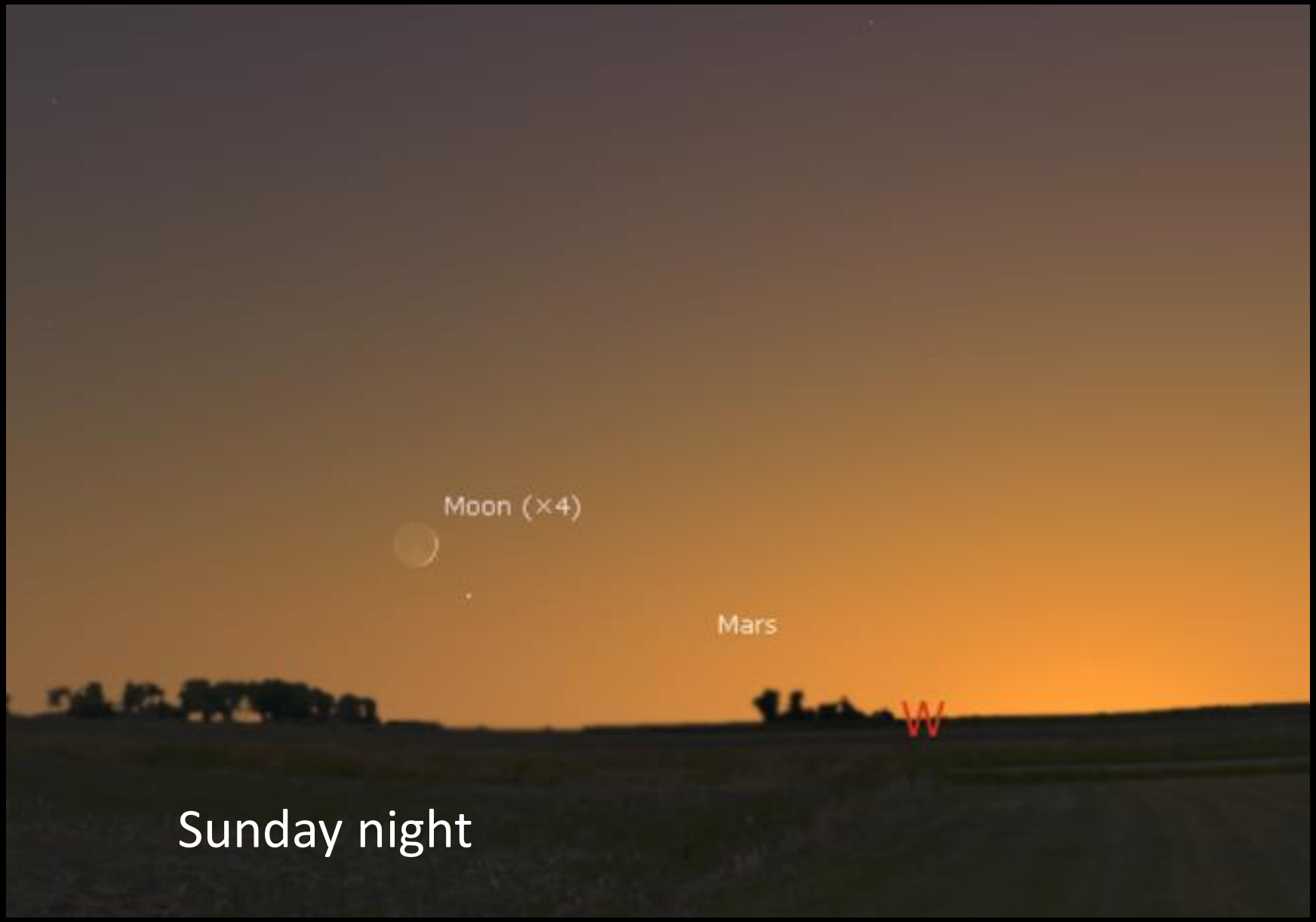
# Session #2 -
# Solar and Lunar Eclipses

