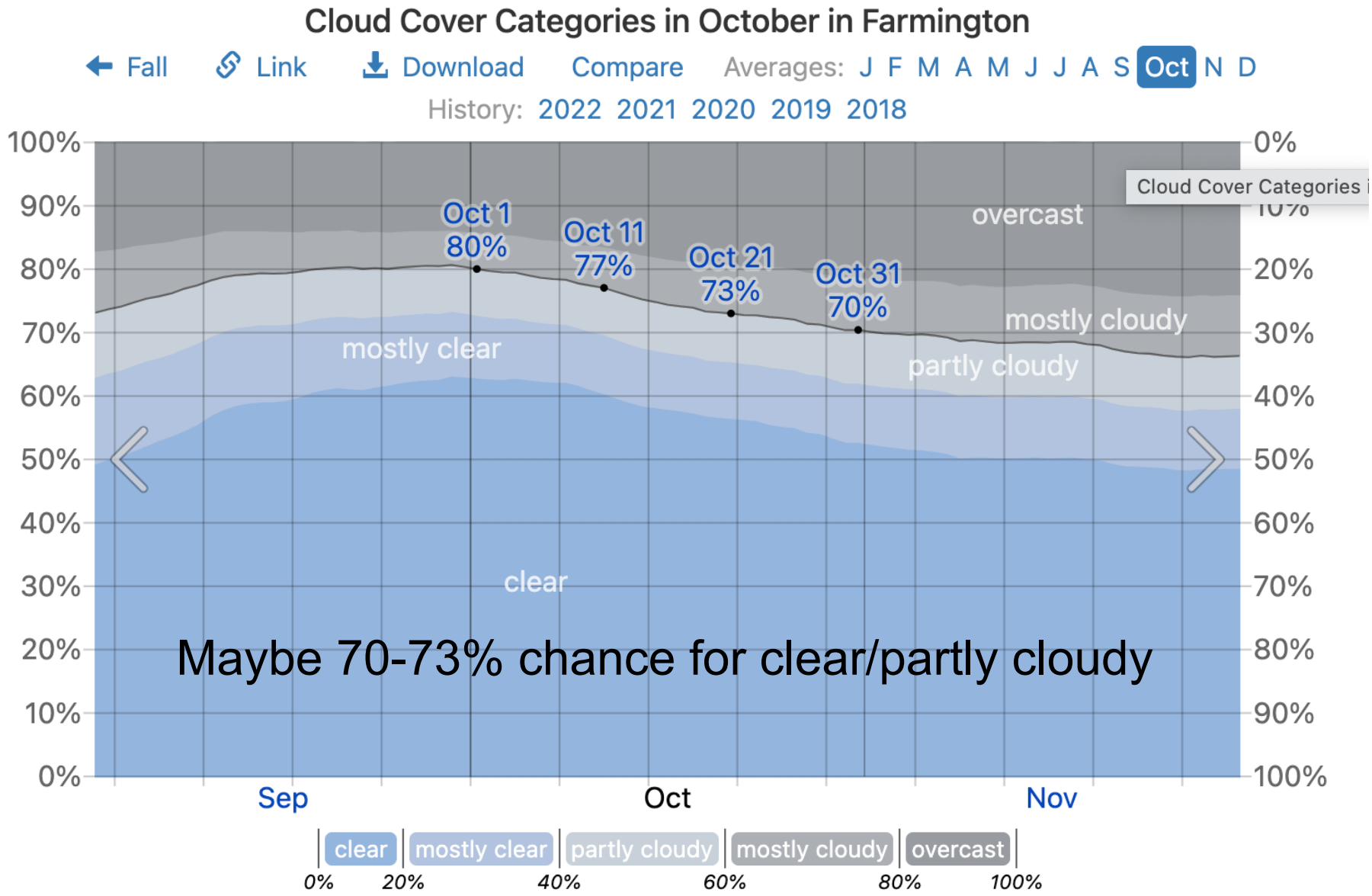
Time	Phase	Event	Direction	Altitude
9:11:41 am Sat, Oct 14		Partial Eclipse begins The Moon touches the Sun's edge.	 117°	 20.5°
10:31:50 am Sat, Oct 14		Full Eclipse begins The Annular phase starts	 134°	 33.4°
10:34:01 am Sat, Oct 14		Maximum Eclipse Moon is closest to the center of the Sun.	 135°	 33.7°
10:36:10 am Sat, Oct 14		Full Eclipse ends The Annular phase ends.	 135°	 34.0°
12:04:57 pm Sat, Oct 14		Partial Eclipse ends The Moon leaves the Sun's edge.	 161°	 43.3°

Eclipse to the **South East**, about **34º** above the **horizon**

(https://www.timeanddate.com/eclipse/in/@5467328?iso=20231014)

Want no clouds in the part of sky with the Moon/Sun

Expected weather



The percentage of time spent in each cloud cover band, categorized by the percentage of the sky covered by clouds.

(https://weatherspark.com/m/3095/10/Average-Weather-in-October-in-Farmington-New-Mexico-United-States#Figures-CloudCover)

Encouraging forecast: maximum eclipse at 10:34am

Hourly Forecast for Saturday 10/14

Saturday 10/14 — 1% / 0 in

Partly cloudy skies. High 72F. Winds S at 5 to 10 mph.

Saturday Night 10/14 — 1% / 0 in

Clear. Low 33F. Winds NNE at 5 to 10 mph.

Time	Conditions	Temp.	Feels Like	Precip	Amount	Cloud Cover	Dew Point	Humidity	Wind	Pressure
12:00 am	Partly Cloudy	40 °F	36 °F	0 %	0 in	57 %	21 °F	46 %	5 mph NE	30.09 in
1:00 am	Partly Cloudy	38 °F	34 °F	0 %	0 in	58 %	21 °F	50 %	5 mph ENE	30.11 in
2:00 am	Partly Cloudy	37 °F	33 °F	1 %	0 in	59 %	21 °F	52 %	6 mph ENE	30.12 in
3:00 am	Mostly Cloudy	37 °F	32 °F	1 %	0 in	65 %	21 °F	54 %	6 mph ENE	30.14 in
4:00 am	Mostly Cloudy	36 °F	31 °F	1 %	0 in	68 %	21 °F	55 %	6 mph ENE	30.15 in
5:00 am	Mostly Cloudy	35 °F	30 °F	1 %	0 in	70 %	22 °F	58 %	6 mph ENE	30.17 in
6:00 am	Partly Cloudy	35 °F	29 °F	1 %	0 in	58 %	23 °F	60 %	7 mph ENE	30.19 in
7:00 am	Partly Cloudy	34 °F	29 °F	1 %	0 in	48 %	22 °F	59 %	7 mph E	30.20 in
8:00 am	Partly Cloudy	37 °F	31 °F	1 %	0 in	39 %	23 °F	57 %	6 mph E	30.21 in
9:00 am	Sunny	42 °F	38 °F	0 %	0 in	17 %	23 °F	46 %	7 mph E	30.21 in
10:00 am	Sunny	49 °F	46 °F	0 %	0 in	17 %	24 °F	36 %	6 mph ESE	30.19 in
11:00 am	Sunny	57 °F	56 °F	0 %	0 in	4 %	23 °F	26 %	6 mph ESE	30.14 in
12:00 pm	Sunny	62 °F	62 °F	0 %	0 in	1 %	20 °F	20 %	4 mph ESE	30.09 in

How to view the eclipse safely

For all Solar eclipses, proper eye protection is essential!

(https://www.timeanddate.com/eclipse/solar/2019-december-26)

Yes, eclipse is amazing but watch “appropriately”

(https://www.nytimes.com/2023/04/20/world/australia/solar-eclipse.html)

Many “solar eclipse” glasses are available

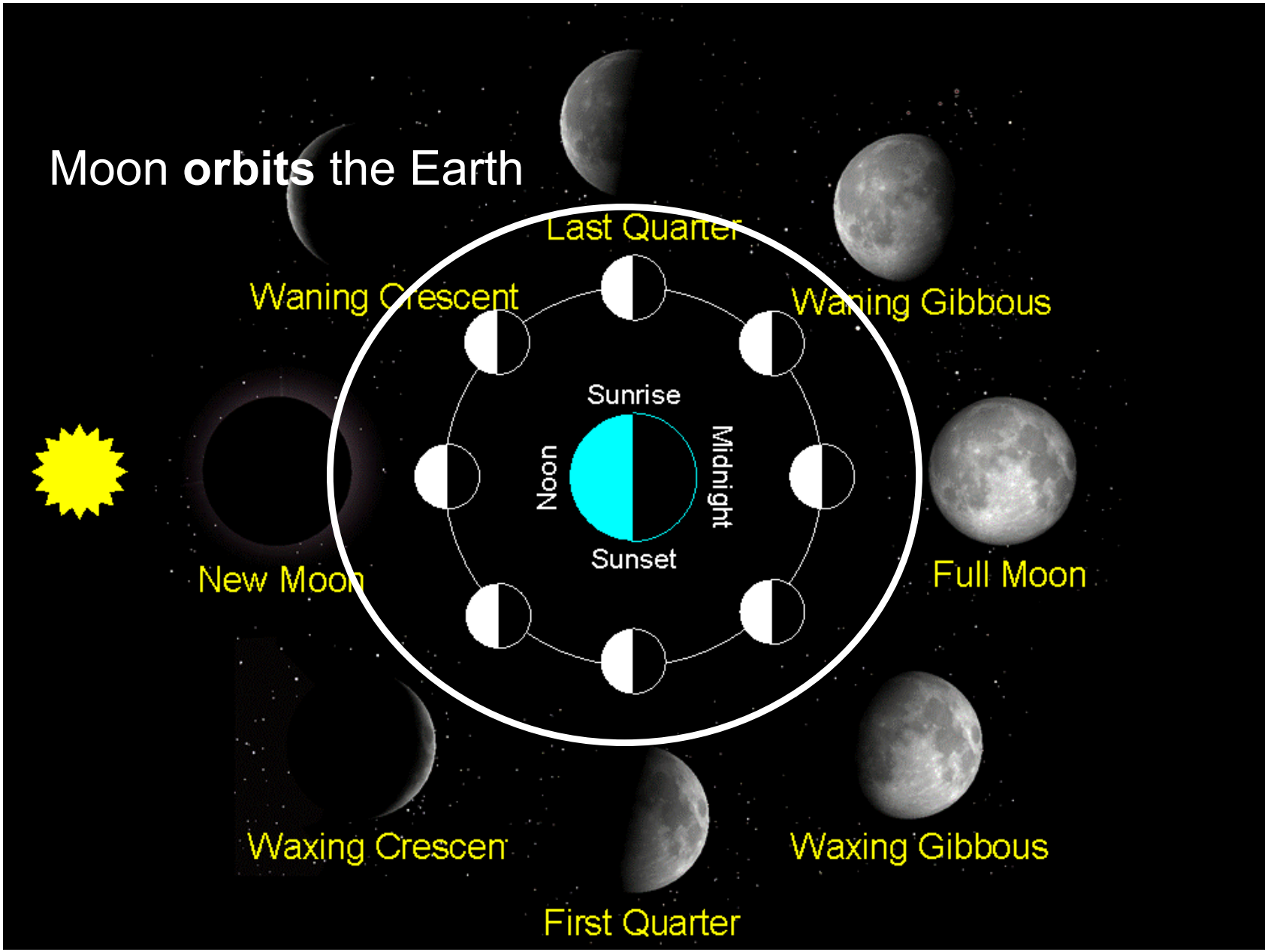
Filters need to be: ISO 12312-2 compliant

