Celestial Shadows: Unveiling the Depths of Lunar Eclipses

Total Lunar Eclipse, 7 Sep, 2025

Sankar Viswanathan

BAS

https://upload.wikimedia.org/wikipedia/commons/4/48/Eclipsing_moon_over_the_Paranal_Observatory_2021.jpg

Goals

- Review foundational principles related to eclipses
- Connect them all together to create a few *Aha* moments
- Gain a deeper understanding

Outline

- Topics
  - What’s a Lunar Eclipse?
  - Moon Phases and Lunar Eclipses
  - Deeper Into Shadows
  - Moon Color
  - Predicting Eclipses
  - 7 Sep 2025 Total Lunar Eclipse

What’s a Lunar Eclipse?

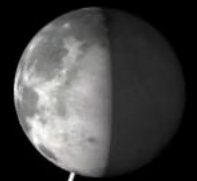
What do we observe?
How does a lunar eclipse progress?
What is the geometry involved?

Lunar eclipse of 13 Feb 2018 shot from Kitt Peak National Observatory near Tucson, Arizona. The WIYN 0.9-meter Telescope appears in the foreground. Composite image.
Source: https://upload.wikimedia.org/wikipedia/commons/5/50/Composite_of_phases_of_the_lunar_eclipse_as_seen_from_Kitt_Peak_National_Observatory_%28noirlab-lunar-eclipse1-3648x5472%29.jpg

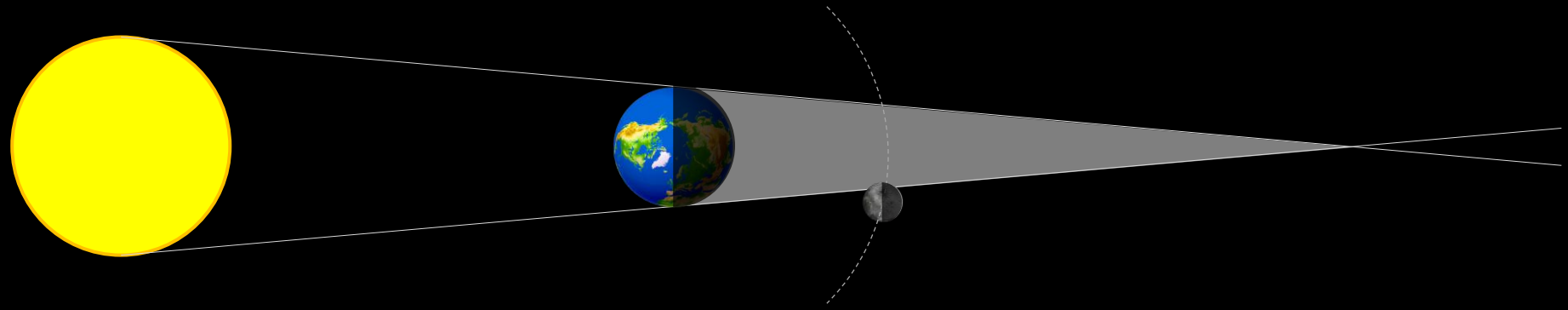
Lunar Eclipse of 8 Oct 2014 shot from San Francisco bay.
Composite image from an eclipse lasting about 4.5 hours.
Angular size of Moon is exaggerated for artistic reasons.
Source: https://www.flickr.com/photos/johnkay/15479351351

Lunar eclipse of 27 Sep 2015. Source: https://upload.wikimedia.org/wikipedia/commons/5/5e/Lunar_eclipse_sequence_%2821153429033%29.jpg

Source: https://en.wikipedia.org/wiki/Lunar_eclipse#/media/File:Lunar_eclipse_04-15-2014_by_R_Jay_GaBany.jpg