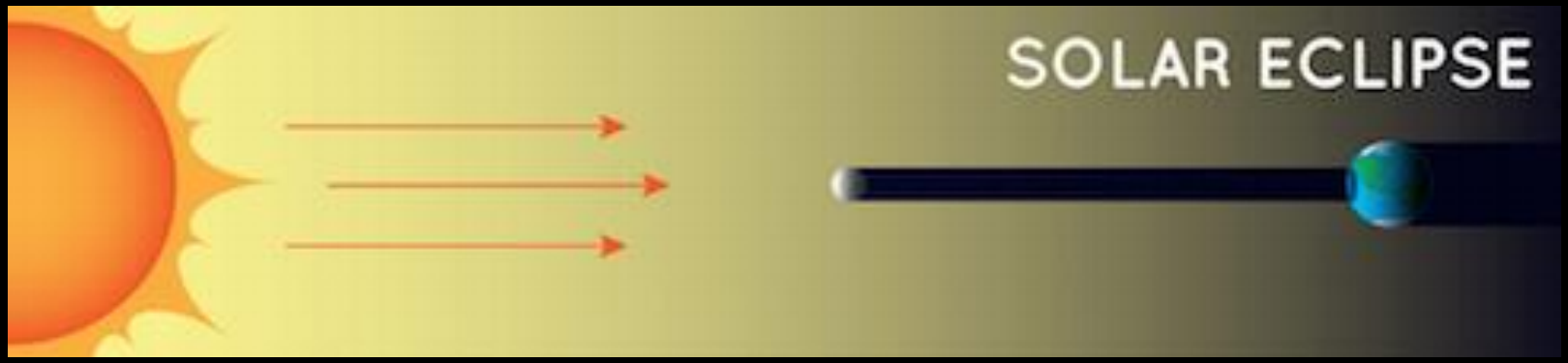


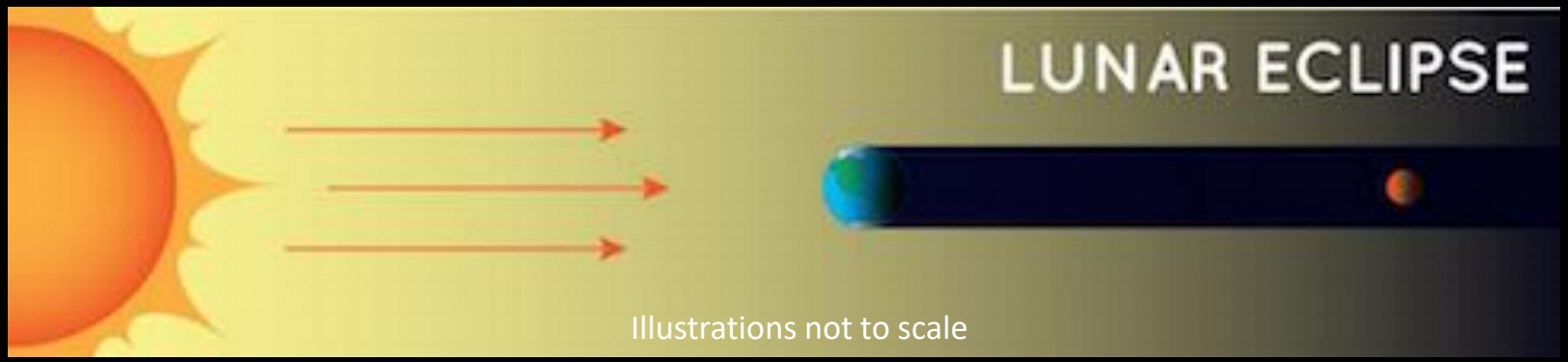

Sunday night

# Types of Eclipses

- Lunar (Full Moon)
  - total
  - penumbral
- Solar (New Moon)
  - Partial
  - Total
  - Annular