No glasses, then project the image of the Sun onto a surface

(https://www.timeanddate.com/eclipse/solar/2019-december-26)

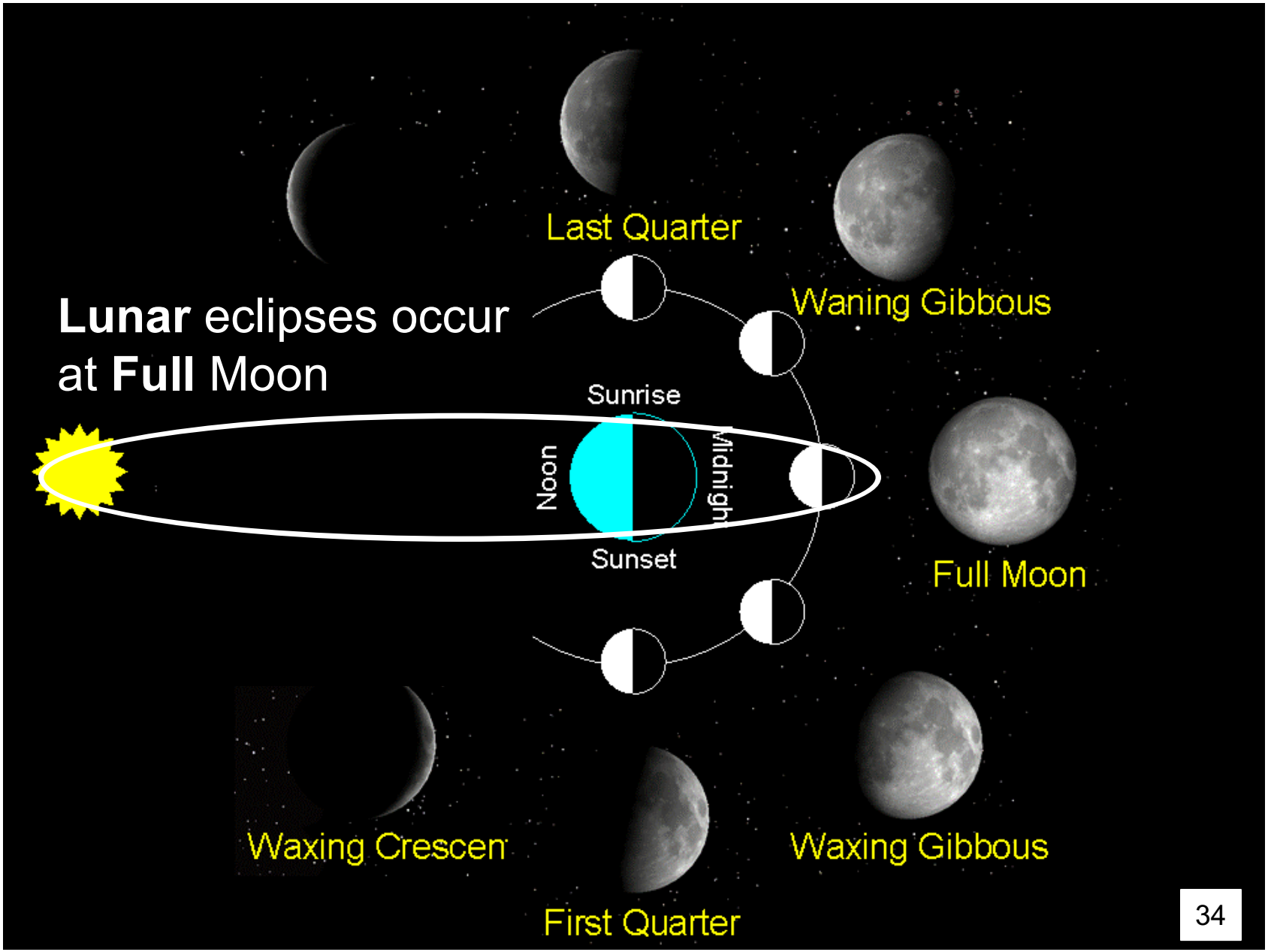
Why are there eclipses?

Eclipses depend on relative Earth, Moon and Sun positions



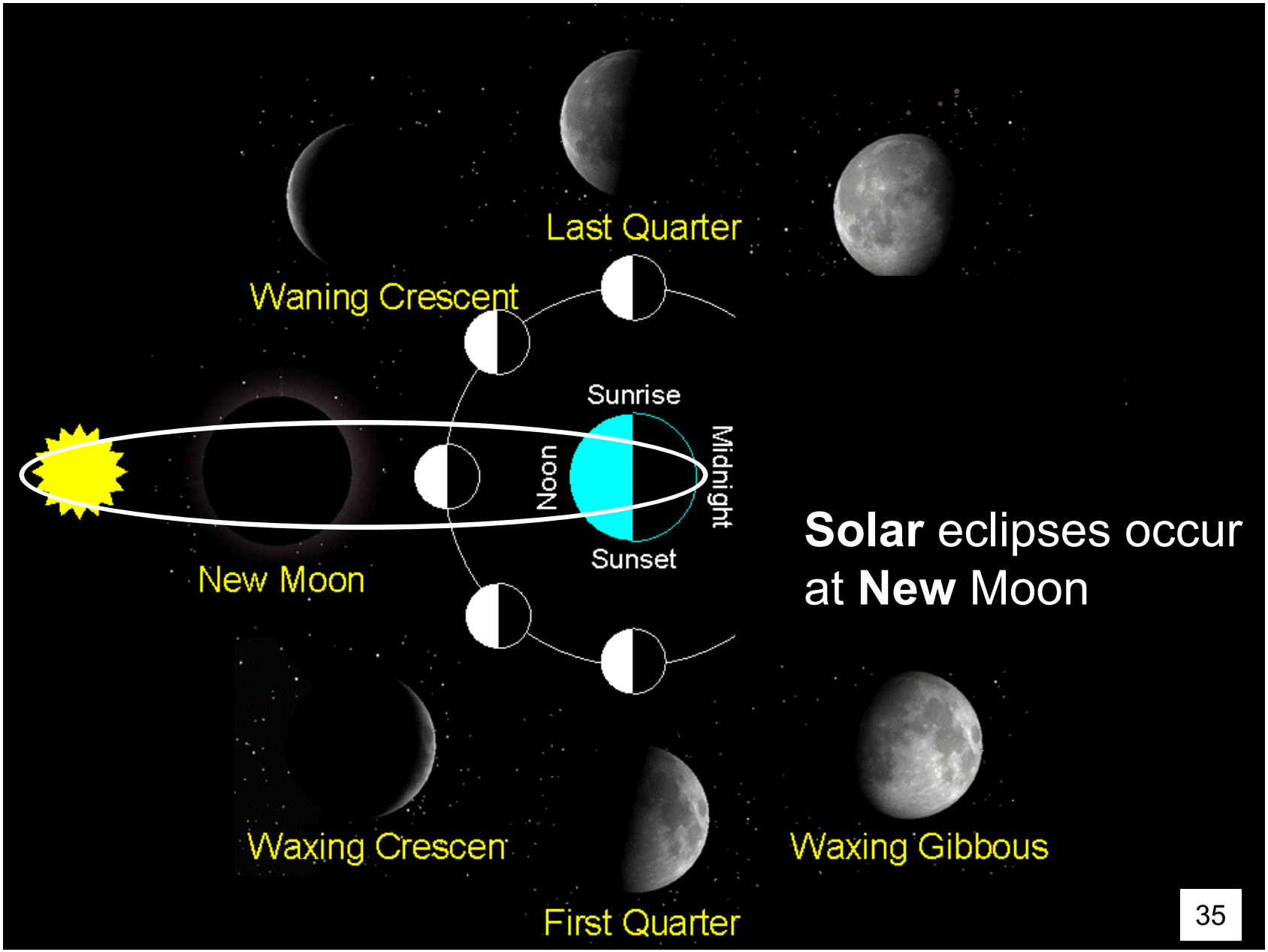
(http://www.astronomy.ohio-state.edu/~pogge/Ast161/Unit2/phases.html)

Lunar eclipses when Earth is between Sun and Moon



(http://www.astronomy.ohio-state.edu/~pogge/Ast161/Unit2/phases.html)

Solar eclipses when Moon is between Sun and Earth

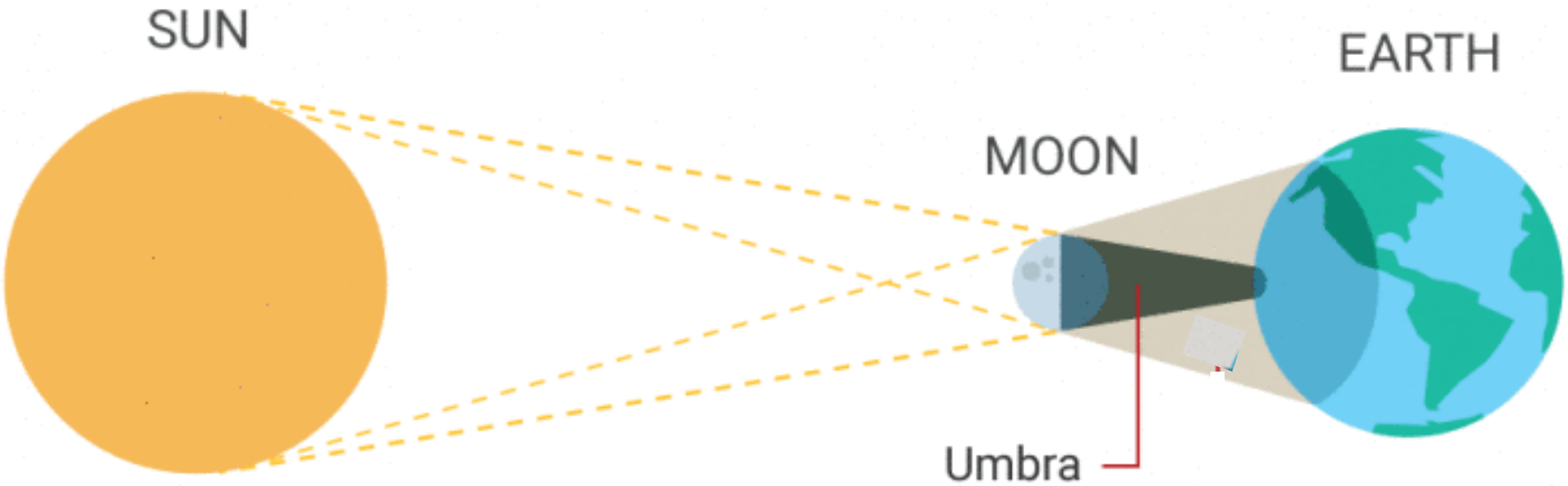


(http://www.astronomy.ohio-state.edu/~pogge/Ast161/Unit2/phases.html)