Lunar Eclipse –Partial Ingress Phase Begins

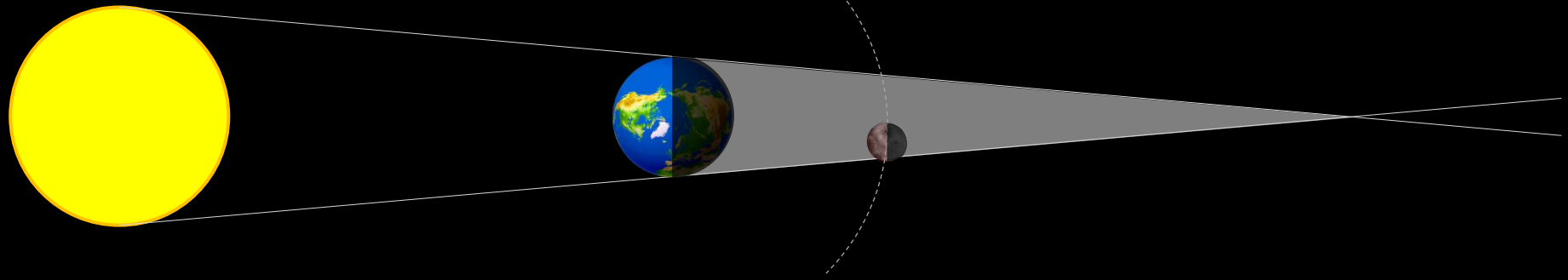


What we see from Earth

Partial Ingress

Drawing is not to scale; penumbra is not shown for simplicity

Lunar Eclipse – Total Phase Begins

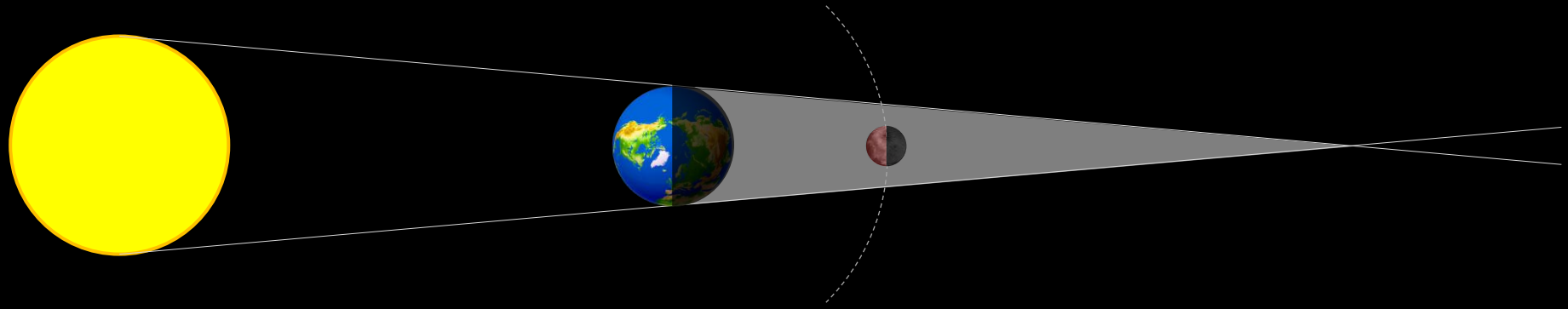


What we see from Earth

Partial Ingress Ends
Total Eclipse Starts

Drawing is not to scale; penumbra is not shown for simplicity

Lunar Eclipse – Maximum Eclipse

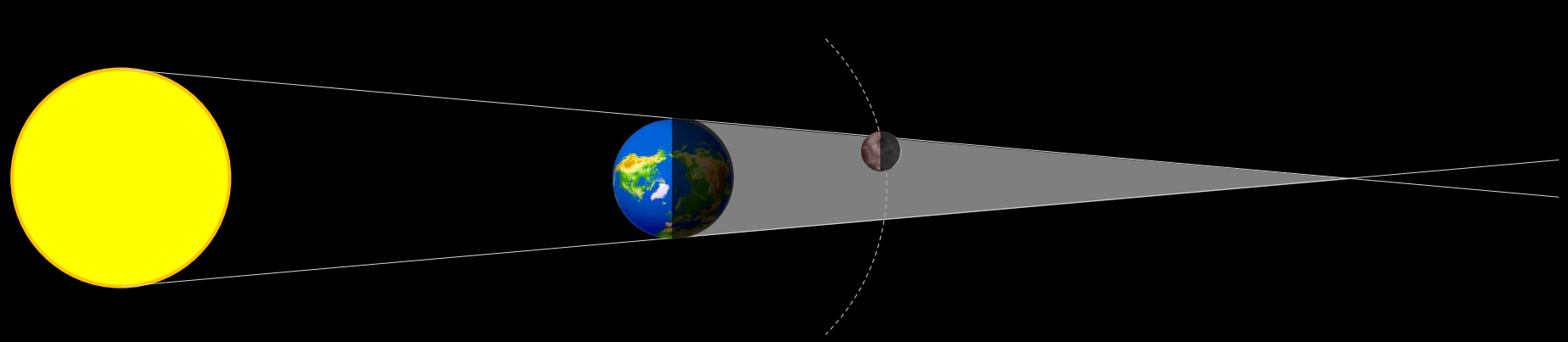


What we see from Earth

Maximum Eclipse

Drawing is not to scale; penumbra is not shown for simplicity

Lunar Eclipse – Total Phase Ends; Partial Egress Phase Starts

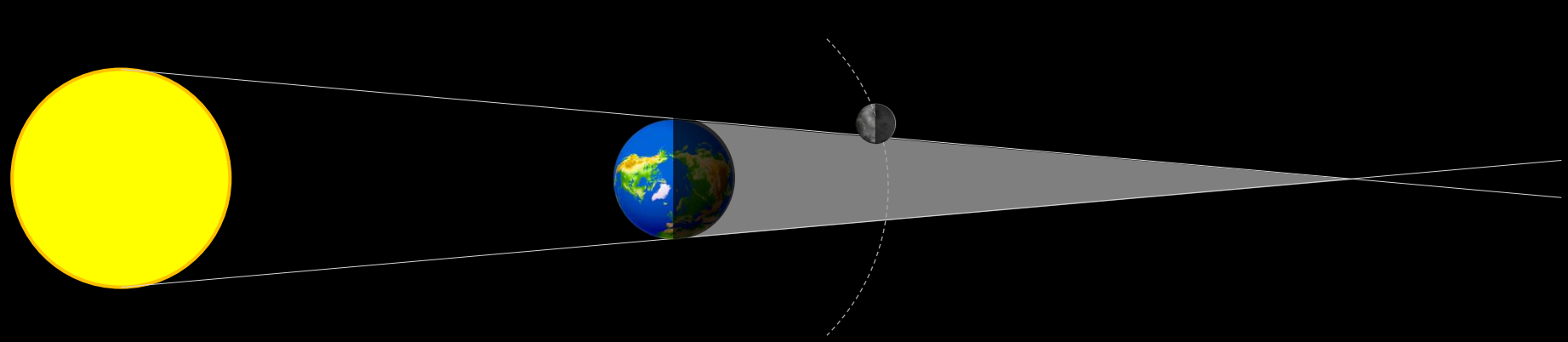


What we see from Earth

Total Eclipse Ends
Partial Egress Starts

Drawing is not to scale; penumbra is not shown for simplicity

Lunar Eclipse – Partial Egress Phase Ends



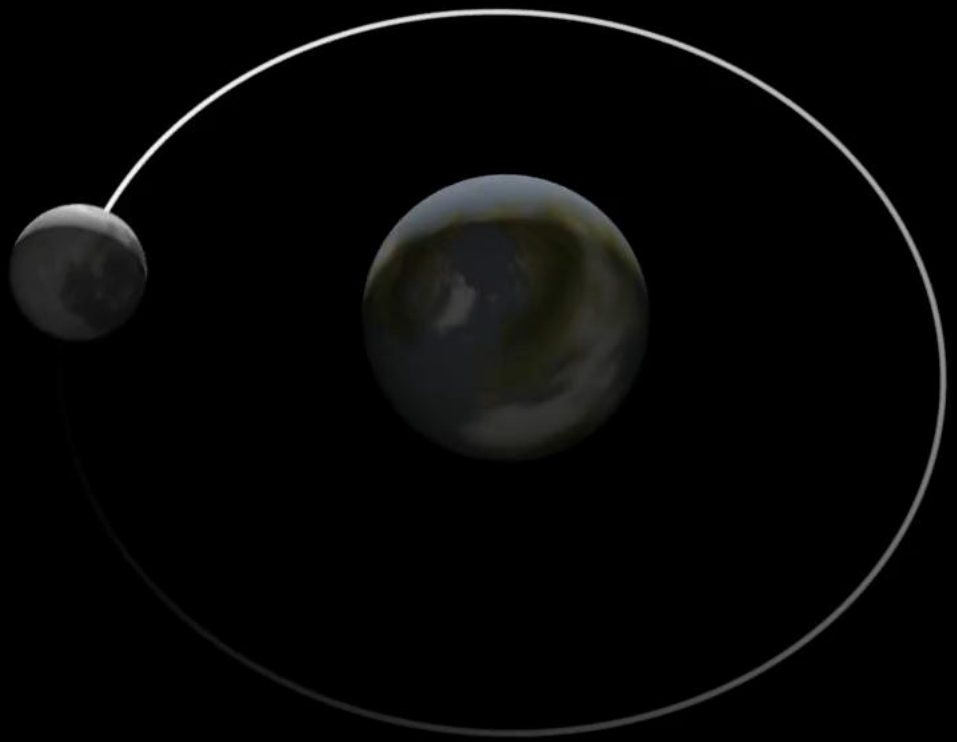
What we see from Earth

Partial Egress Ends

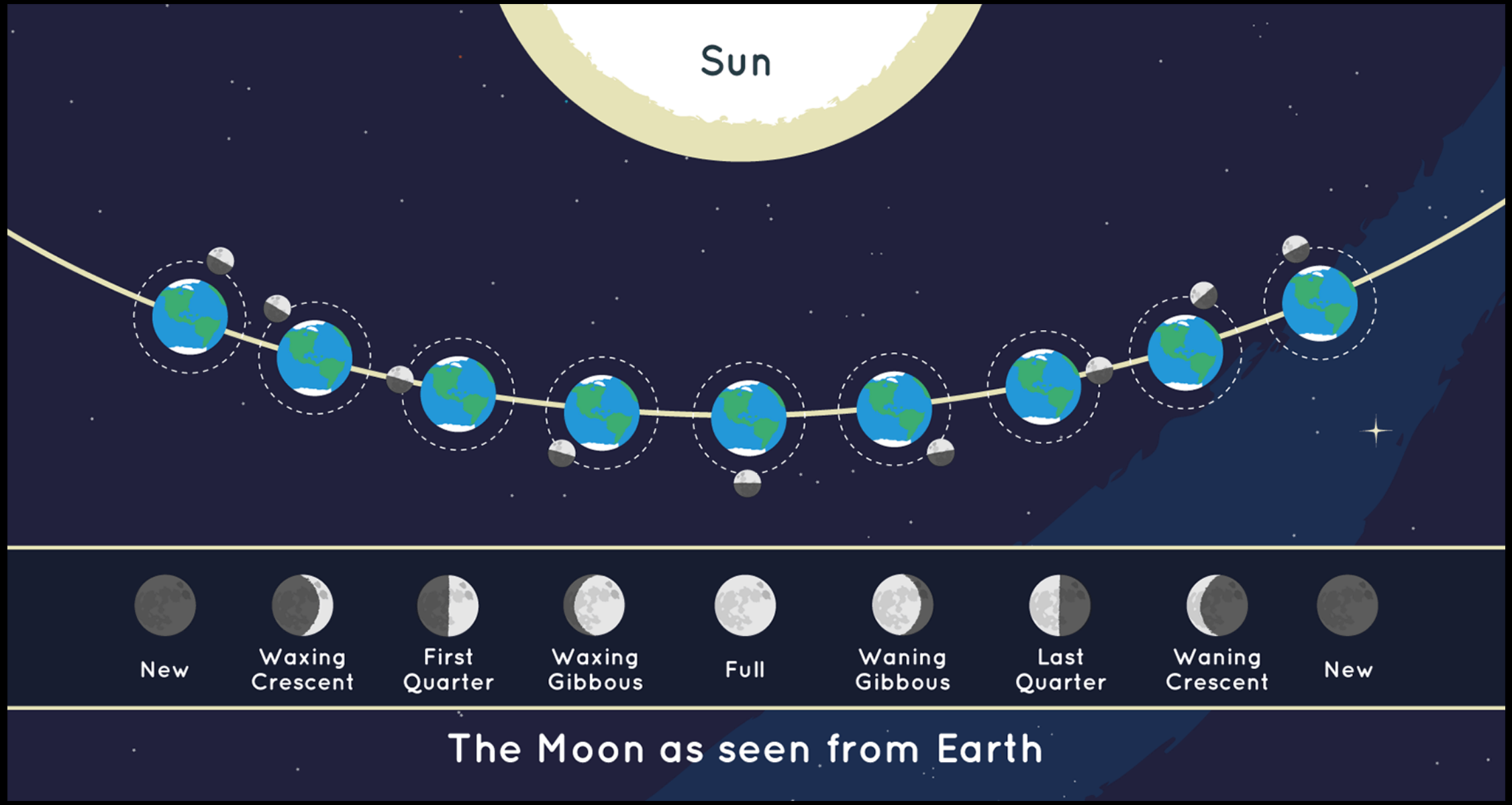
Drawing is not to scale; penumbra is not shown for simplicity

Moon Phases and Lunar Eclipses

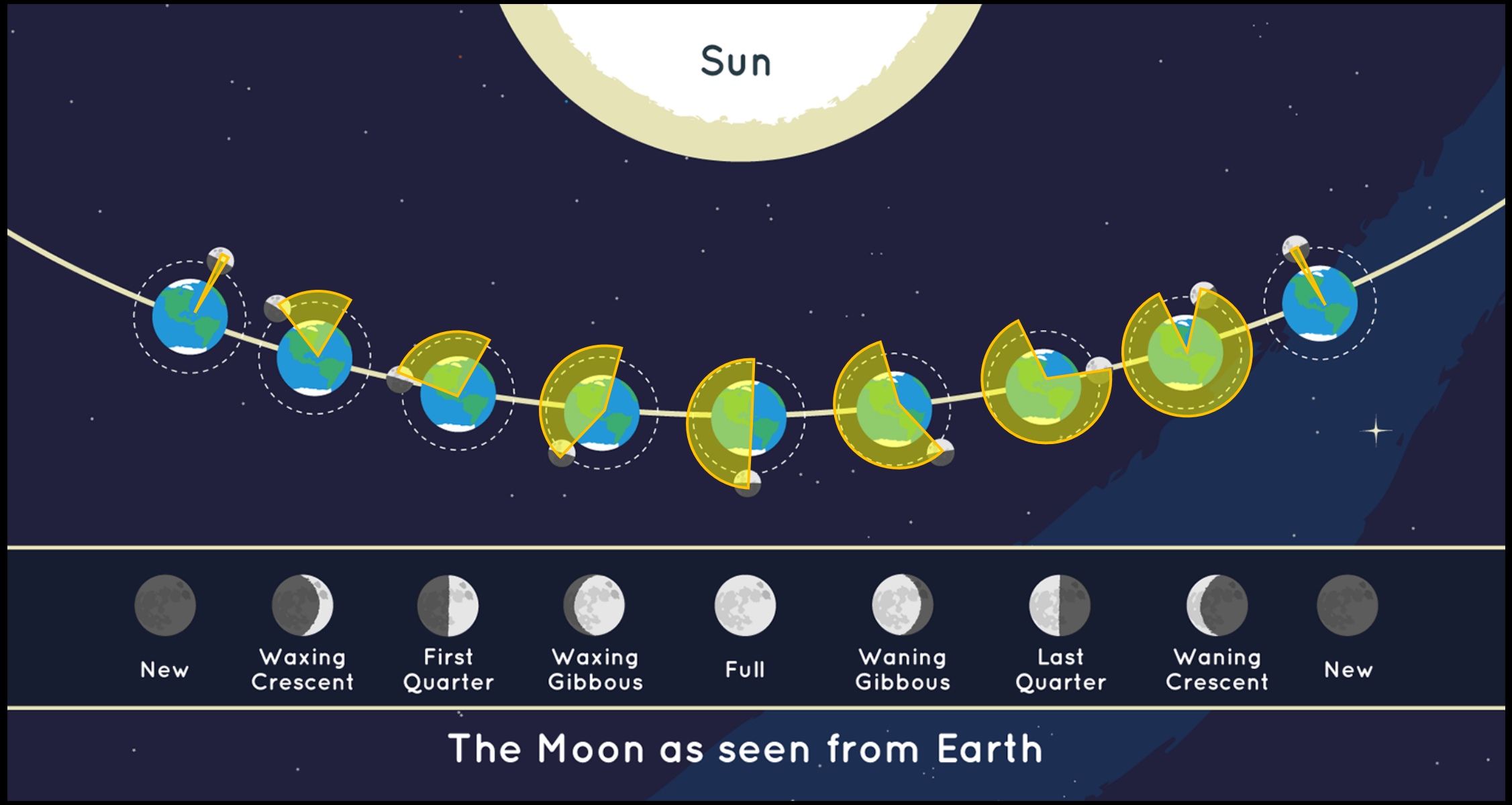
Why do Lunar Eclipses occur only on Full Moon?
Why not on all Full Moons?