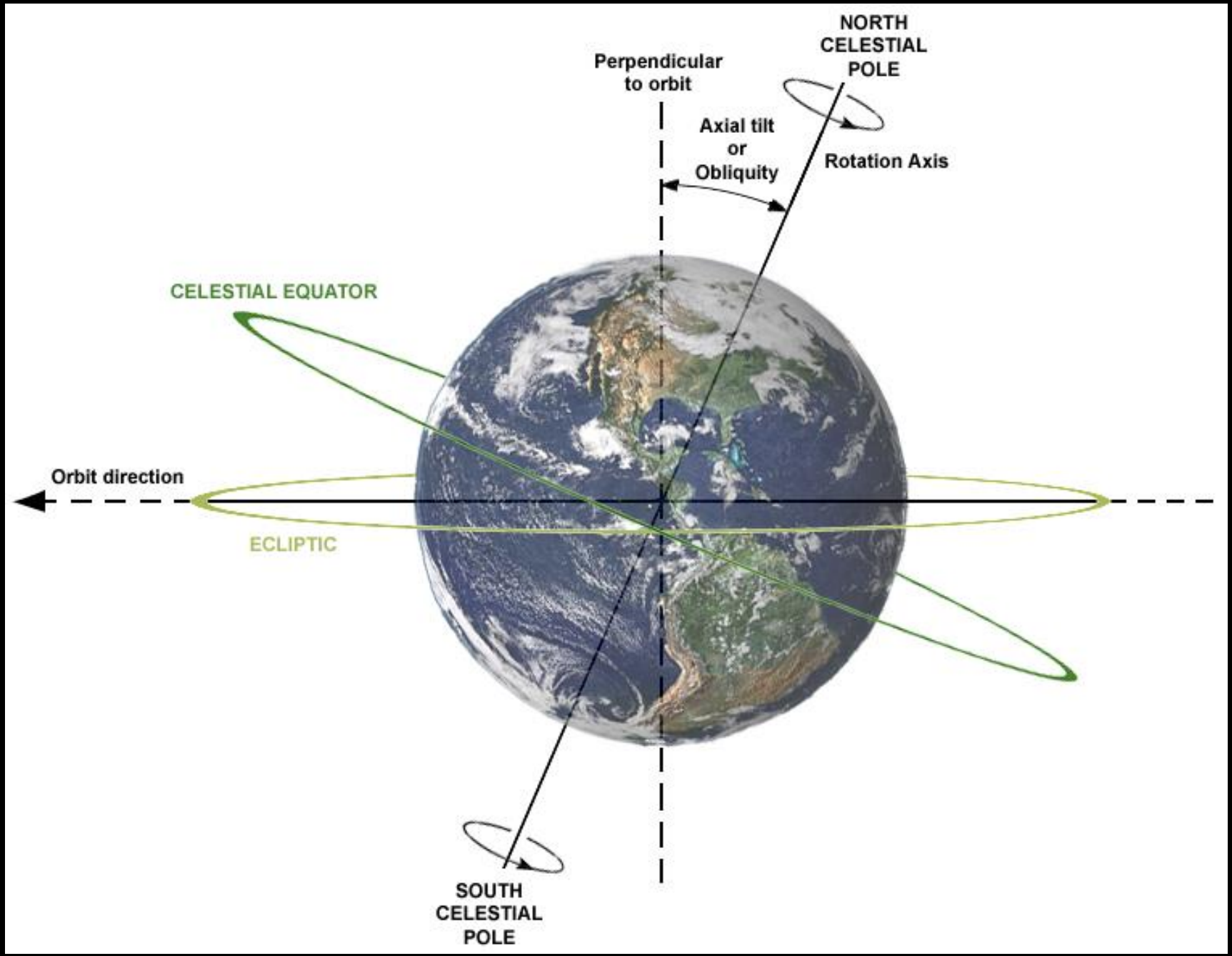
# Basic types of eclipses

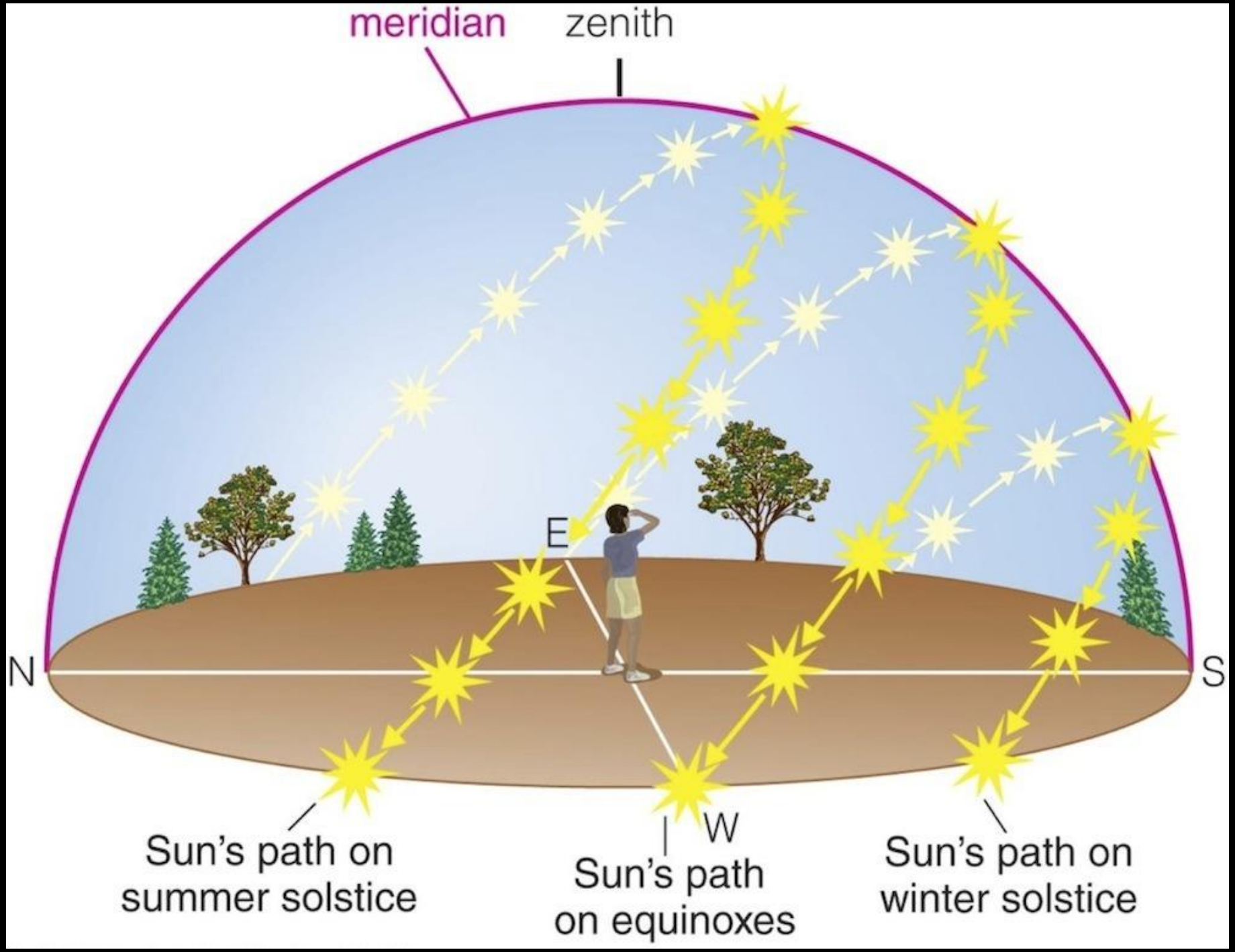


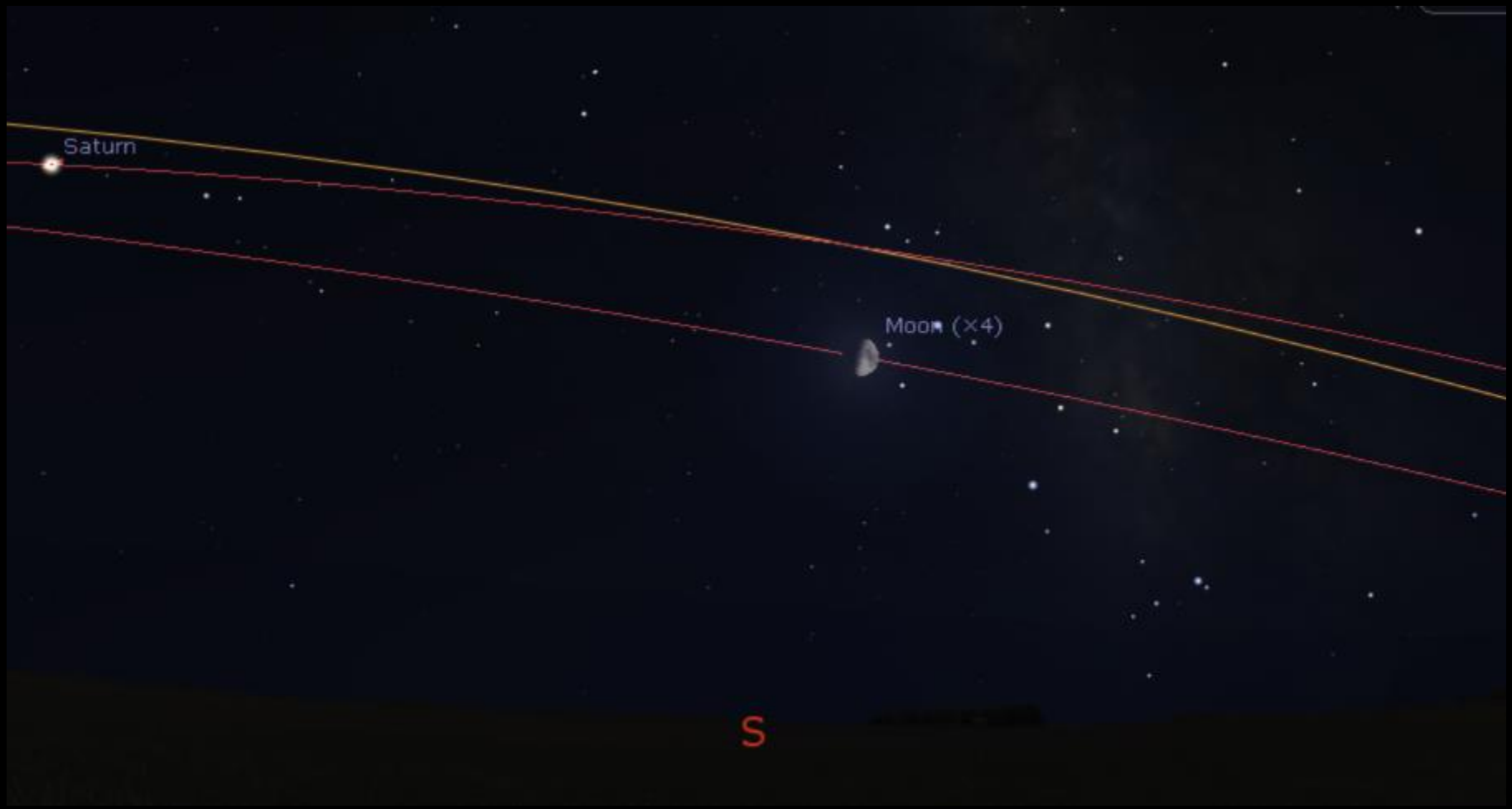

Illustrations not to scale