Solar eclipse depends critically on Moon’s tapered shadow

Total eclipse when Moon's tapered shadow reaches the Earth

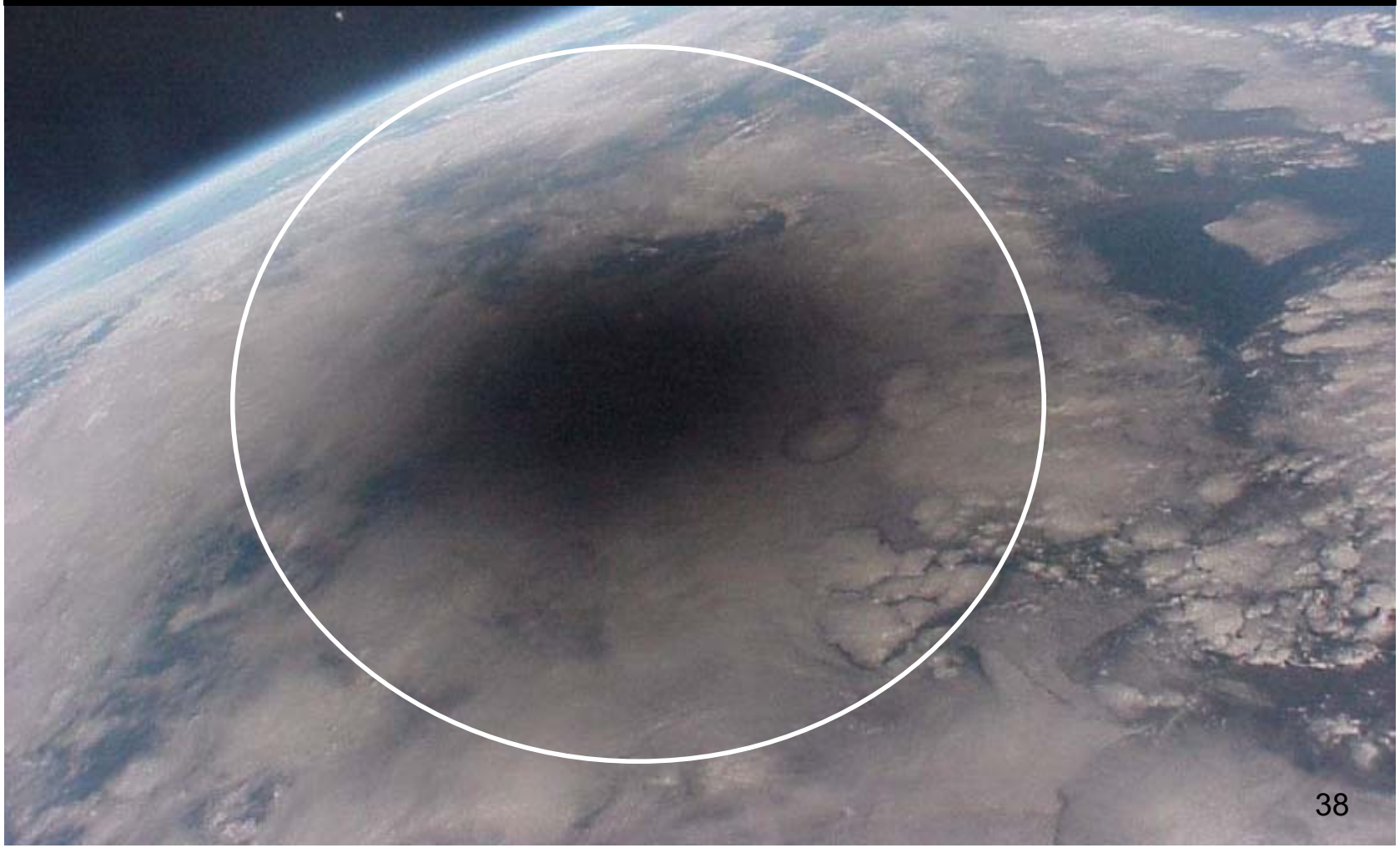
What you see then depends on where you are on the Earth!



None of Sun is visible

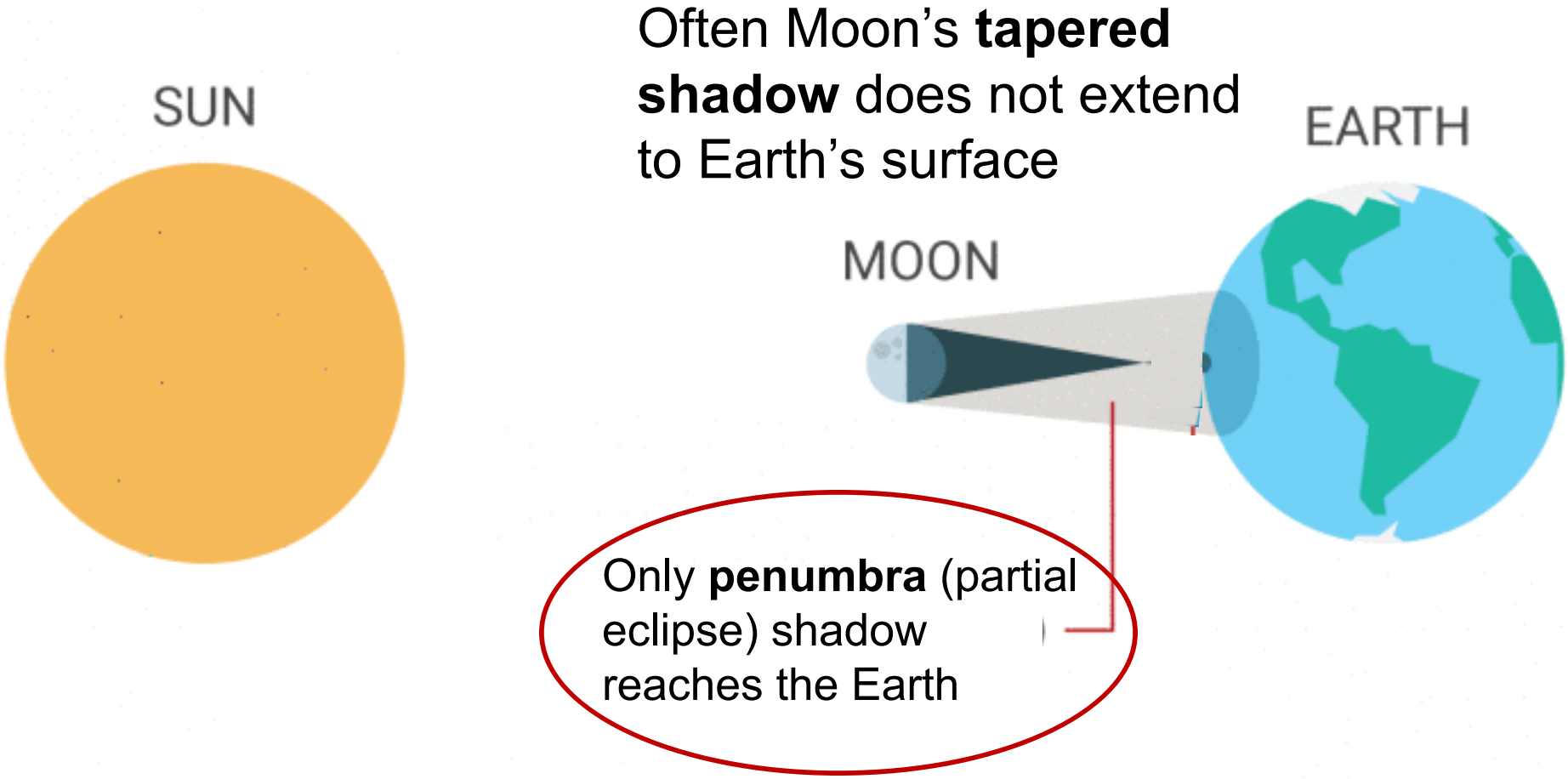
Total eclipse shadow is quite small!

Total solar eclipse of 11 August 1999 photographed by French astronaut Jean-Pierre Haignere aboard the Russian Mir space station