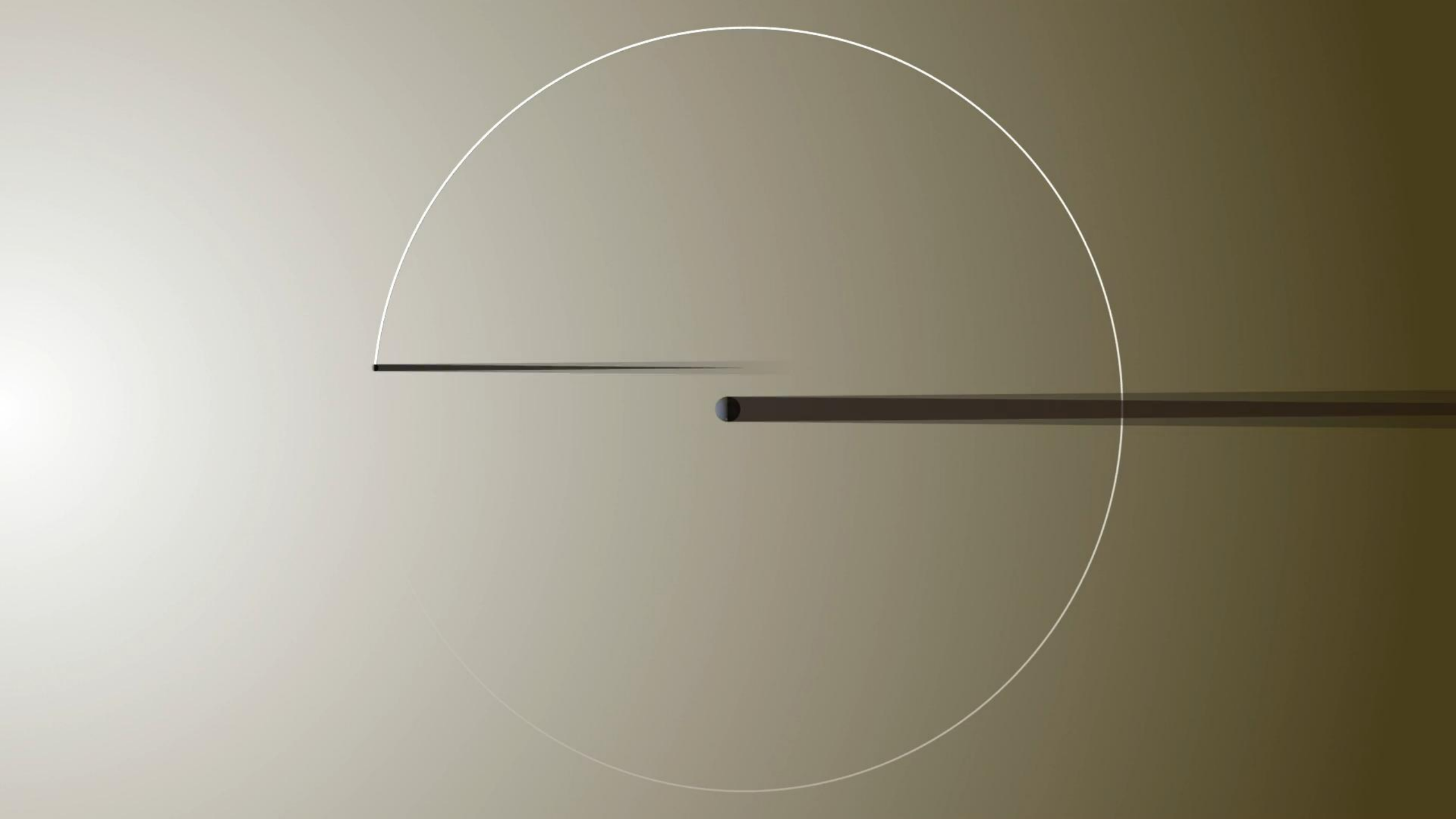


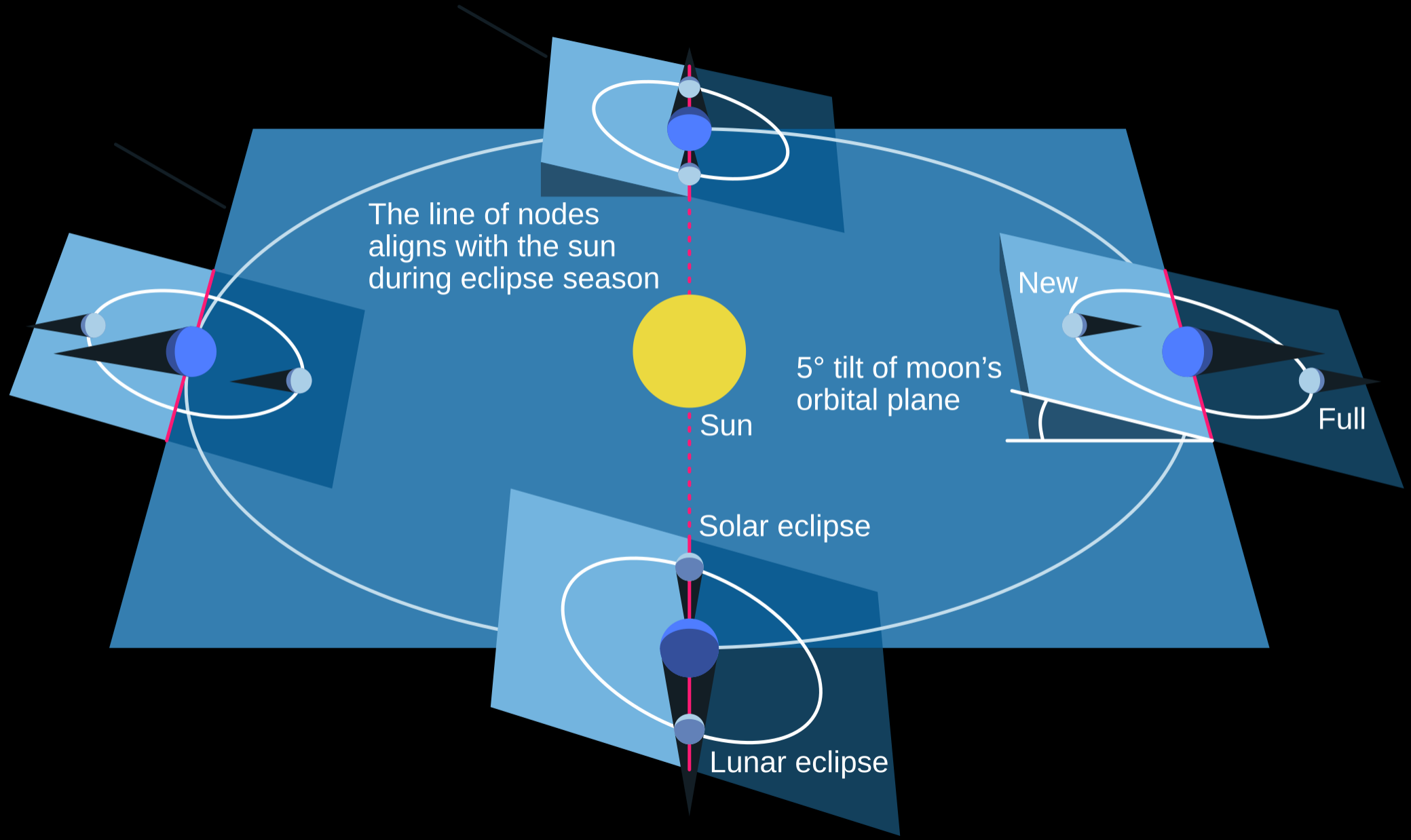
Phases of the Moon



Phases of the Moon

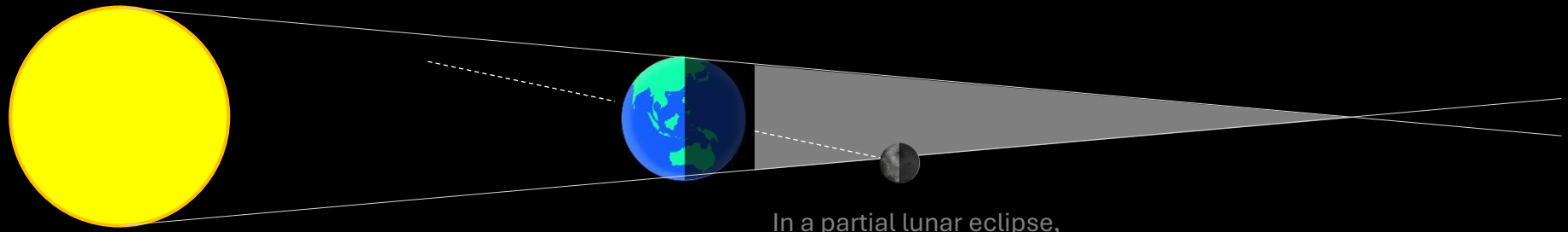






Source: https://en.wikipedia.org/wiki/Eclipse_season#/media/File:Eclipse_vs_new_or_full_moons,_annotated.svg

Partial Lunar Eclipse



In a partial lunar eclipse,
the Moon does *not*
fully get immersed
in the umbral shadow

What we see from Earth

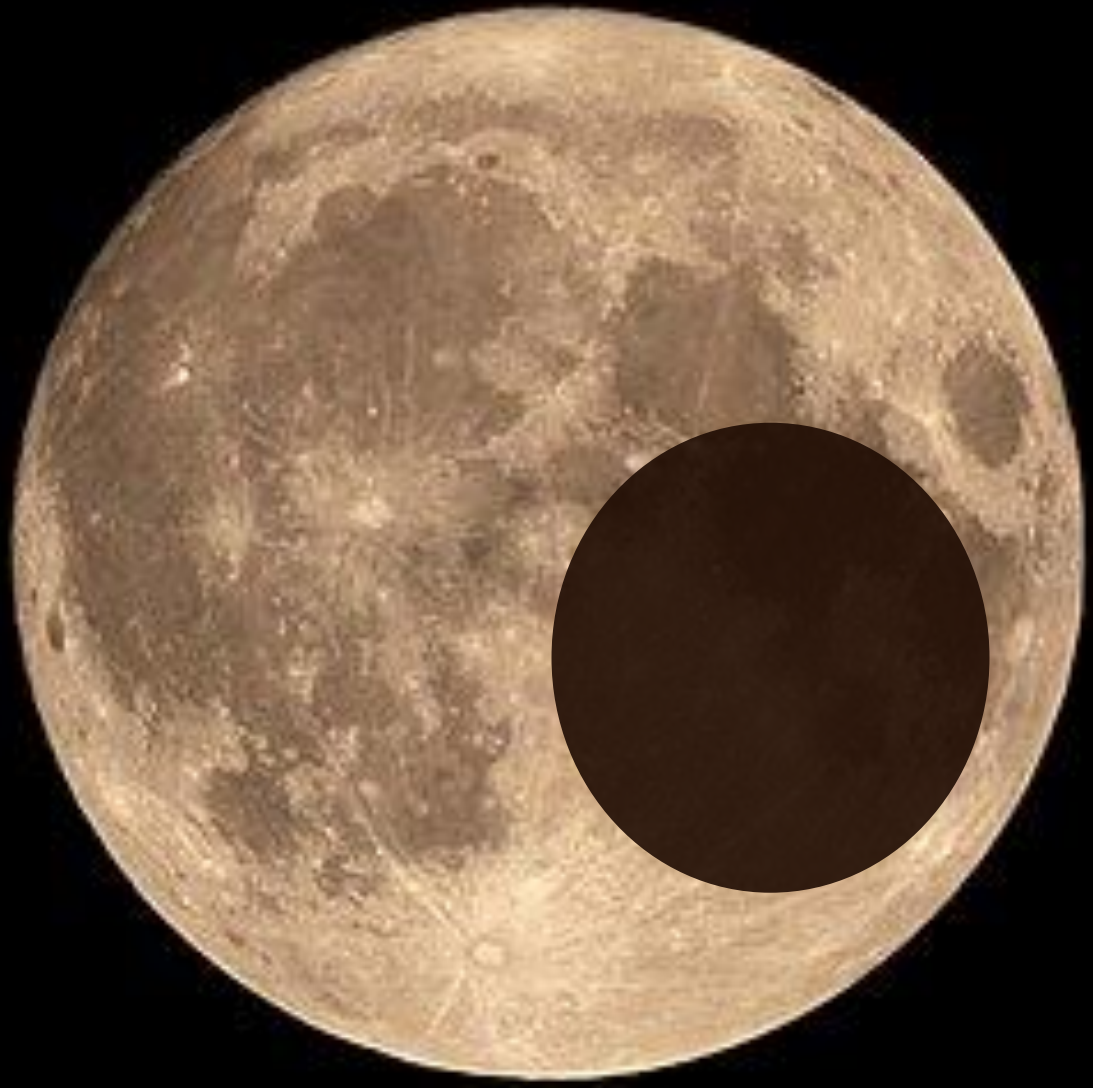
Partial Eclipse

Drawing is not to scale; penumbra is not shown for simplicity

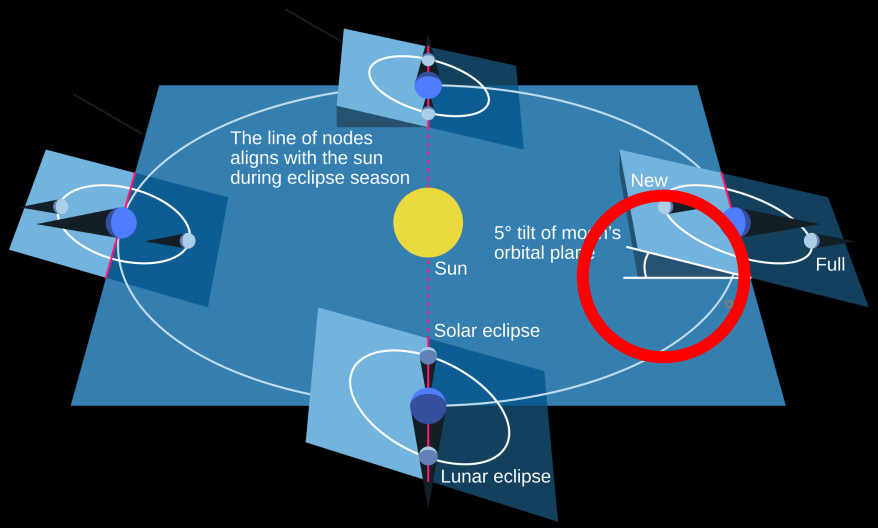
Deeper Into Shadows

Can We See the Earth’s Shadow in its Entirety on the Moon?
Is 5° inclination enough?
Umbra and Penumbra
A deeper journey into the sizes and shapes of shadows

Possible?