NASA / JPL-Caltech / SSI / Jason Major

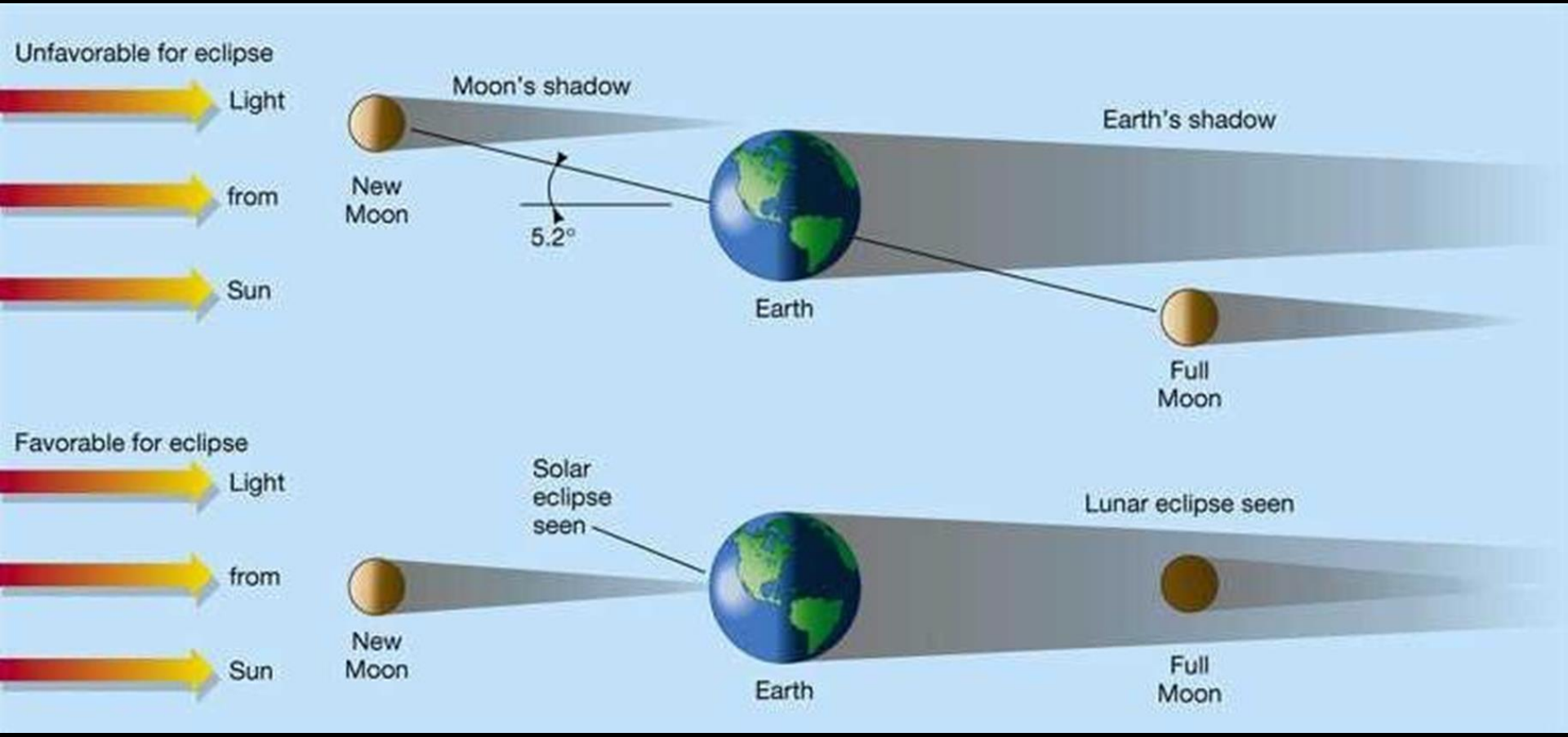

NORTH
CELESTIAL
POLE
Perpendicular
to orbit
Axial tilt
or
Obliquity
Rotation Axis
CELESTIAL EQUATOR
Orbit direction