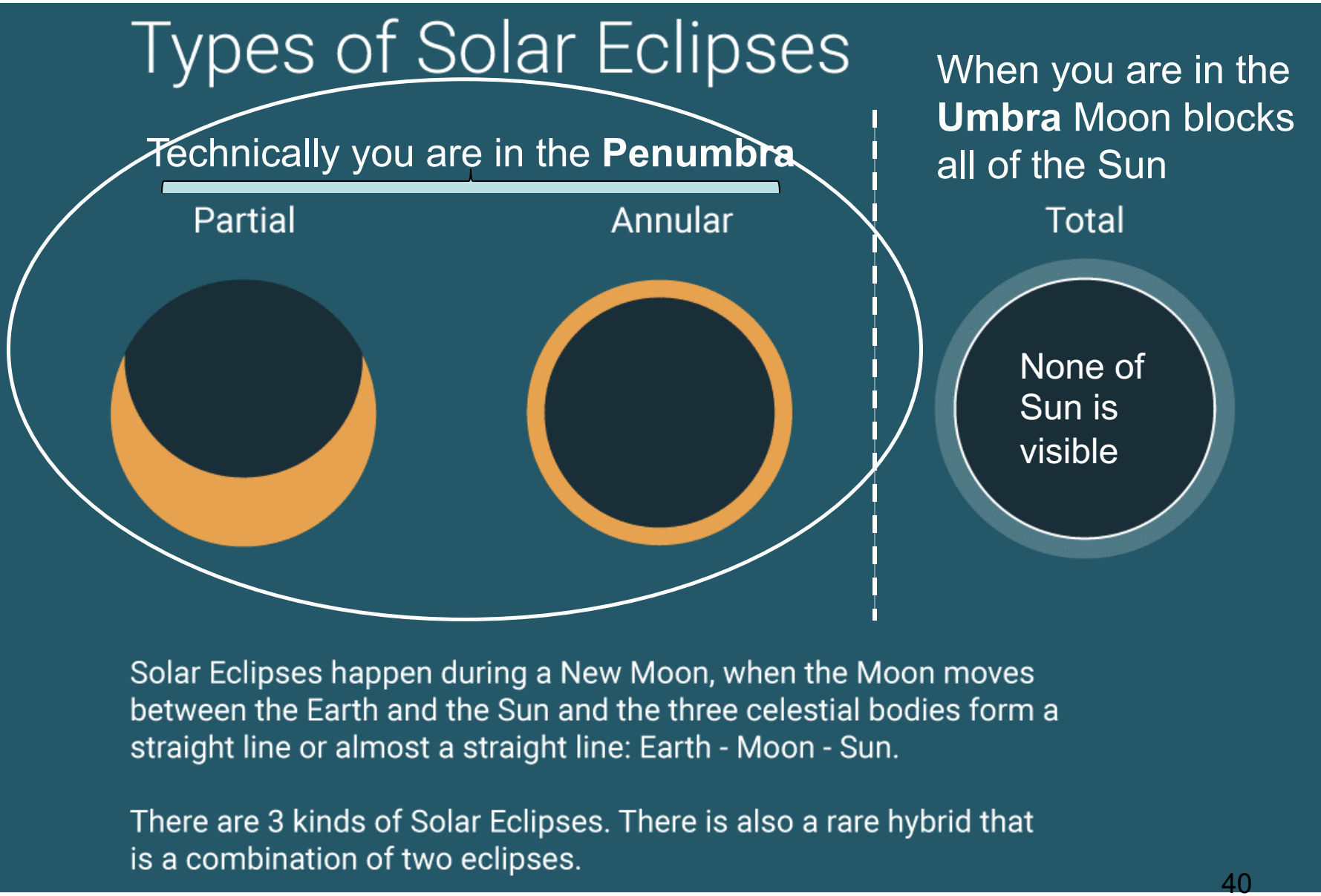
(https://www.theguardian.com/science/gallery/2015/mar/15/solar-eclipse-1999-in-pictures)

On Oct 14, 2023 Moon's shadow will not extend to the Earth



(https://www.timeanddate.com/eclipse/annular-solar-eclipse.html)

Penumbra shadow means some of the Sun is visible

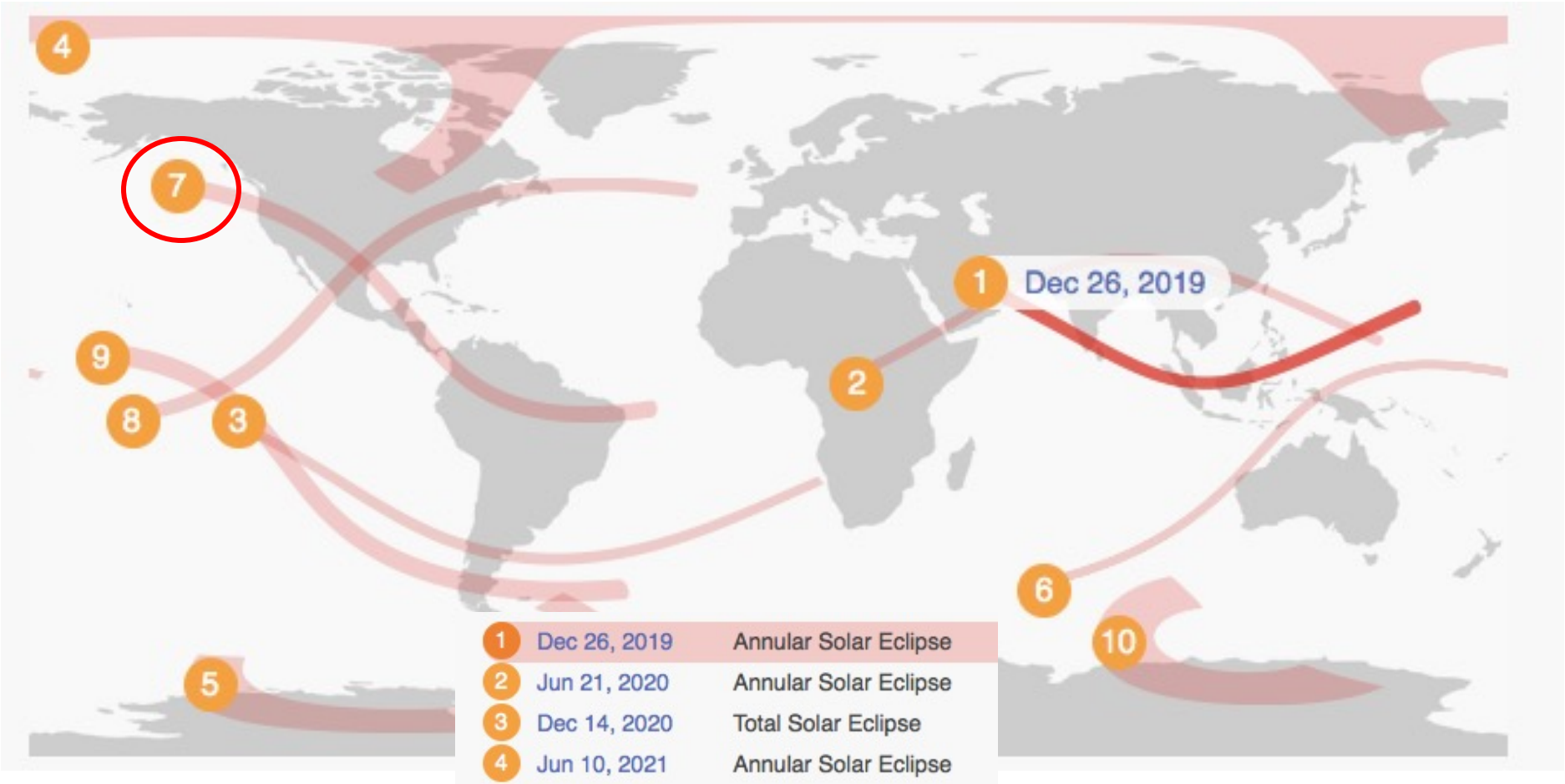


Solar Eclipses happen during a New Moon, when the Moon moves between the Earth and the Sun and the three celestial bodies form a straight line or almost a straight line: Earth - Moon - Sun.

There are 3 kinds of Solar Eclipses. There is also a rare hybrid that is a combination of two eclipses.

(https://www.timeanddate.com/eclipse/eclipse-information.html)

Moon's small shadow restricts where eclipses are visible



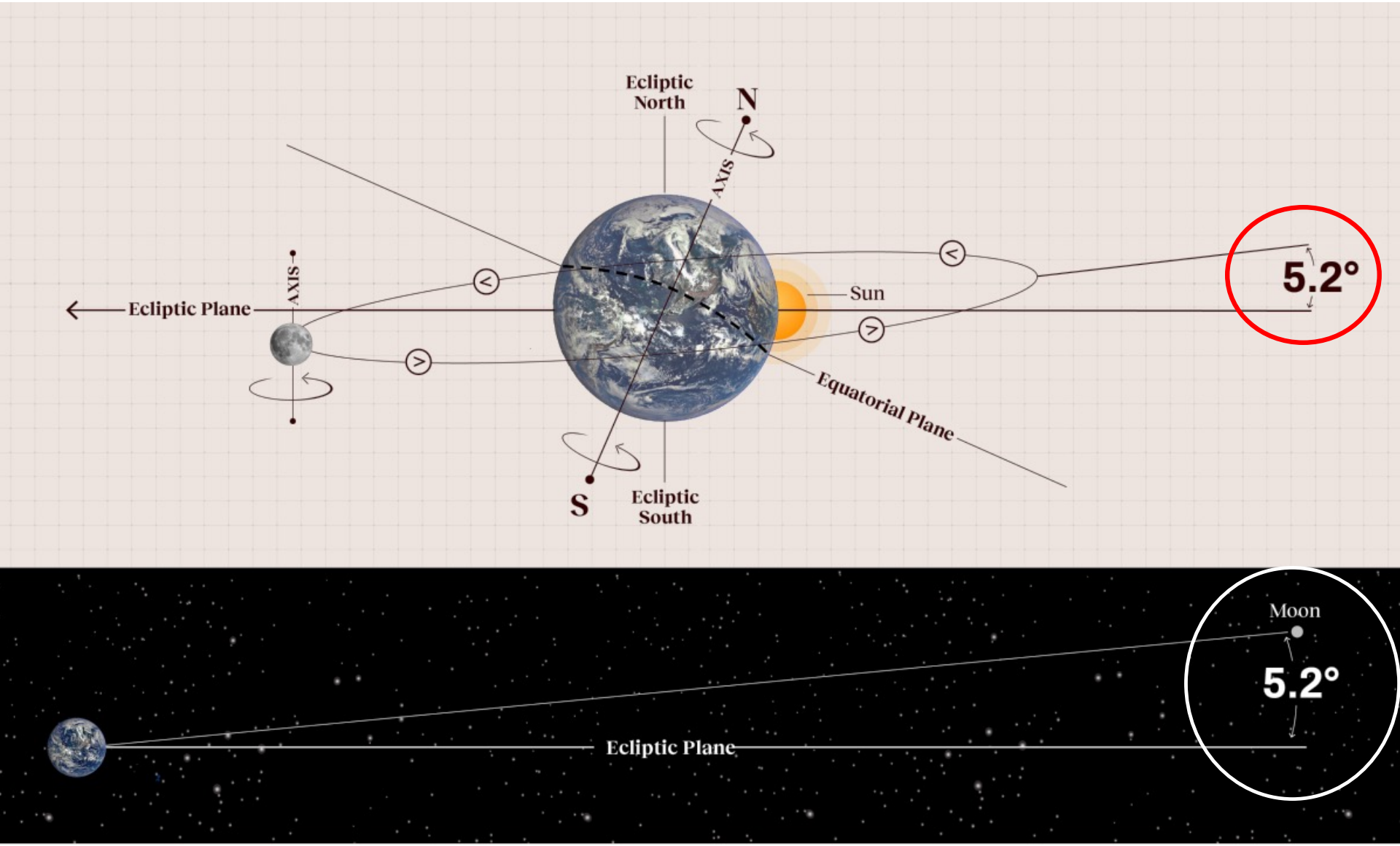
1	Dec 26, 2019	Annular Solar Eclipse
2	Jun 21, 2020	Annular Solar Eclipse
3	Dec 14, 2020	Total Solar Eclipse
4	Jun 10, 2021	Annular Solar Eclipse
5	Dec 4, 2021	Total Solar Eclipse
6	Apr 20, 2023	Total Solar Eclipse
7	Oct 14, 2023	Annular Solar Eclipse
8	Apr 8, 2024	Total Solar Eclipse
9	Oct 2, 2024	Annular Solar Eclipse
10	Feb 17, 2026	Annular Solar Eclipse

Moon casts a "small" shadow

(https://www.timeanddate.com/eclipse/solar/2019-december-26)

Why are solar eclipses not at each new Moon?