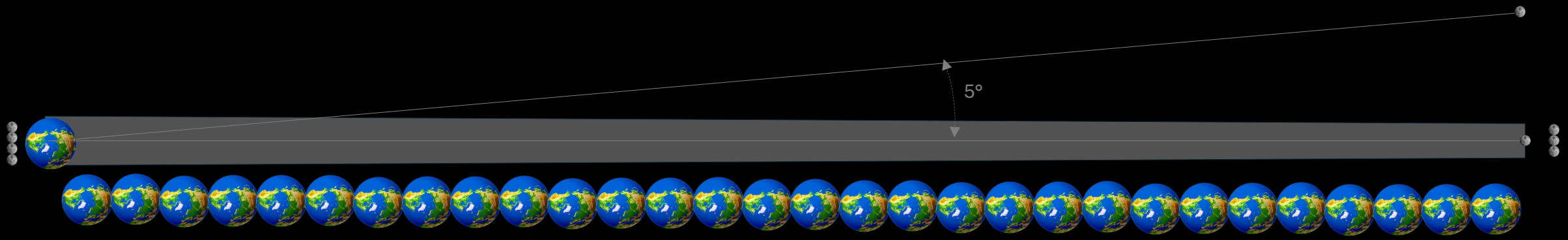


Does a Small 5° Inclination Matter?



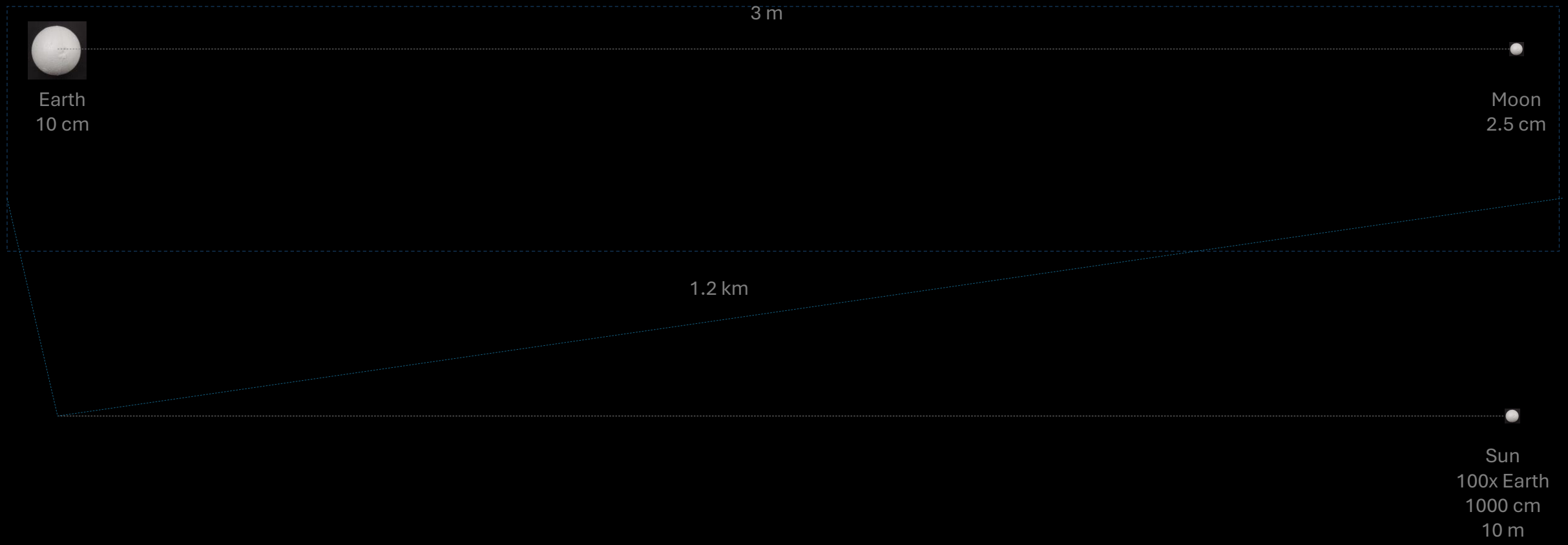
That's not 5°!

Shadows to Scale



Metric	Value	Relative to Earth Diameter	Relative to Earth-Moon Distance
Moon Diameter	3,500 km	¼ x	
Earth Diameter	12,800 km	1 x	
Earth-Moon Distance	384,000 km	30 x	1 x
Earth Umbral Cone Length	1,400,000 km	~ 100 x	3.6 x
Sun Diameter	1,392,700 km	~100 x	
Earth-Sun Distance	150,000,000 km	~12,000 x	~400 x

Scale of the Solar System



Lunar Umbral Shadow
~2.7x Moon Angular Diameter

https://upload.wikimedia.org/wikipedia/commons/5/5e/Lunar_eclipse_sequence_%2821153429033%29.jpg

Lunar Eclipse of November 19, 2021

Image credit and © Zoltan Levay
Source: https://skyandtelescope.org/observing/solar-and-lunar-eclipses-in-2022/
Source: https://www.flickr.com/photos/zoltlevay/51693464621

Crescent Moon or Lunar Eclipse?

https://upload.wikimedia.org/wikipedia/commons/4/44/The_Crescent_Moon.jpg

Crescent Moon or Lunar Eclipse?

https://upload.wikimedia.org/wikipedia/commons/4/44/The_Crescent_Moon.jpg

Gibbous Moon or Lunar Eclipse?

06-Sep-2025

Gibbous Moon vs. Lunar Eclipse

Gibbous Moon Source: https://en.wikipedia.org/wiki/Lunar_phase#/media/File:2013-01-02_00-00-55-Waning-gibbous-moon.jpg
Eclipsed Moon Source: https://commons.wikimedia.org/wiki/File:Partial_Moon_Eclipse.jpg

Moon Phases vs. Lunar Eclipse

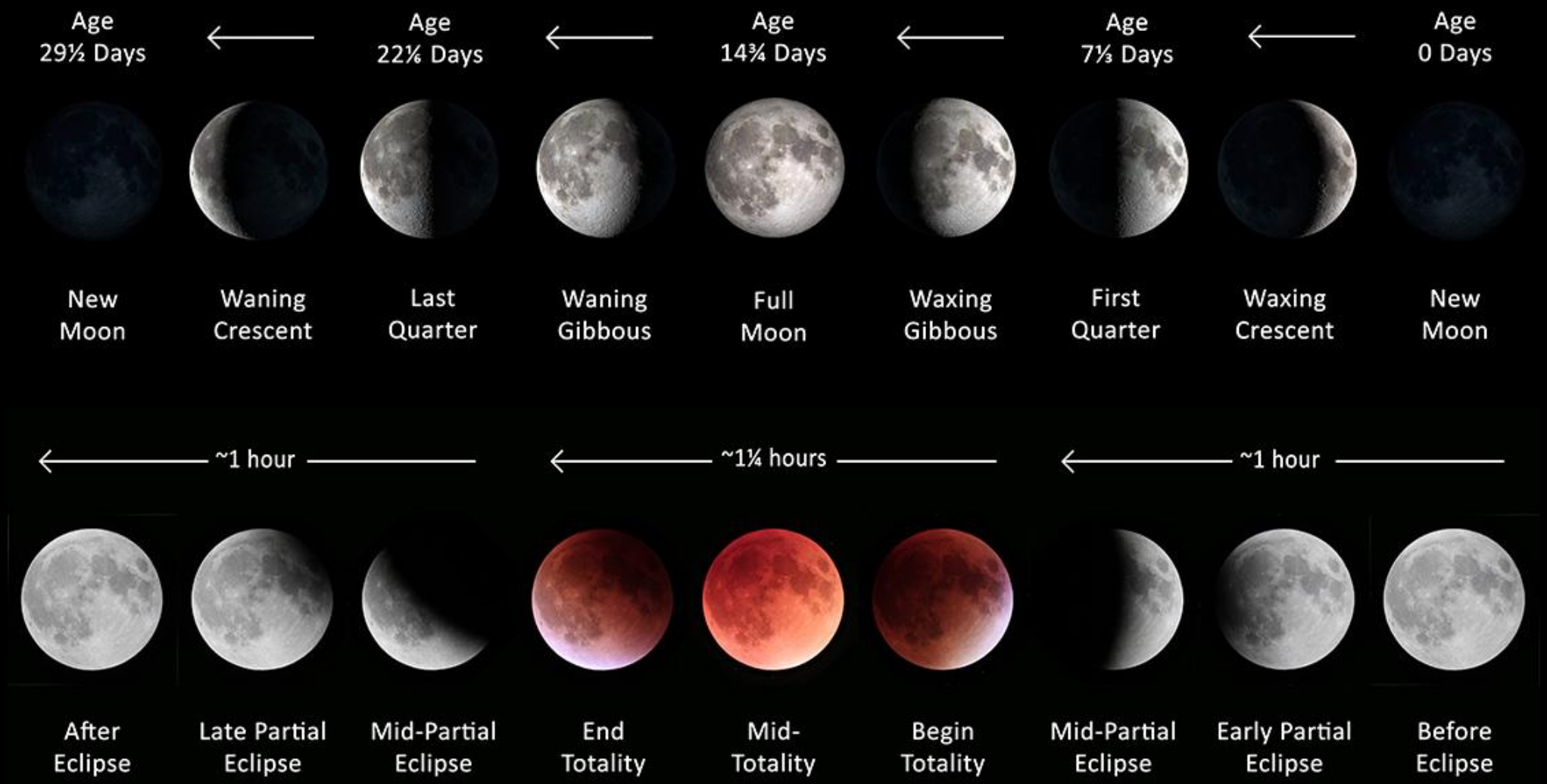
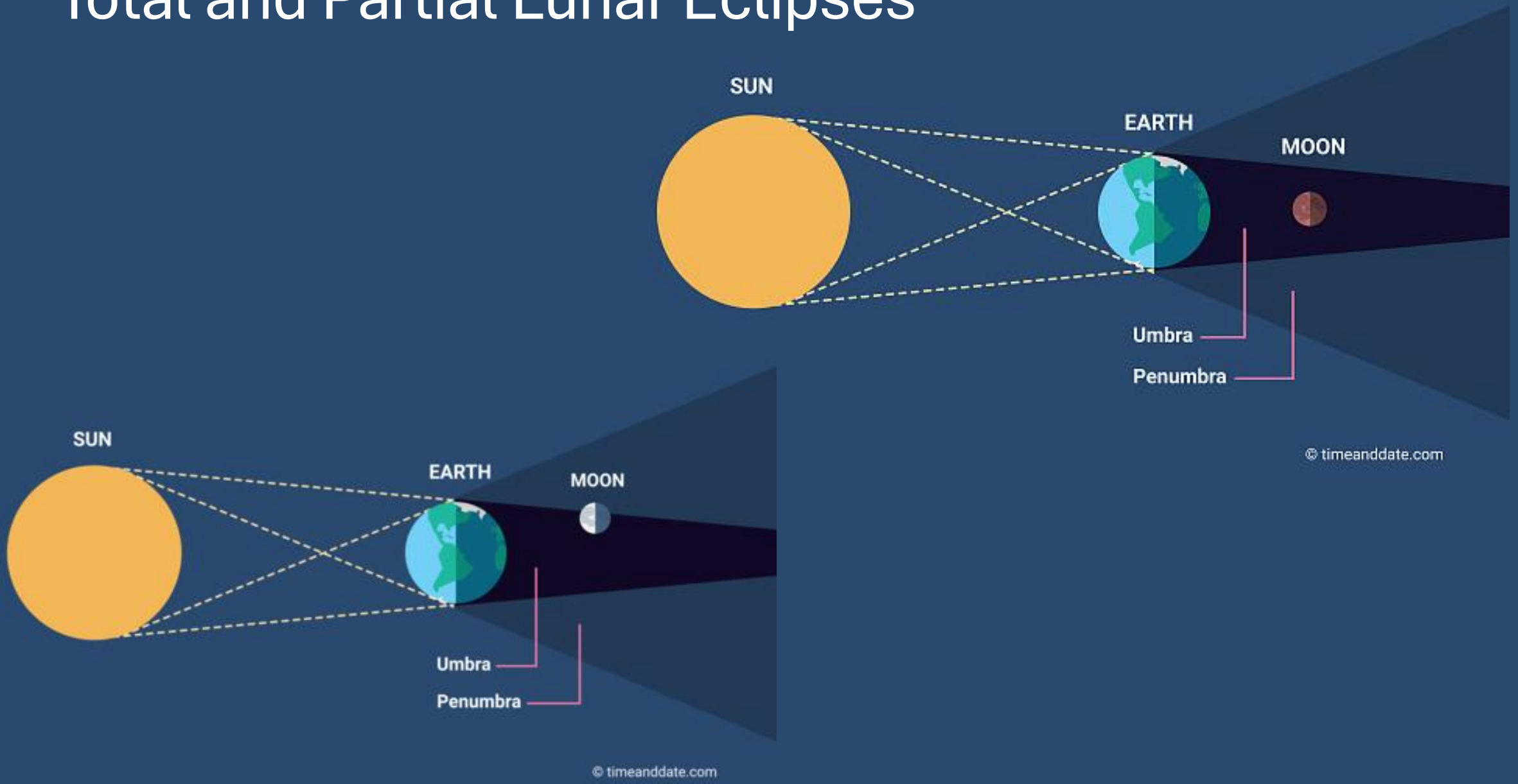
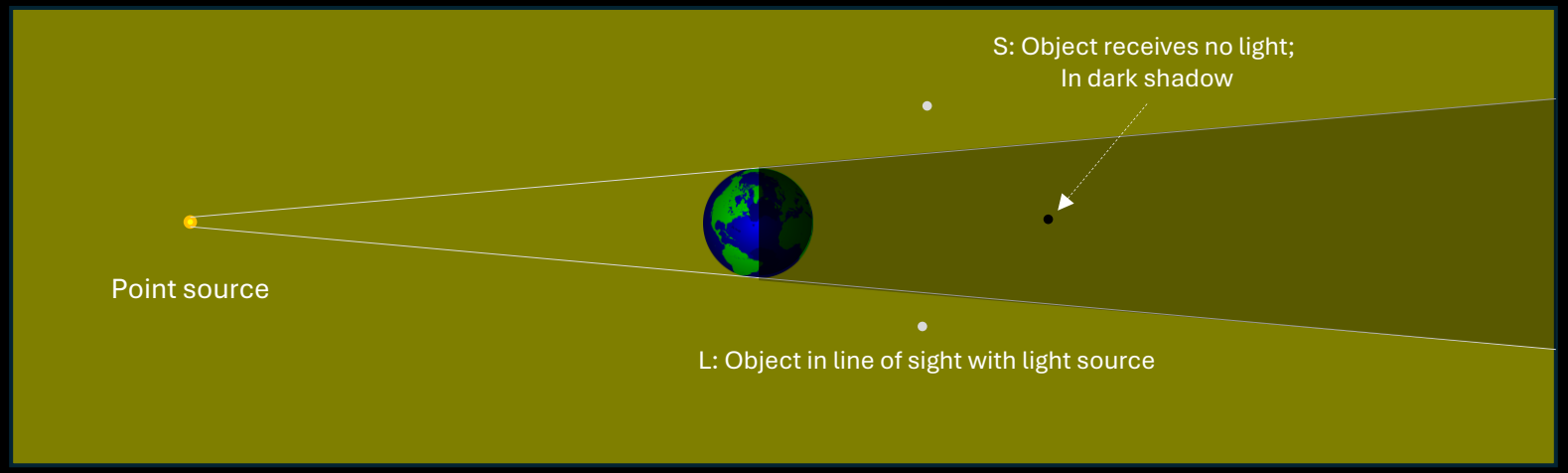