ECLIPTIC
SOUTH
CELESTIAL
POLE

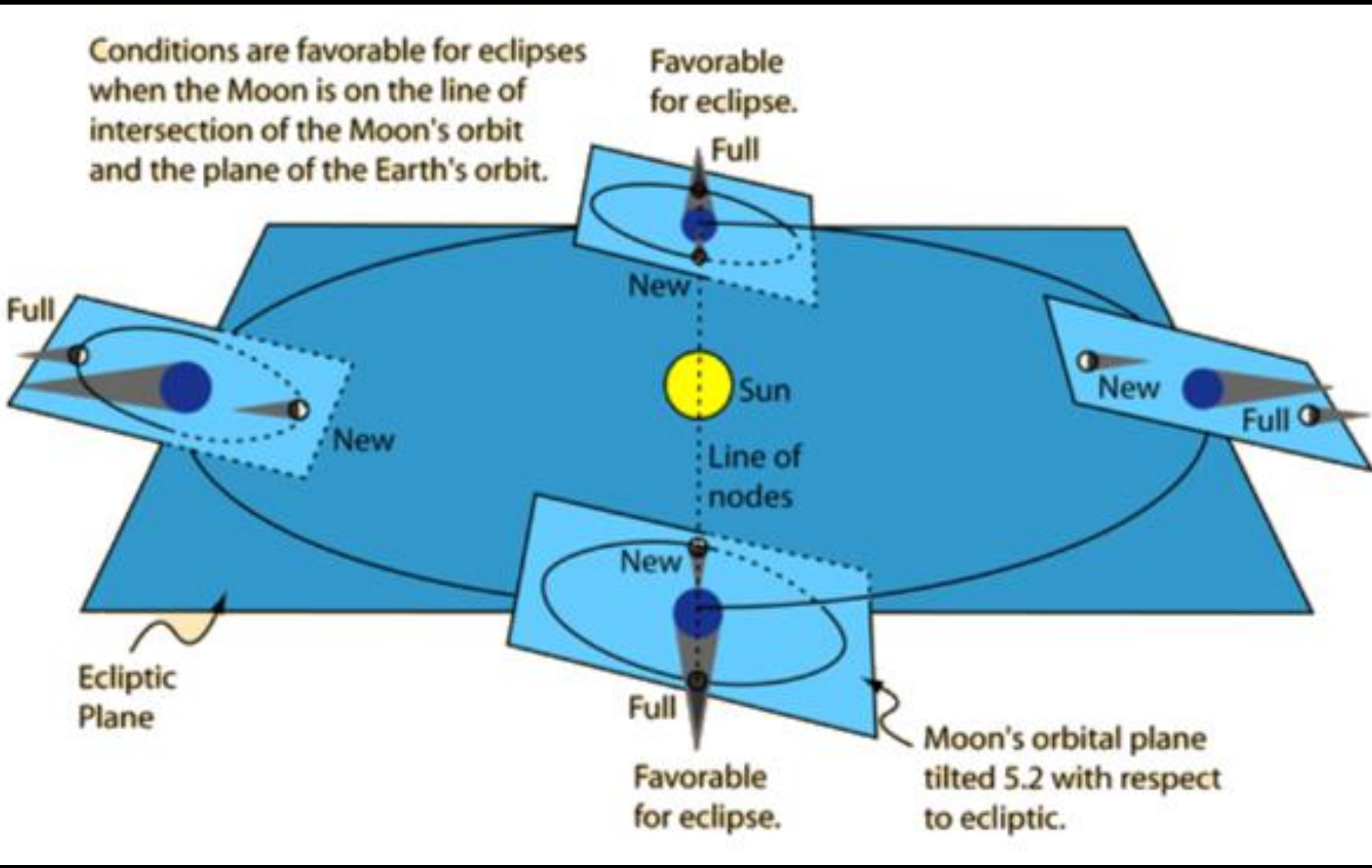

meridian
zenith
E
N
S
W
Sun's path on summer solstice
Sun's path on equinoxes
Sun's path on winter solstice