Plane of Moon's orbit is tilted from plane of Earth's orbit

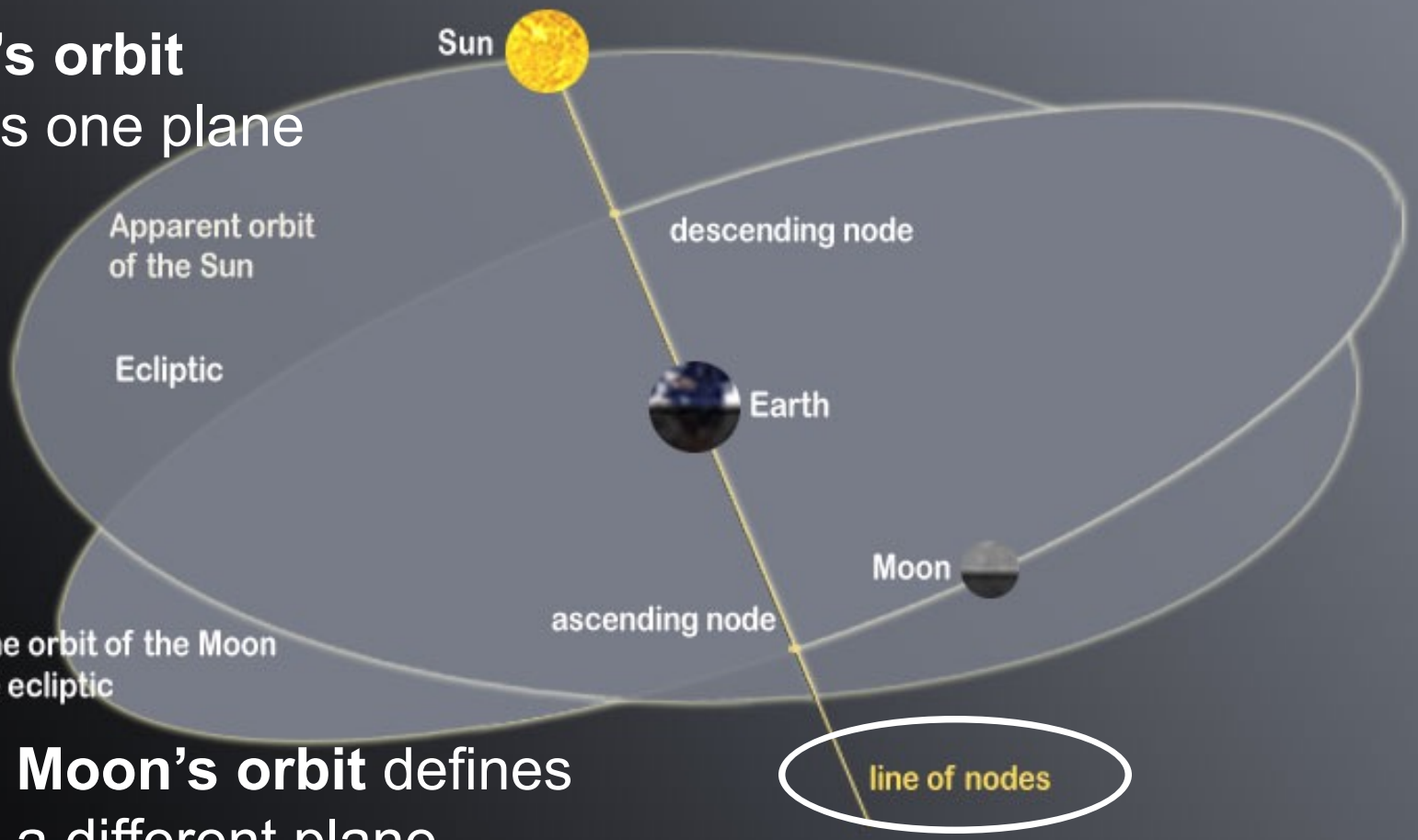


(https://bigthink.com/starts-with-a-bang/october-14-annular-eclipse-consequences/)

Earth and Moon motion each define a plane

Orbit planes cross along a line called **Line of Nodes**

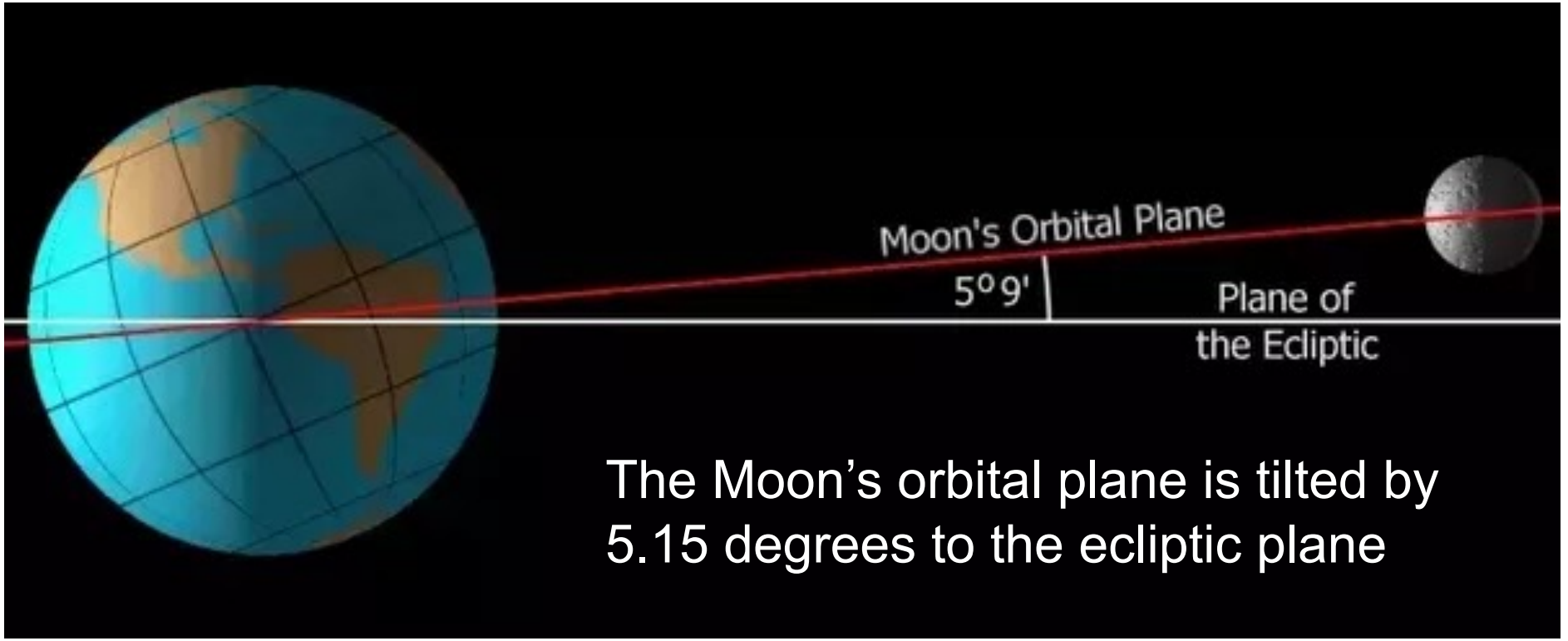
Earth's orbit
defines one plane



Moon's orbit defines
a different plane

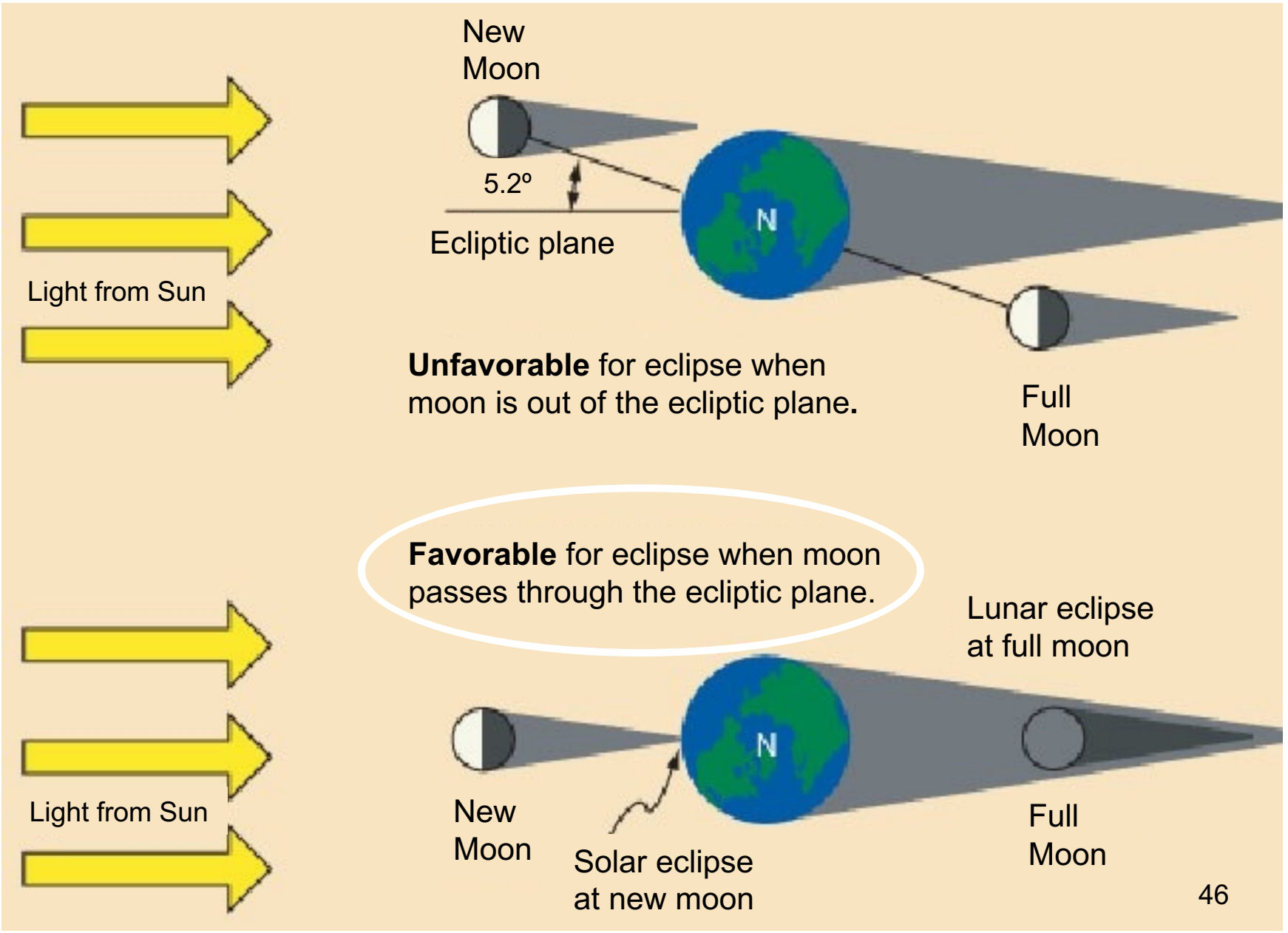
http://www.astronoo.com/en/articles/eclipses.html