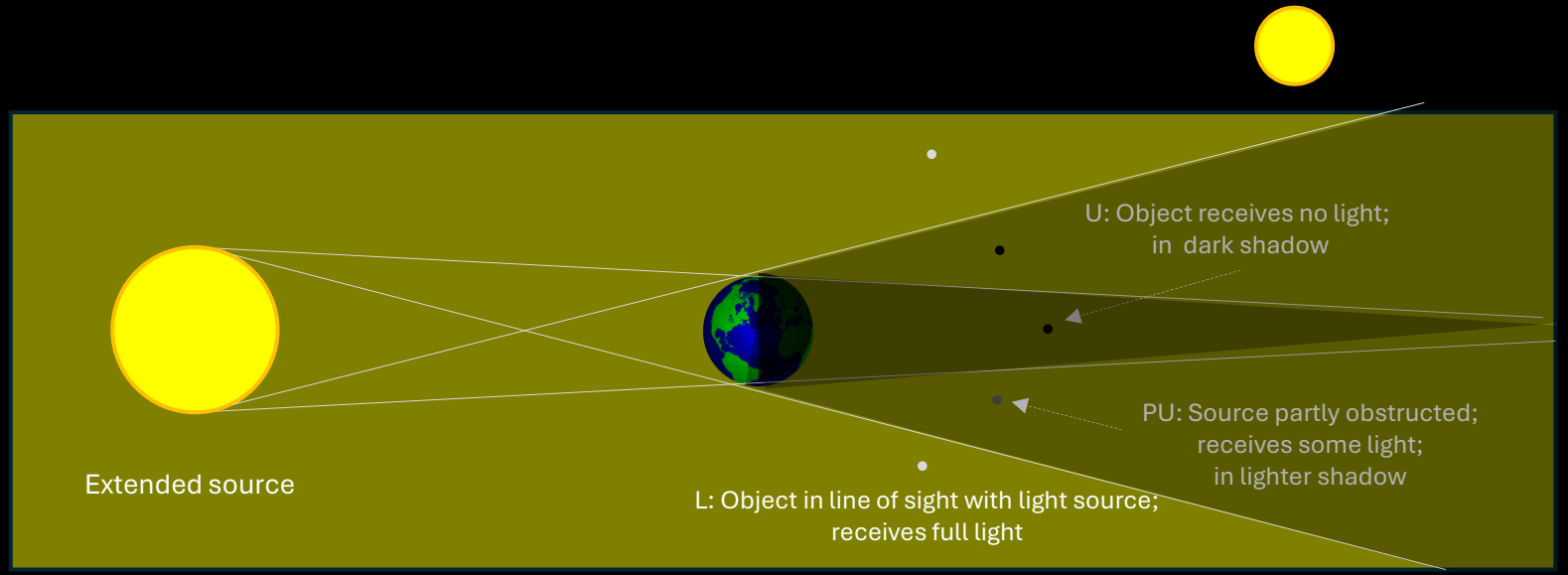
Image copyright and credit American Astronomical Society
https://eclipse.aas.org/eclipse-america/sun-moon-shapes