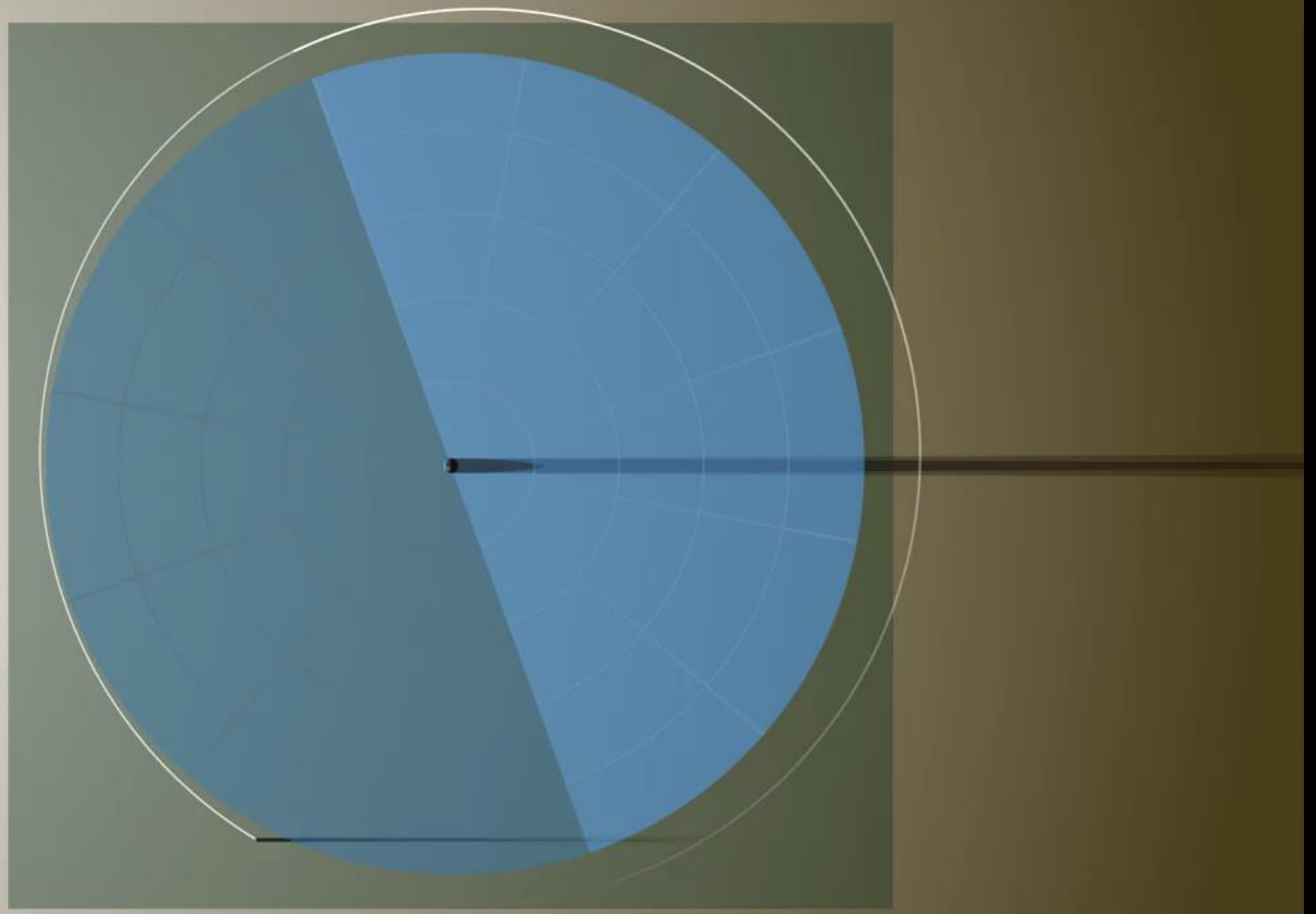
# *But first* . . .back to the Moon's orbit