Viewed along the Line of Nodes the planes become lines



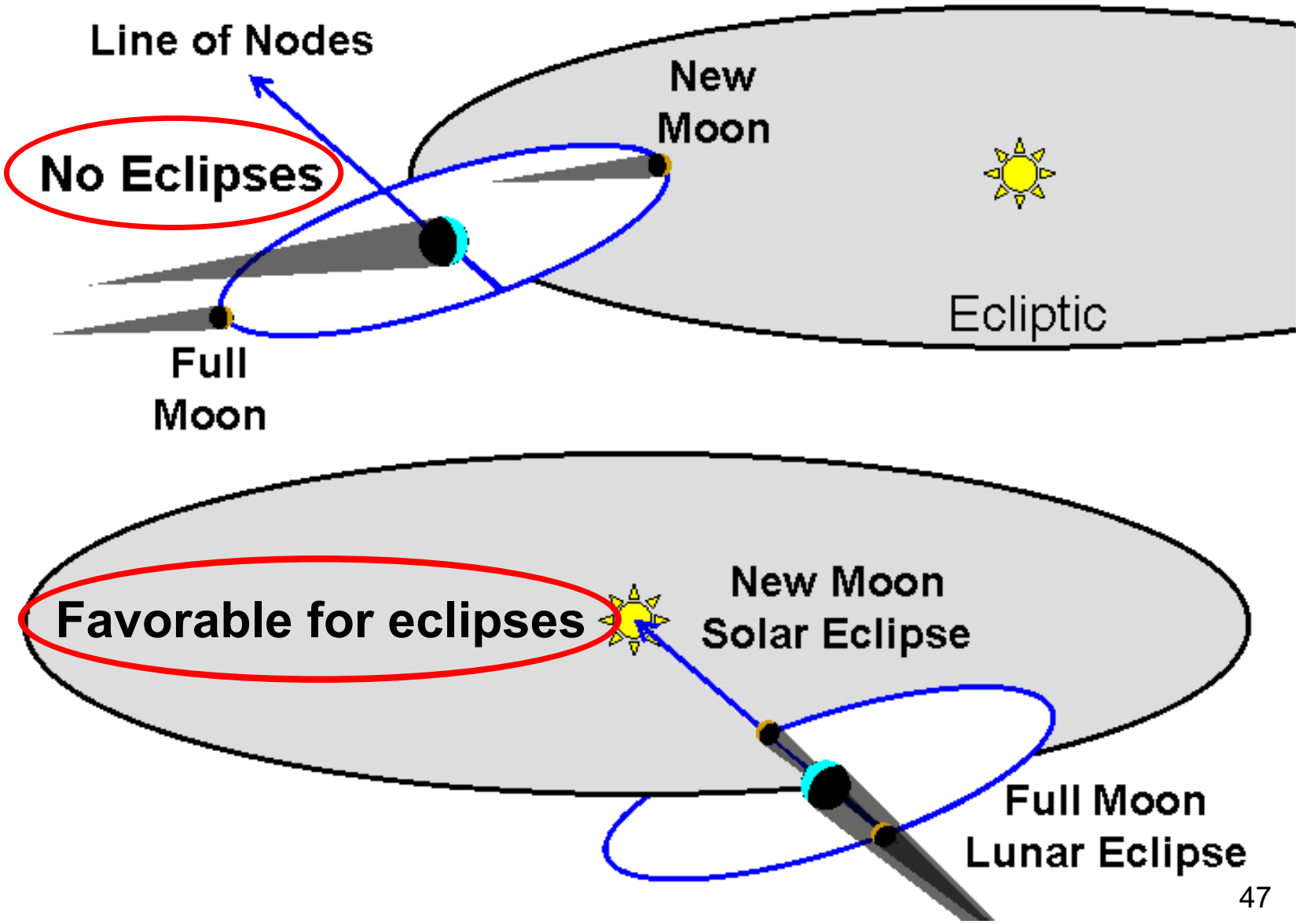
(https://www.quora.com/Why-doesnt-the-moon-show-up-in-EPIC-DSCOVR-pictures)

The tilt of Moon's orbit has a big impact on eclipses!



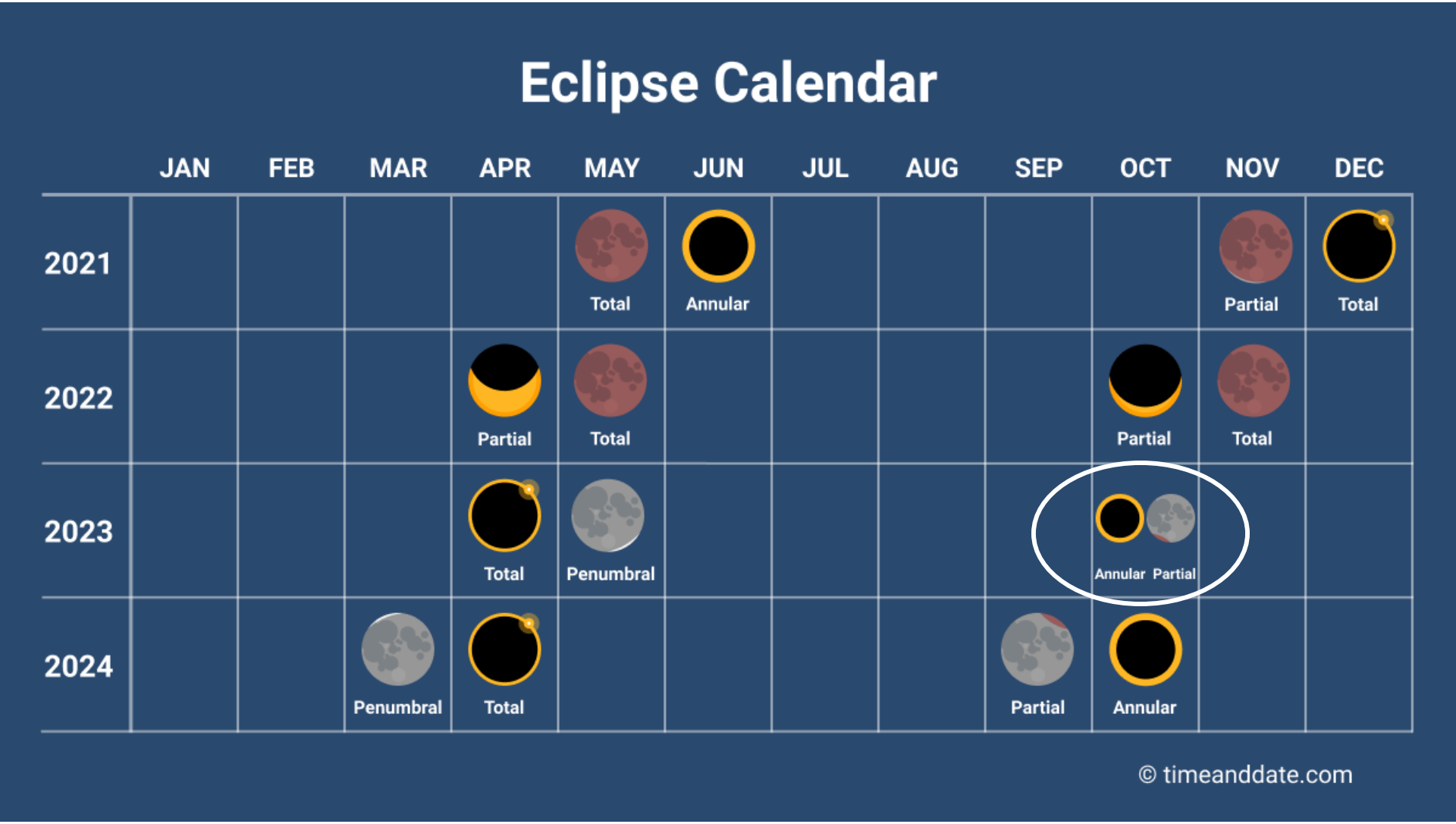
(https://astrobob.areavoices.com/2011/11/12/meet-the-ecliptic-one-of-astronomys-scariest-concepts/)

For eclipses the Sun must also be near the Line of Nodes



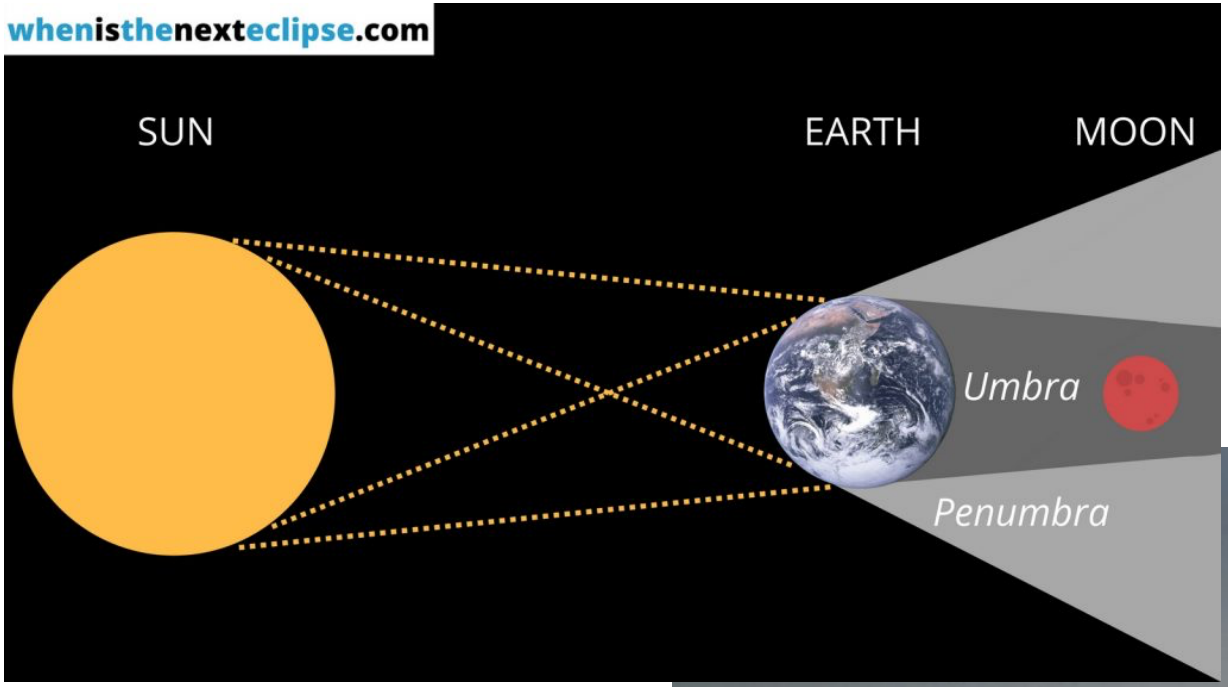
(http://www.astronomy.ohio-state.edu/~pogge/Ast161/Unit2/eclipses.html)