Total and Partial Lunar Eclipses

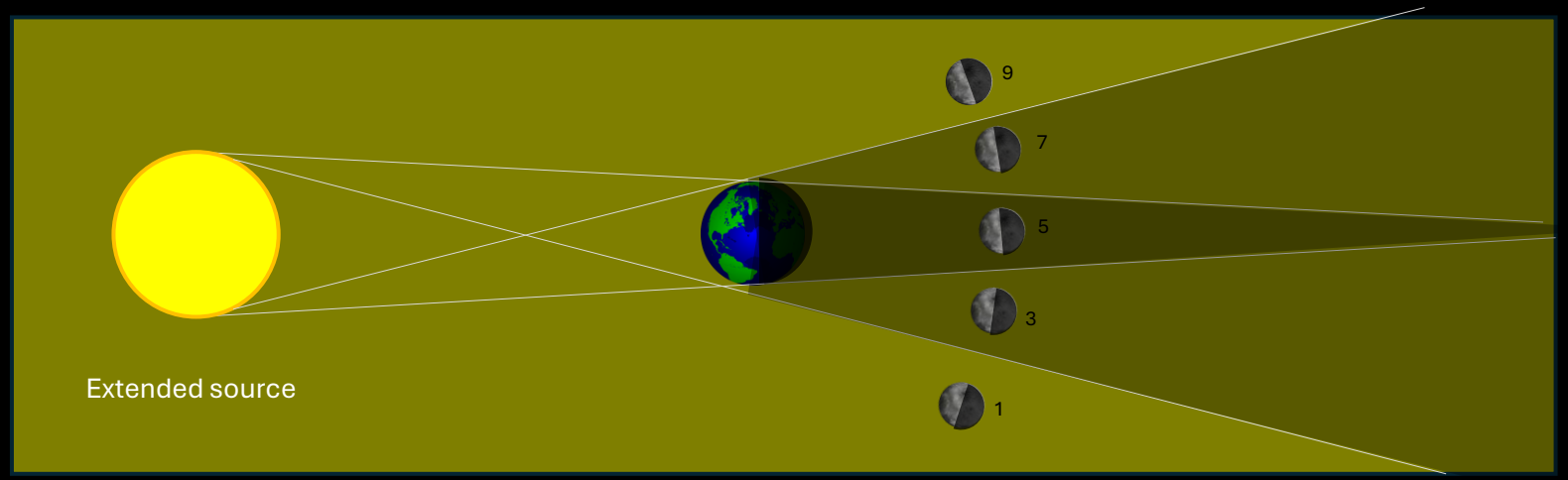


Umbra and Penumbra – 1





Umbra and Penumbra – 2

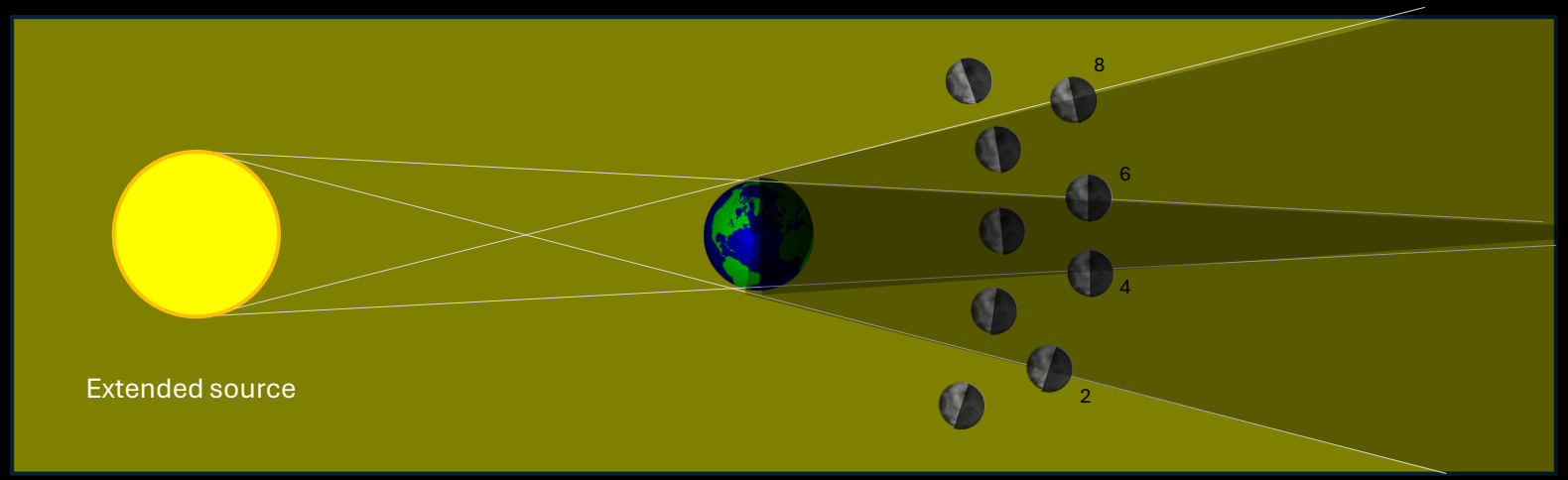


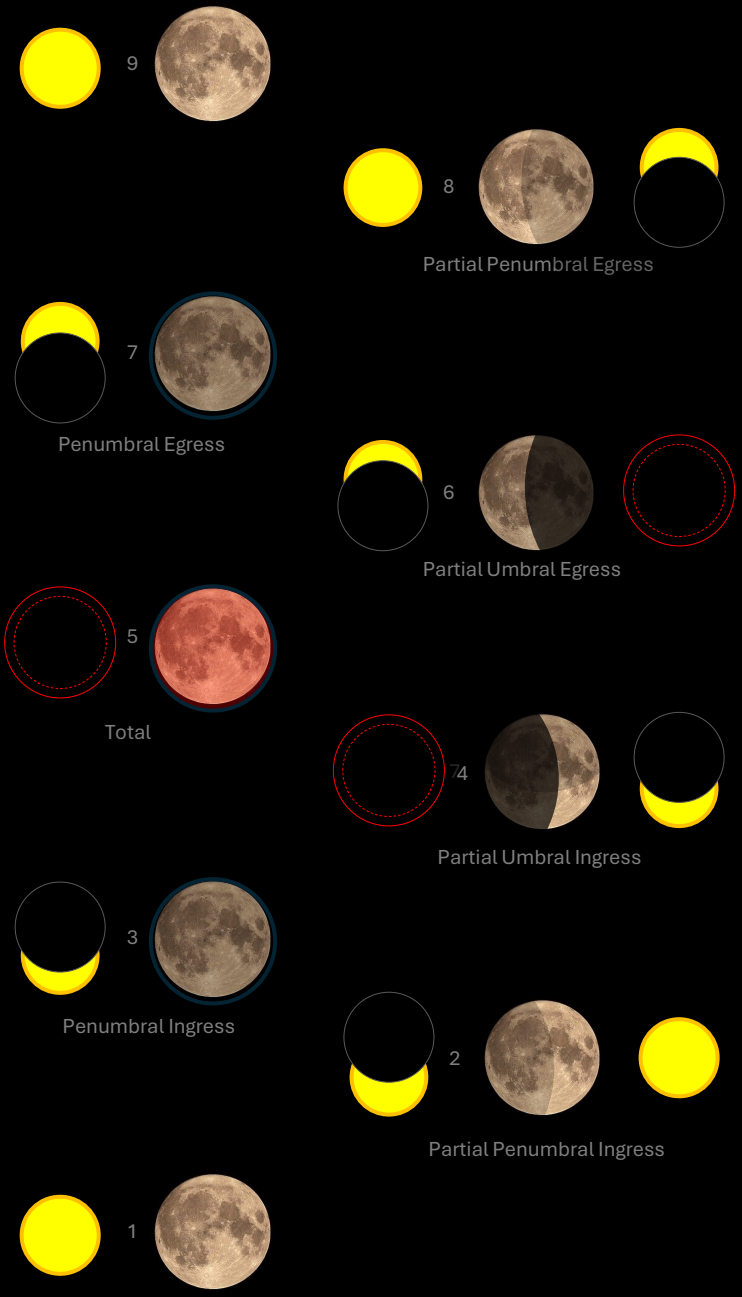
Penumbral Egress

Total

Penumbral Ingress

Umbra and Penumbra – 3

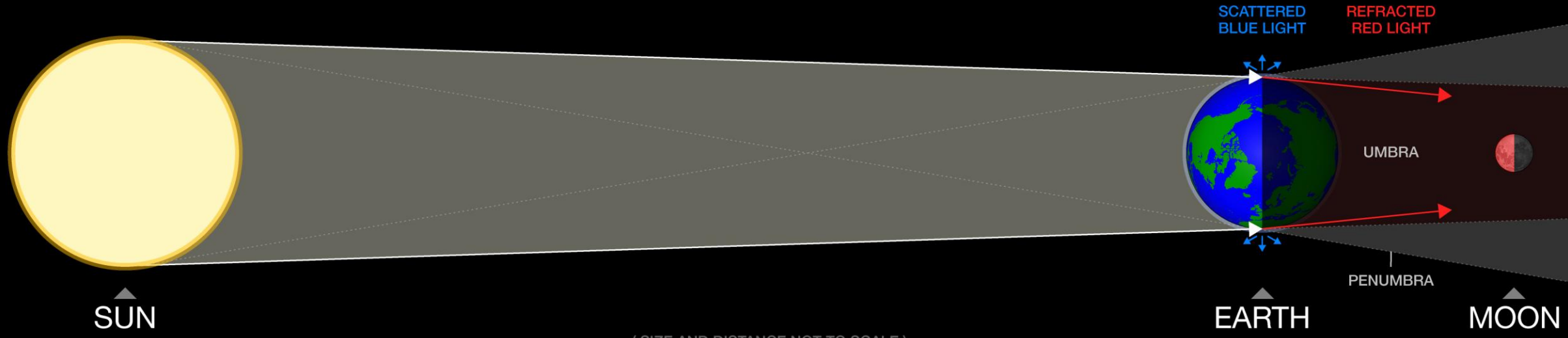




Moon Color

space.rice.edu/eclipse/
reiff@rice.edu

LUNAR ECLIPSE

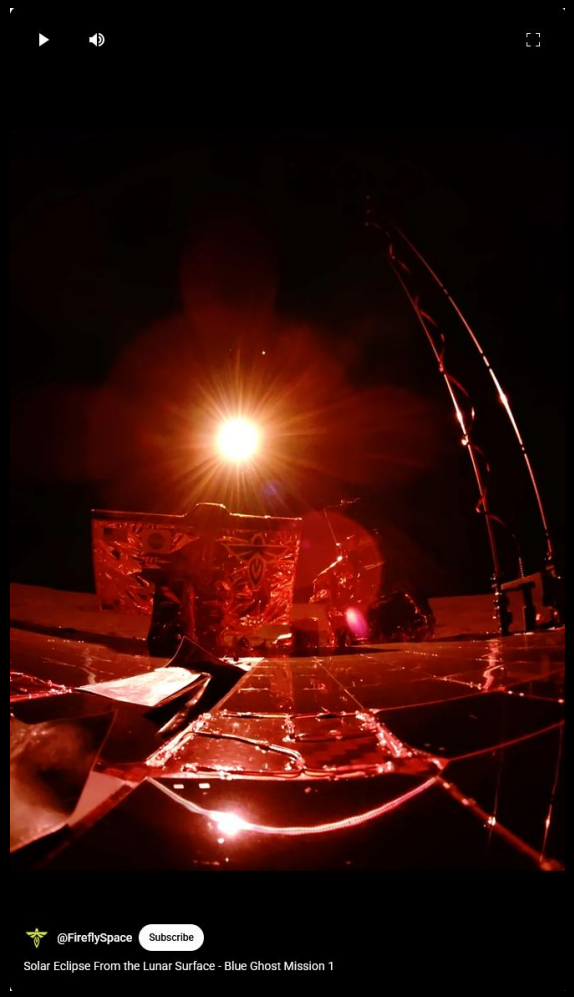


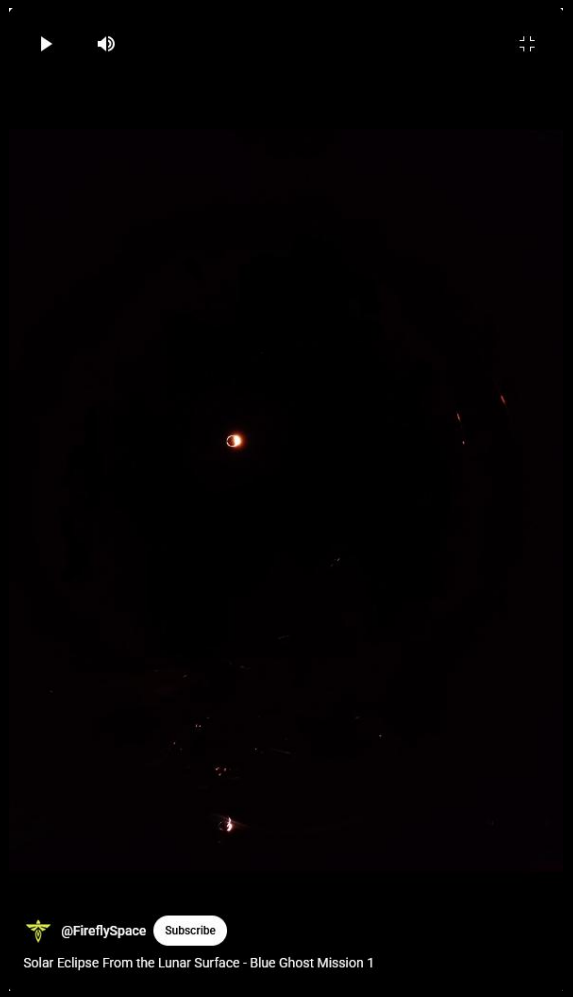
(SIZE AND DISTANCE NOT TO SCALE)

https://space.rice.edu/eclipse/img/eclipse_diagram_lunar.jpg

Solar Eclipse from Firefly Aerospace *Blue Ghost*

- The *Blue Ghost* spacecraft captured a solar eclipse (as seen from the Moon) on 14 March 2025.
- Seen as a lunar eclipse from Earth.





Predicting Eclipses

Prediction Mechanisms

- Olden times
  - Empirical methods
  - Geometric improvements
  - Inability to predict exact times and locations

- Modern times
  - Newtonian mechanics
  - Direct and high precision distance and angle measurements
  - High precision ephemerides using numerical integration

Eclipse Geometry Patterns

- Sun-Earth-Moon in near linear alignment
  - Necessary conditions
    - Close to new moon (solar eclipse) or full moon (lunar eclipse)
    - Sun and Moon close to either of the lunar nodes
  - Time cycles
    - Draconic month (node to node) – 27.2122 days
    - Sidereal month (revolution against stars) – 27.3217 days
    - Anomalistic month (perigee to perigee) – 27.5545 days
    - Synodic month (new moon to new moon) – 29.5306 days
  - Eclipse year - 346.62 days
    - Time it takes for Sun to return to a node
      - Due to lunar orbital plane precession, it's slightly less than 1 year
    - Beat period of synodic and draconic months
      - EY = N x SM = (N+1) x DM
      - N = SM * DM / (SM – DM)

Frequency of Eclipses

- At least one solar eclipse each eclipse season
  - At least one each eclipse season; at most two
  - At least two in an eclipse year of 346.22 days
  - At least two in a calendar year
  - Usually a max of four in a calendar year; occasionally five
  - In this century, 224 eclipses of which 144 are central