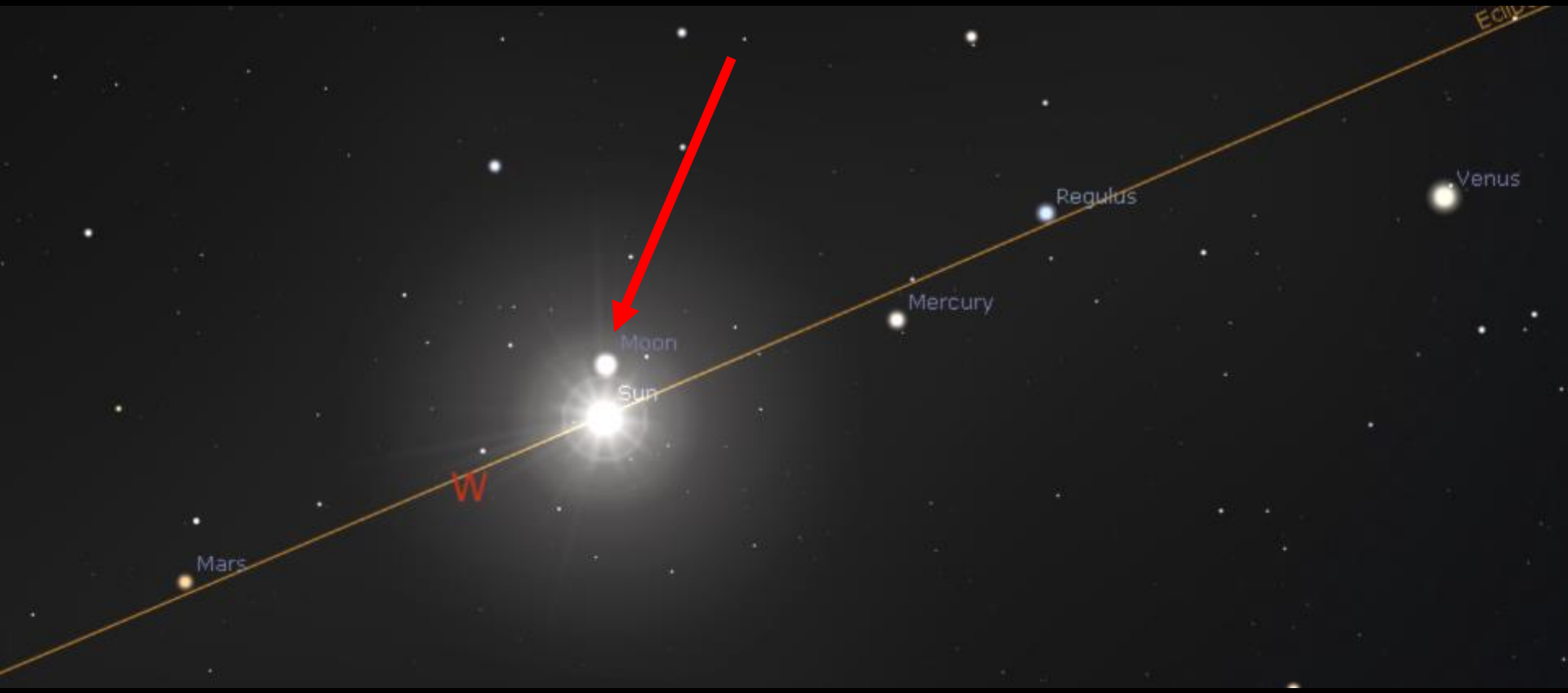


# Why don’t eclipses happen <u>every</u> month?


Unfavorable for eclipse
Light
from
Sun
Moon's shadow
New
Moon
5.2°
Earth
Earth's shadow
Full
Moon
Favorable for eclipse
Light
from
Sun
Solar
eclipse
seen
New
Moon
Earth
Lunar eclipse seen
Full
Moon