“Favorable for eclipses” occurs in 2 time-windows/year



(https://www.timeanddate.com/eclipse/eclipse-season.html)

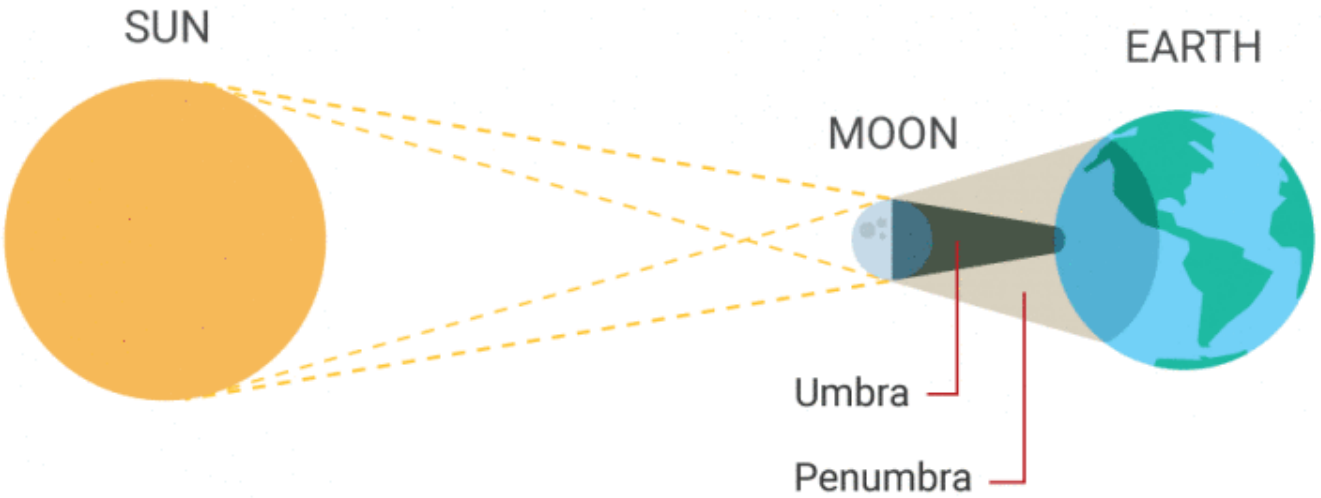
Summary: total lunar eclipse when Moon is in Earth's umbra

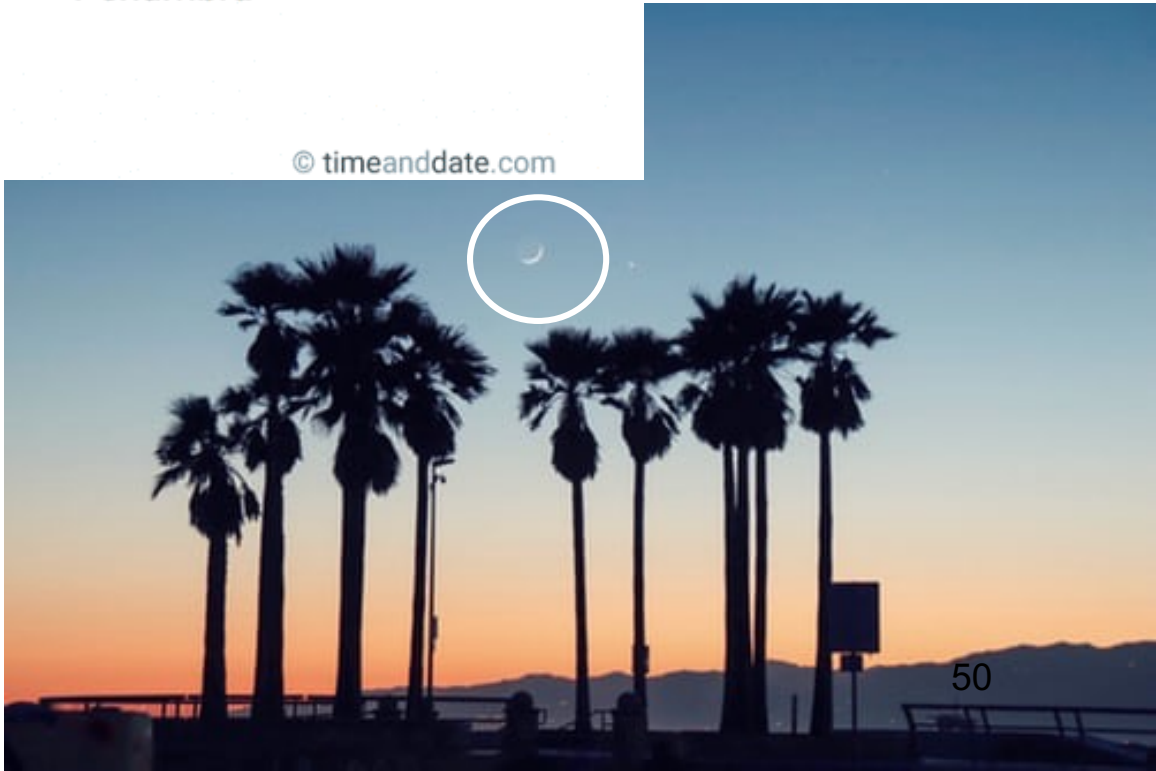


Lunar eclipse happens at **full moon**

(https://whenisthenexteclipse.com/what-is-a-lunar-eclipse/)

Summary: total solar eclipse when Earth is in Moon's umbra

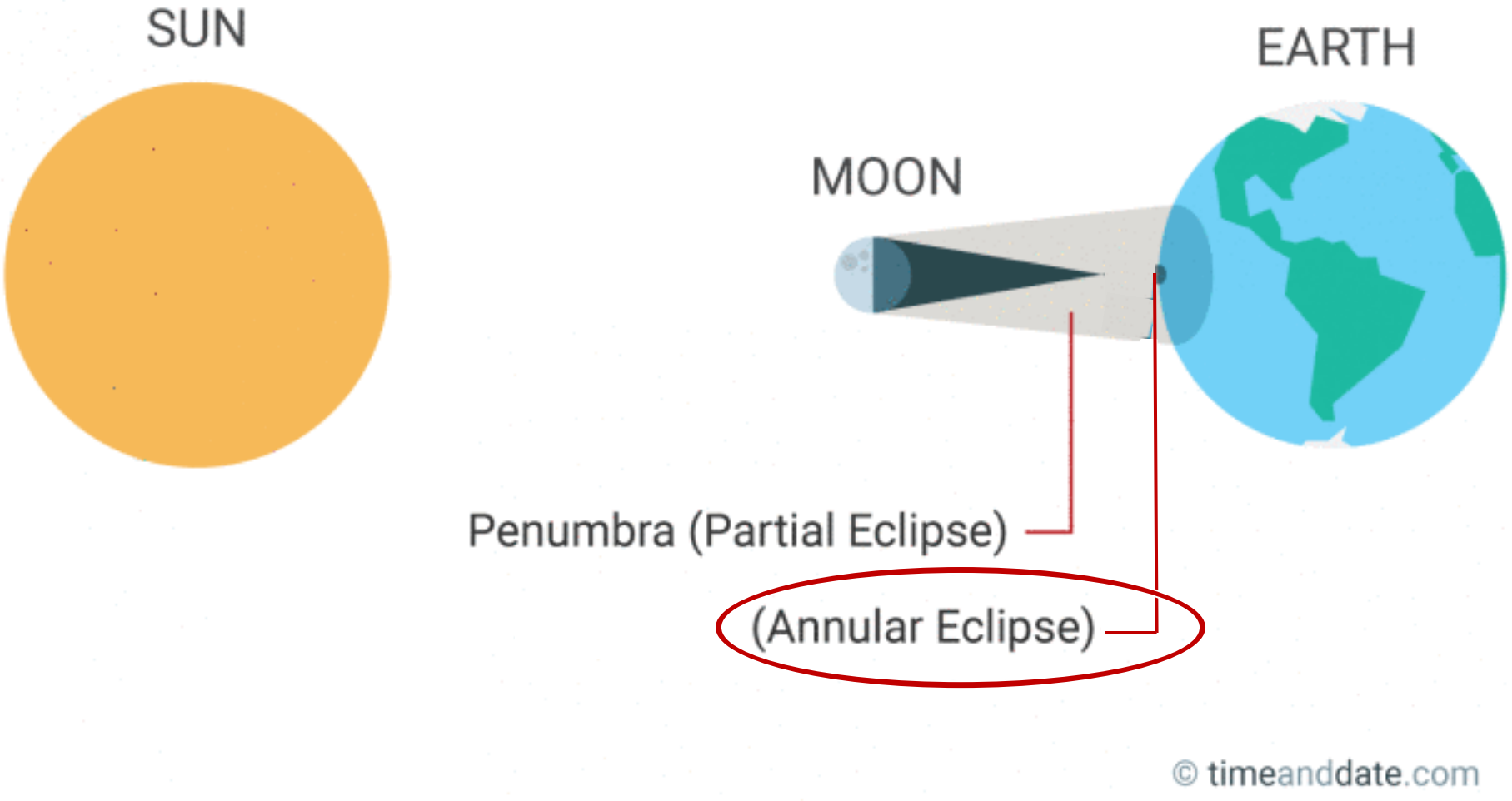




Solar eclipse happens at **new moon** (a couple of days before this photo)