- Two lunar eclipses in most years
  - None in a few
  - At most three in a few

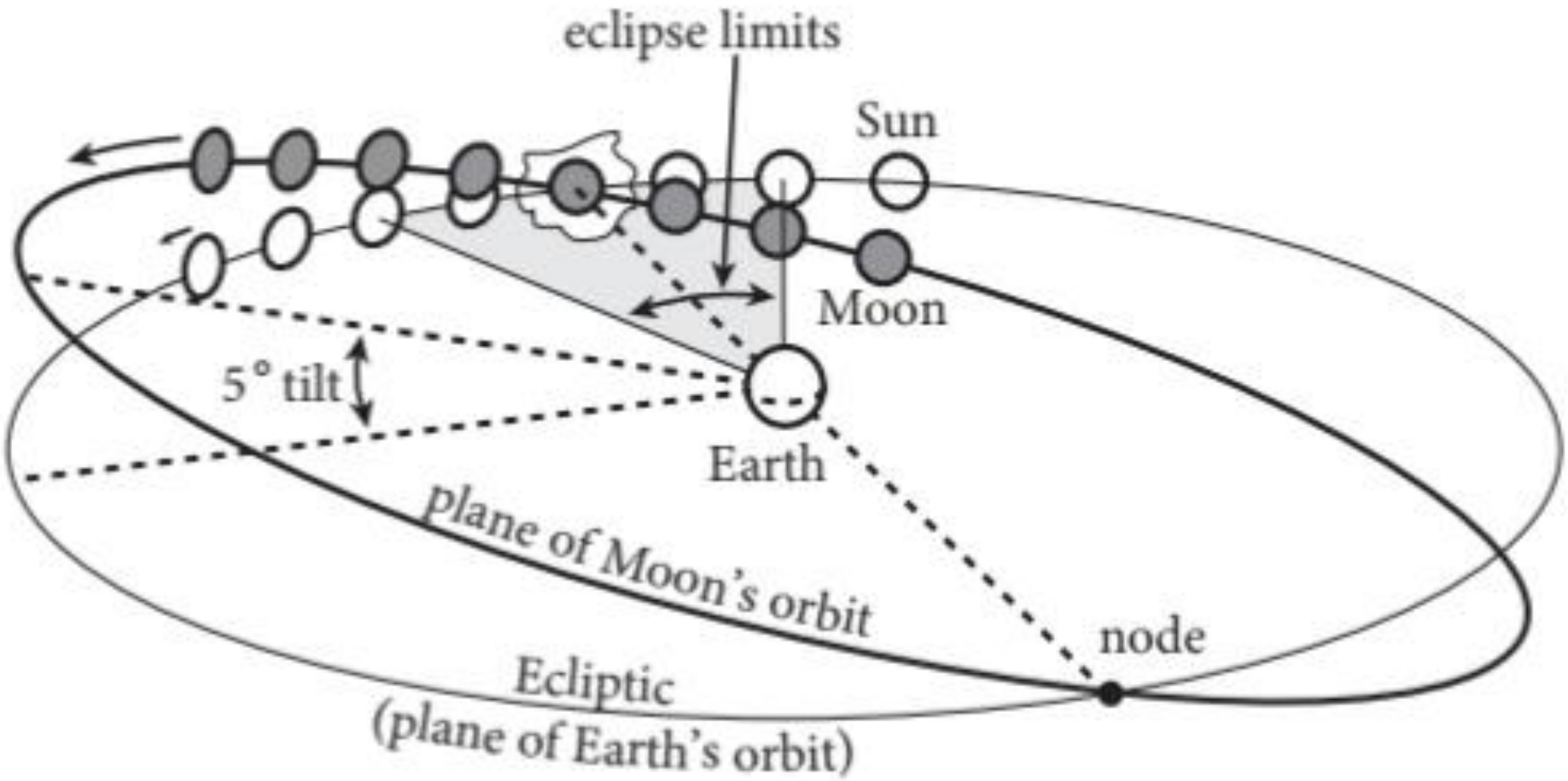


Image credit and © Mark Littman and Fred Espenak: Totality, The Great North American Eclipse of 2024.

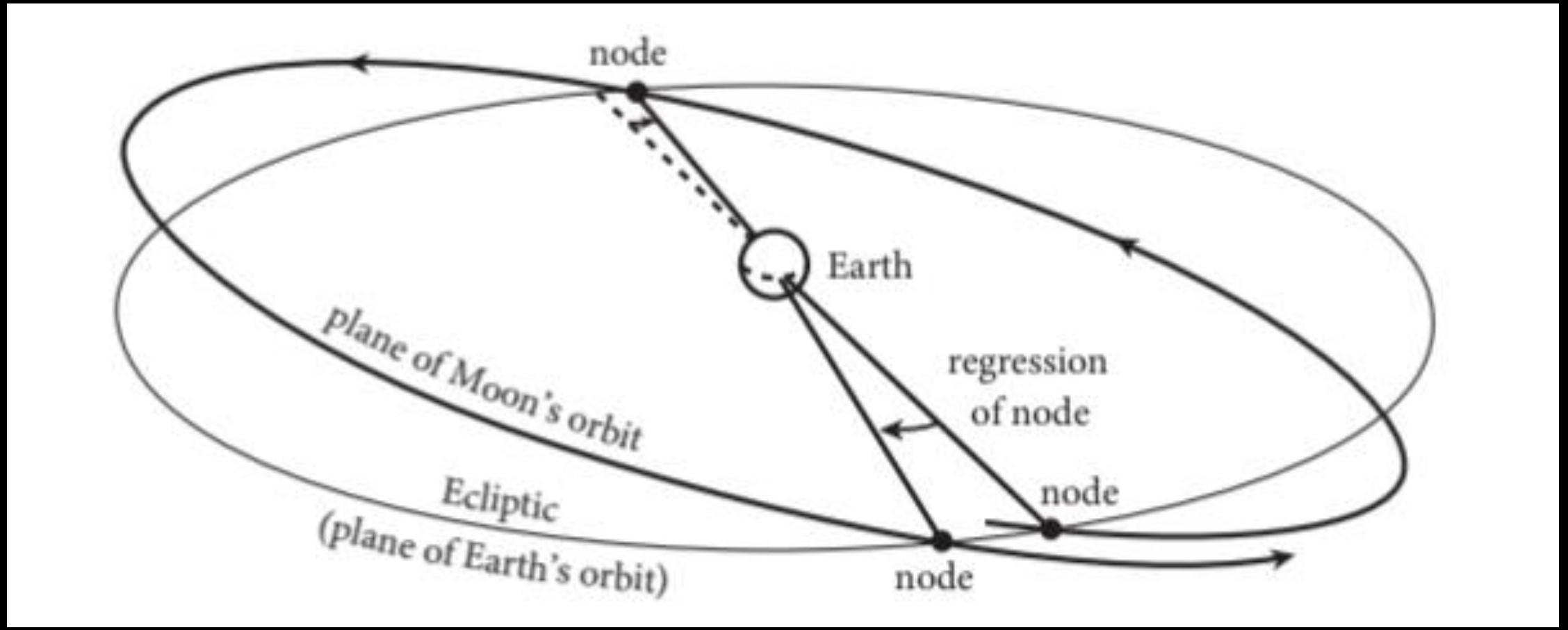
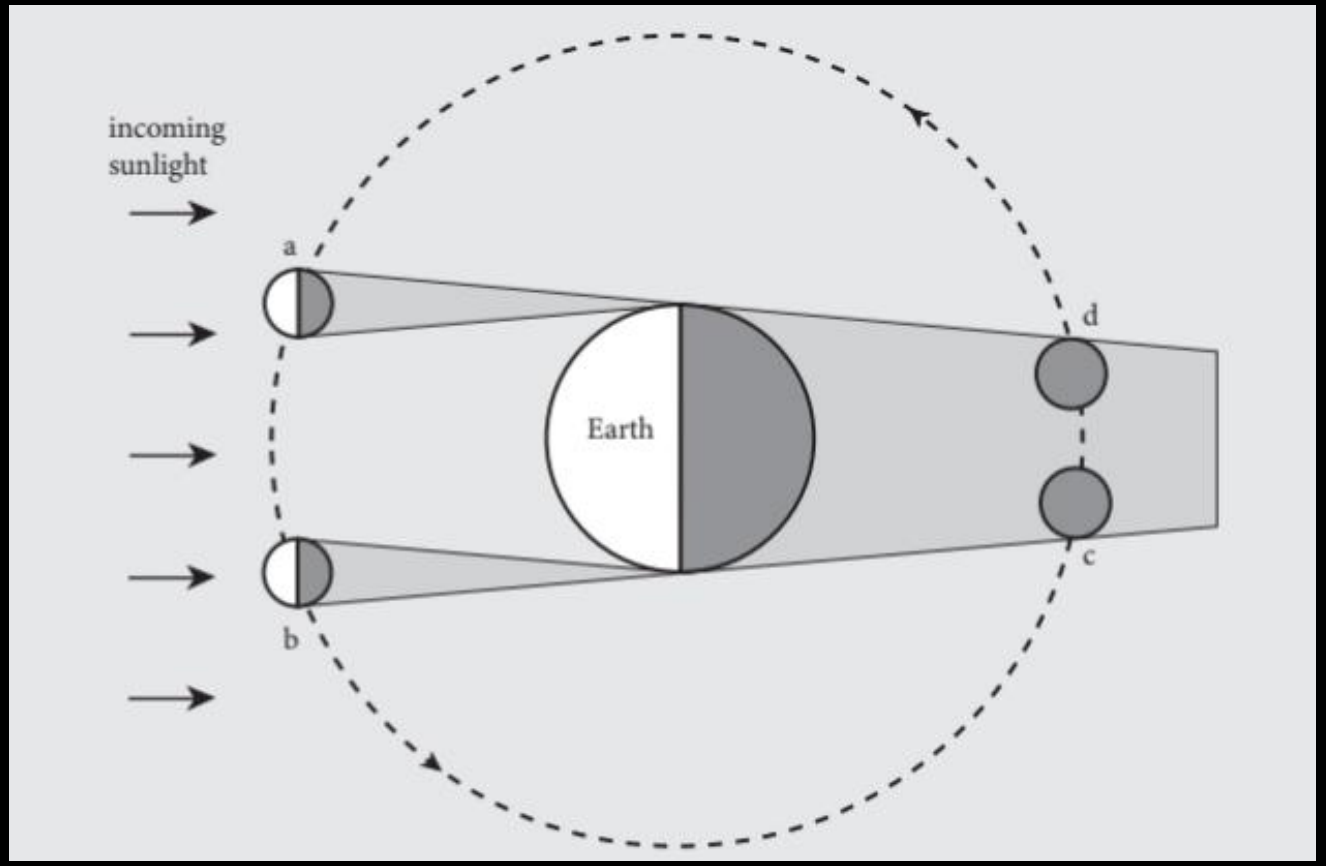


Image credit and © Mark Littman and Fred Espenak: Totality, The Great North American Eclipse of 2024.


incoming
sunlight
a
b
c
d
Earth

7 Sep 2025 Lunar Eclipse

Eclipse in context
Where in the sky?
What happens when?
What to expect?
How to see?

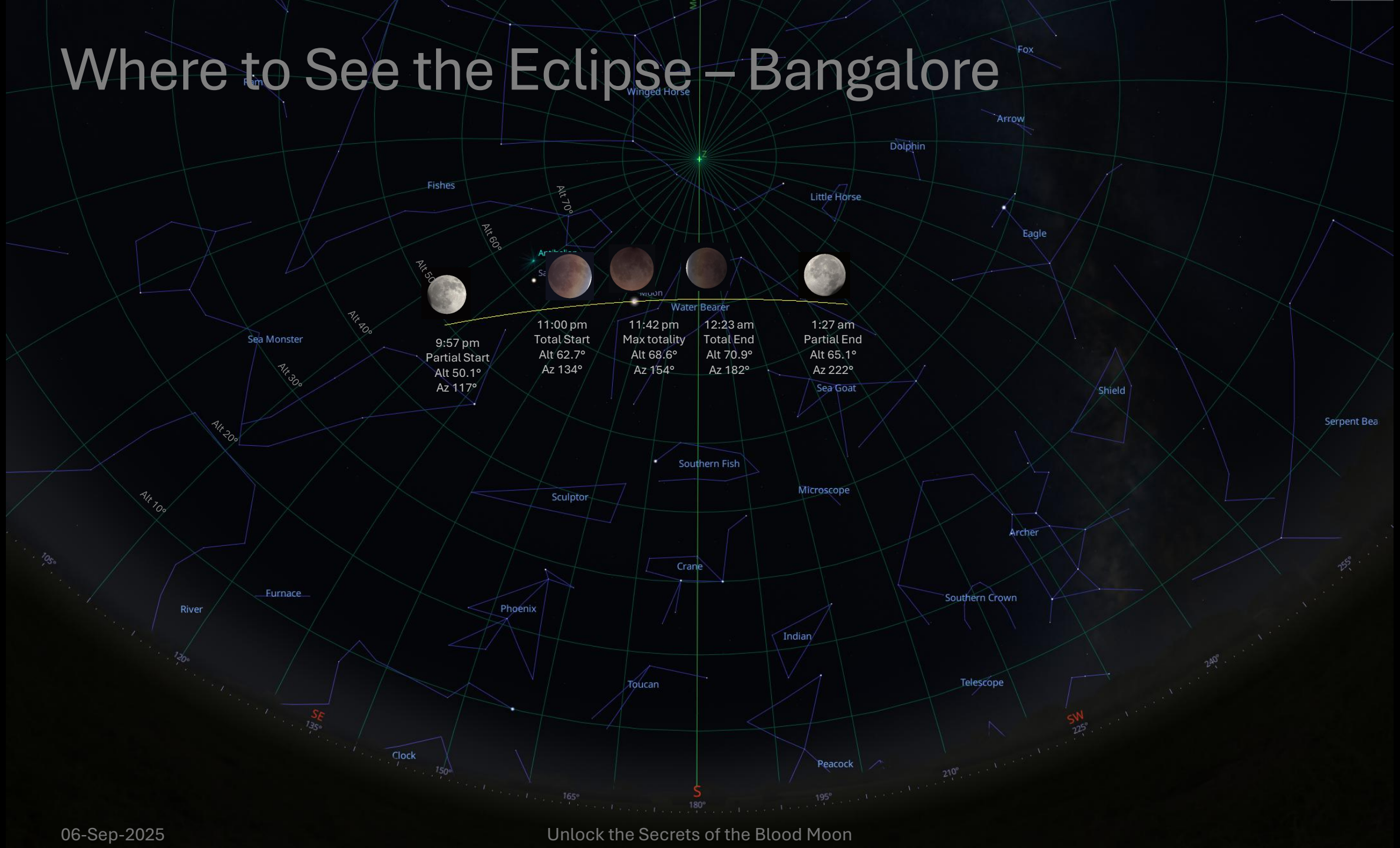
7 Sep 2025 Total Lunar Eclipse in Context

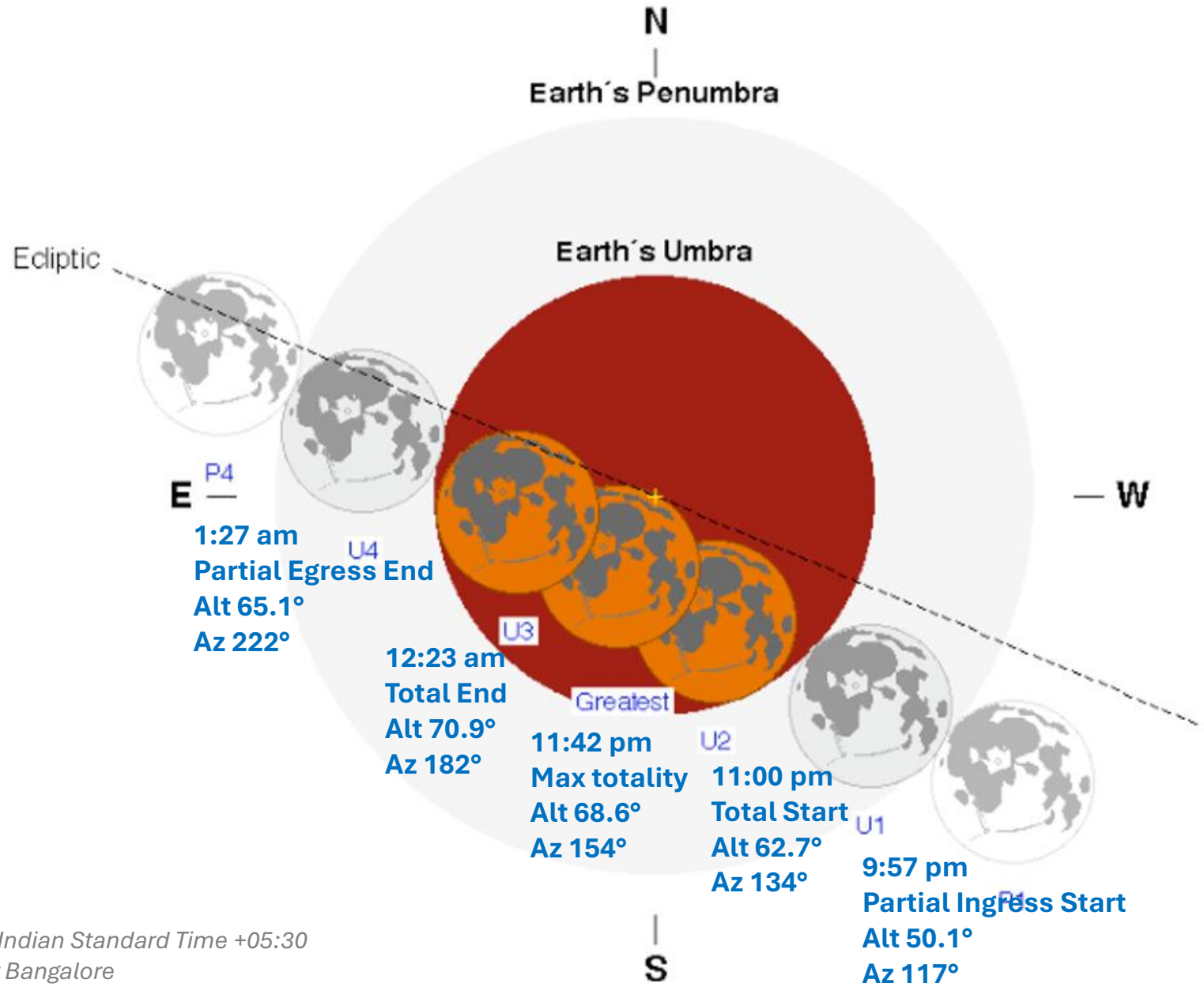
2010-2030 Lunar Eclipses			
	Bad or Not Visible	Good or Perfect	Total
Penumbral	12	5	17
Partial	6	6	12
Total	13	6	19
	31	17	48

Last total eclipse visible from India – 28 July 2018

Next total lunar eclipse visible from India – 31 Dec 2028

Where to See the Eclipse – Bangalore





Times in Indian Standard Time +05:30
Alt/Az for Bangalore

How to View the Eclipse?

Naked Eyes
No Protection Needed
Moon in context
Most dramatic

Binoculars
Brighter and closer
Better color hues
Umbral edge details

Telescope
High resolution
Even better color hues
Subtle contrasts

Wishing You Clear Skies!

9:57 pm
Partial Start

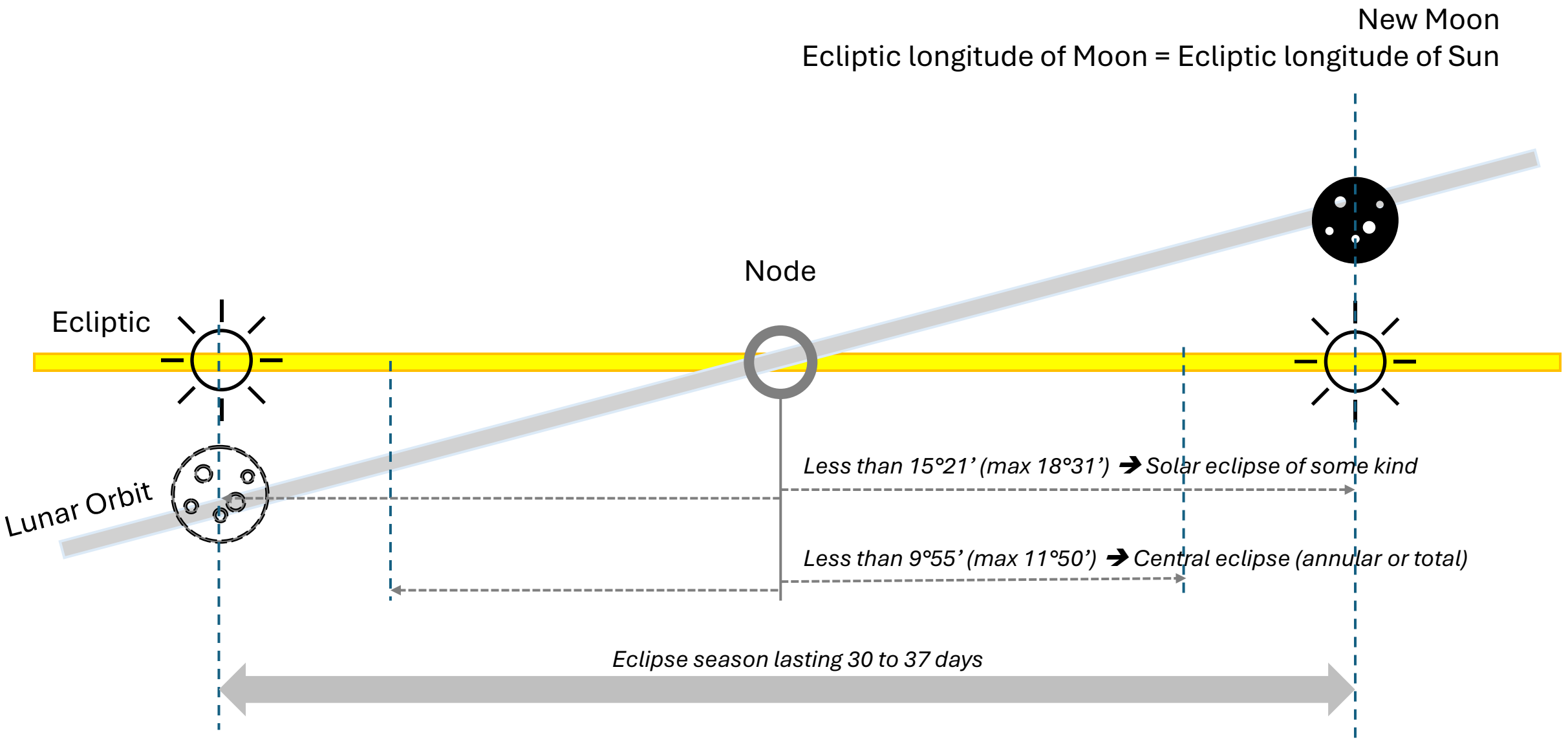
11:00 pm
Total Start

11:42 pm
Total Mid

12:23 am
Total End

01:27 am
Partial End

Additional Material


New Moon
Ecliptic longitude of Moon = Ecliptic longitude of Sun
Node
Ecliptic
Lunar Orbit
Less than 15°21’ (max 18°31’) ➔ Solar eclipse of some kind
Less than 9°55’ (max 11°50’) ➔ Central eclipse (annular or total)
Eclipse season lasting 30 to 37 days

Saros Cycle

27.2122
Draconic

27.3217
Sidereal

27.5545
Anomalistic

29.5306
Synodic

Nodes precess in retrograde ↻

Orbit precesses in prograde ⟲

Sun moves in prograde ⟲

Draconic Months	Anomalistic Months	Synodic Months
241.999	238.992	223.000
6585.32 days	6585.32 days	6585.32 days
18 years + 10/11/12 days	18 years + 10/11/12 days	18 years + 10/11/12 days

One saros period after an eclipse, the Sun, Earth, and Moon return to approximately the same relative geometry, a near straight line, and a nearly identical eclipse will occur, in what is referred to as an eclipse cycle. A sar is one half of a saros.