(https://www.timeanddate.com/eclipse/umbra-shadow.html)

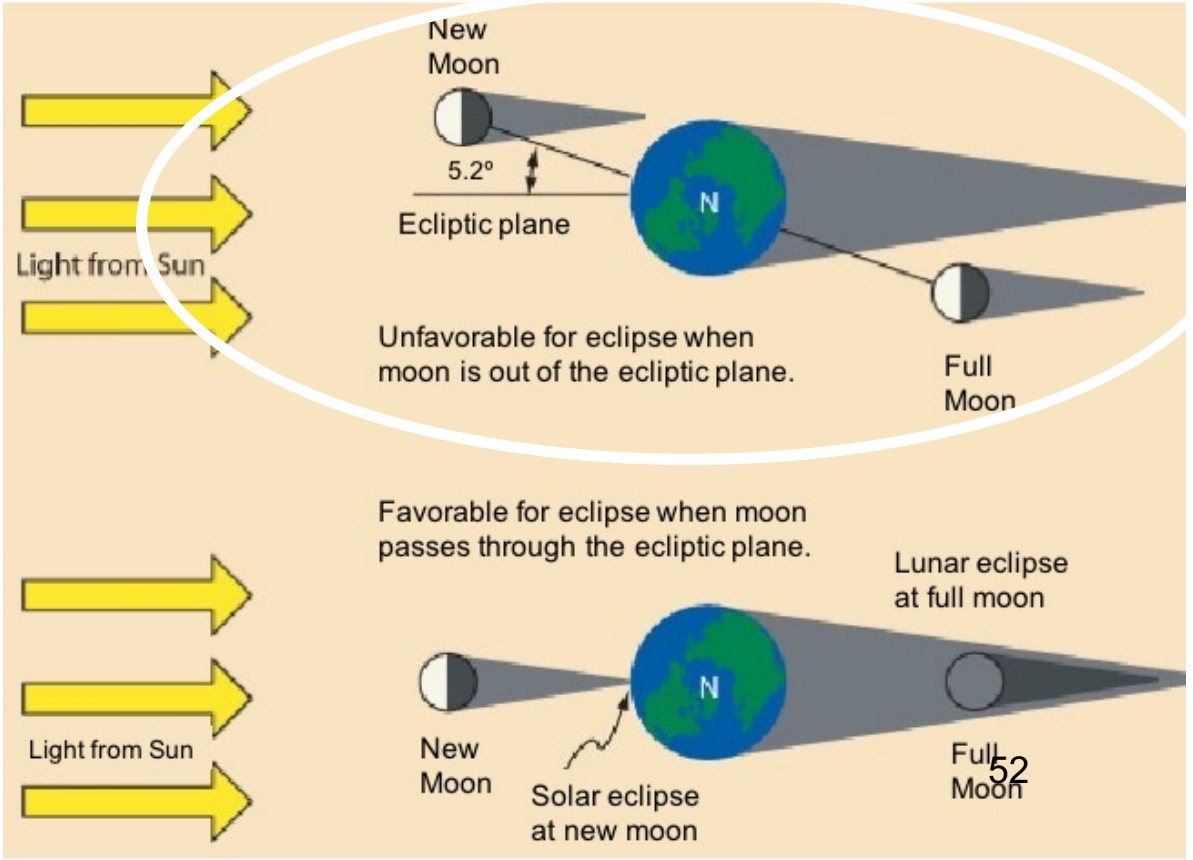
Summary: elliptical orbits cause some eclipses to be annular



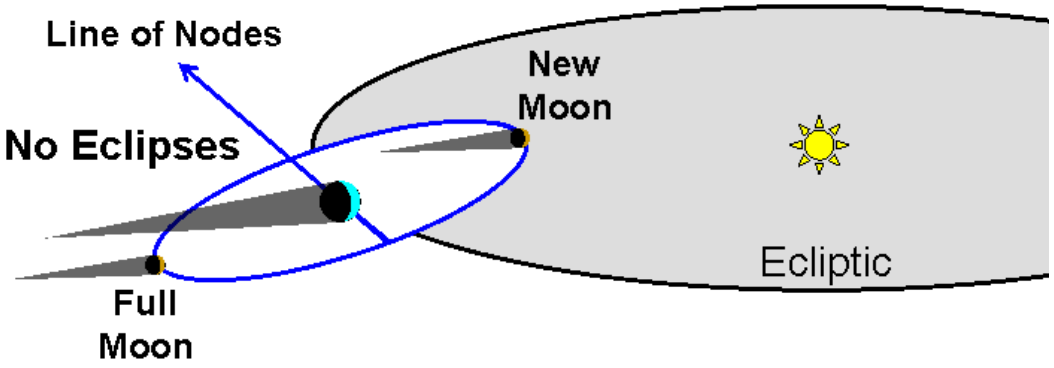
(https://www.timeanddate.com/eclipse/annular-solar-eclipse.html)

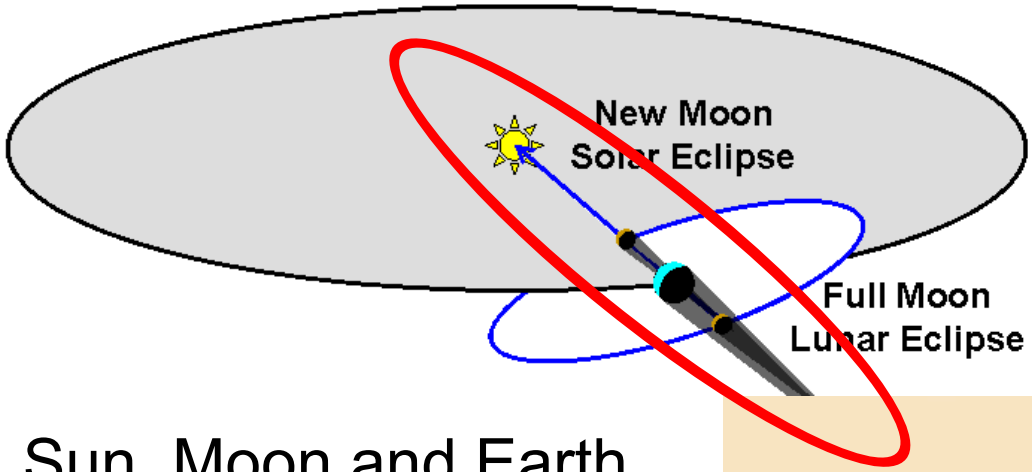
Summary: often position of Moon and/or Sun is not favorable

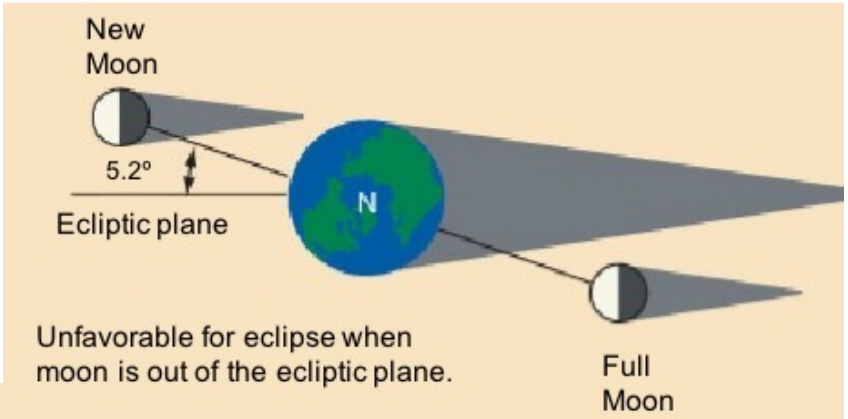
Tilt of Moon's orbit means that the Moon is often **above**, or **below**, Earth's orbital plane around the Sun.



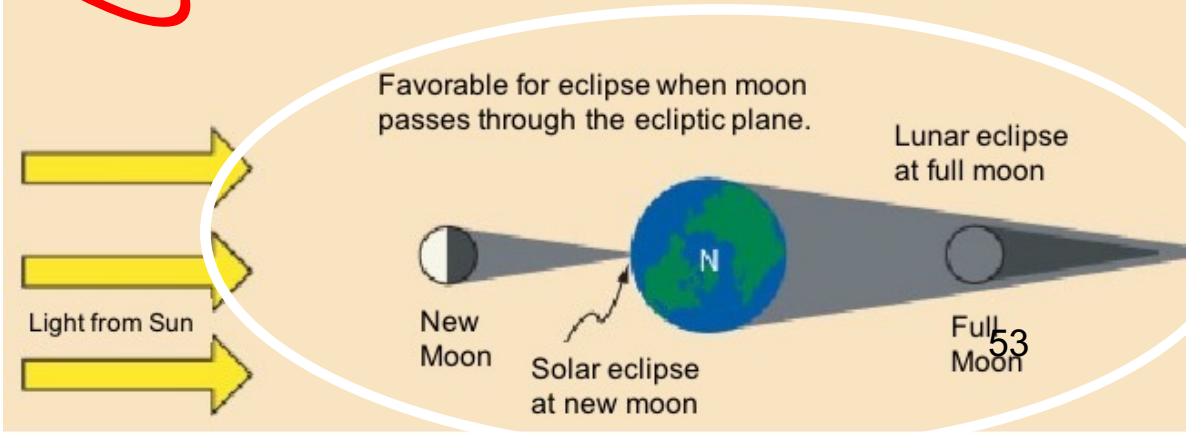
Summary: necessary alignment about 2 time-windows/year







Sun, Moon and Earth are only in a line when **Line of Nodes** points close to the Sun!



Summary: putting it all together, about 2 solar eclipses/year

THE FOUR ECLIPSES OF 2023

Below are brief descriptions of the four eclipses that take place in 2023. You'll find more details in *Sky & Telescope* magazine or on this website as the date of each draws near. Times are given in Universal Time (UT) except as noted. Adjust these to get those for your time zone: for example, PST = UT – 8, and EST = UT – 5. (But be sure to allow for daylight or "summer" time: PDT = UT – 7, and EDT = UT – 4.)

Date	Type	Maximum	Visibility
April 20	Hybrid solar eclipse	4:17 UT	southeast Asia, Australia
May 5	Penumbral lunar eclipse	17:23 UT	central and eastern Asia, Australia
October 14	Annular solar eclipse	18:00 UT	North, Central, and South America
October 28	Partial lunar eclipse	20:14 UT	Europe, Africa, Asia, w. Australia

(https://skyandtelescope.org/observing/solar-and-lunar-eclipses-in-2023/)

Thank you

John Matthews
Professor of Physics
U. of New Mexico
1 (505) 948-3241
johnm@unm.edu

The Solar Eclipse