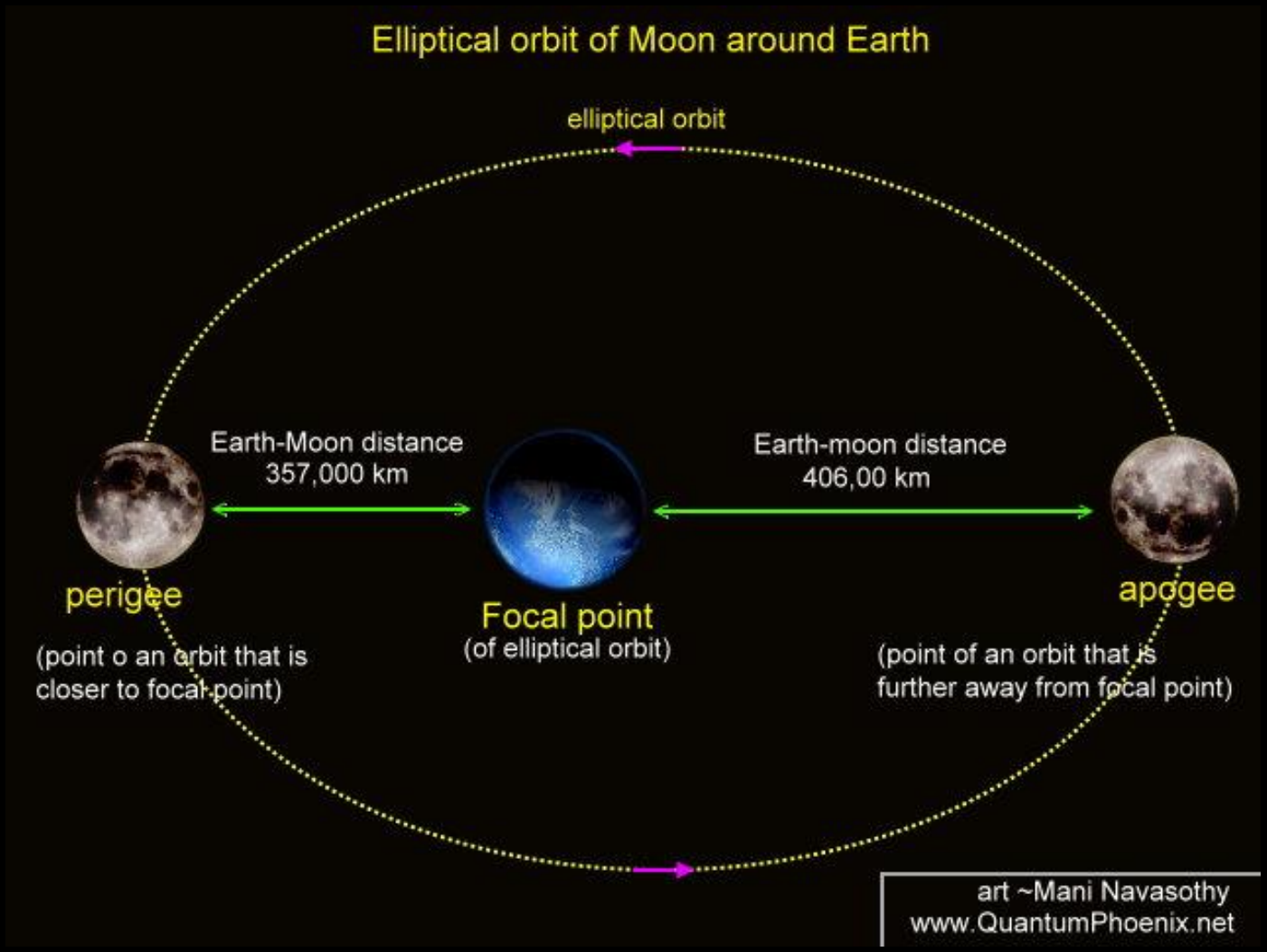

Conditions are favorable for eclipses when the Moon is on the line of intersection of the Moon's orbit and the plane of the Earth's orbit.
Favorable for eclipse.
Full
New
Full
New
Sun
New
Full
Line of nodes
New
Full
Ecliptic Plane
Favorable for eclipse.
Moon's orbital plane tilted 5.2 with respect to ecliptic.





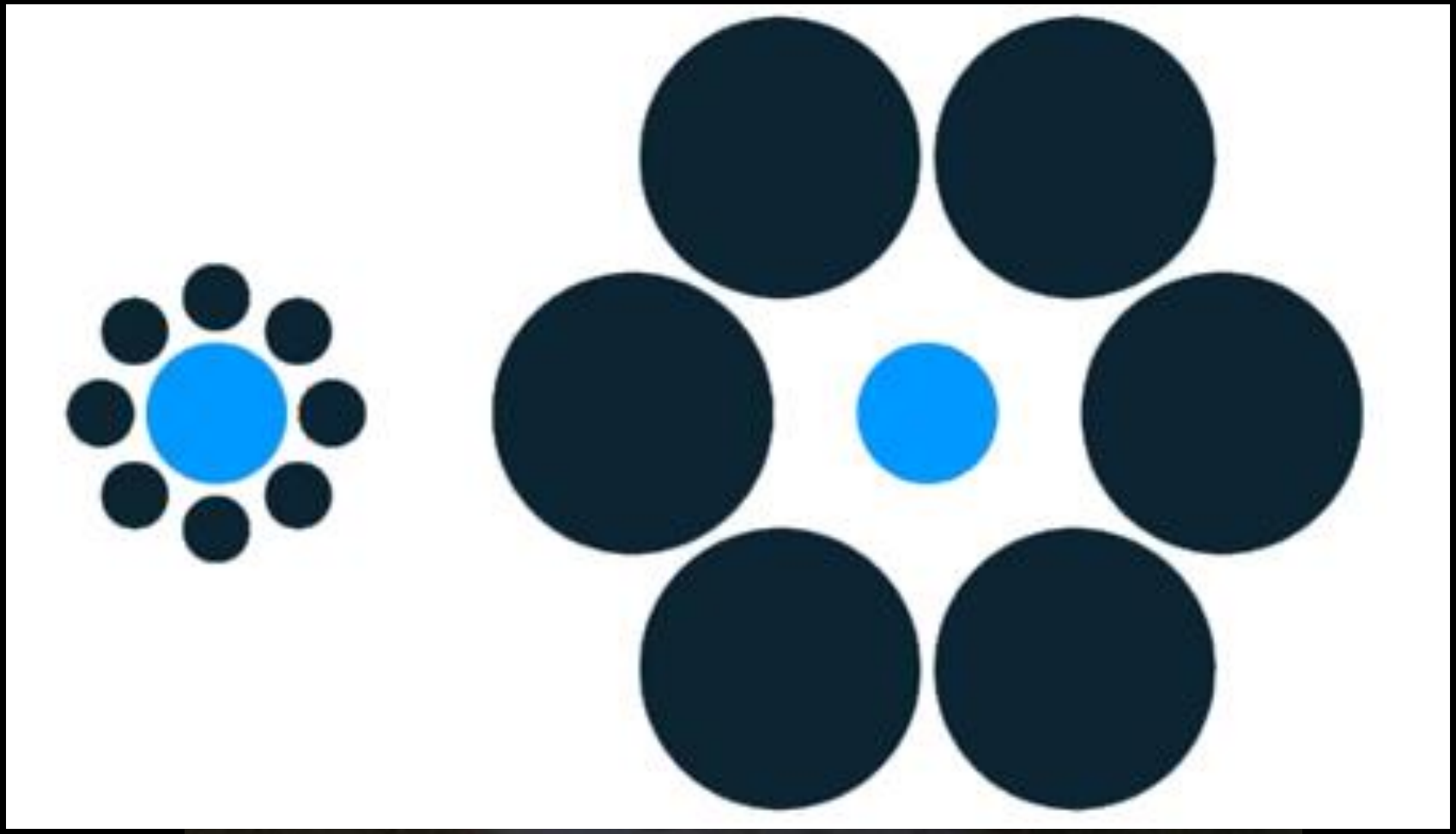

**Tomorrow's Sun/Moon positions**

# Moon’s orbit is not a perfect circle

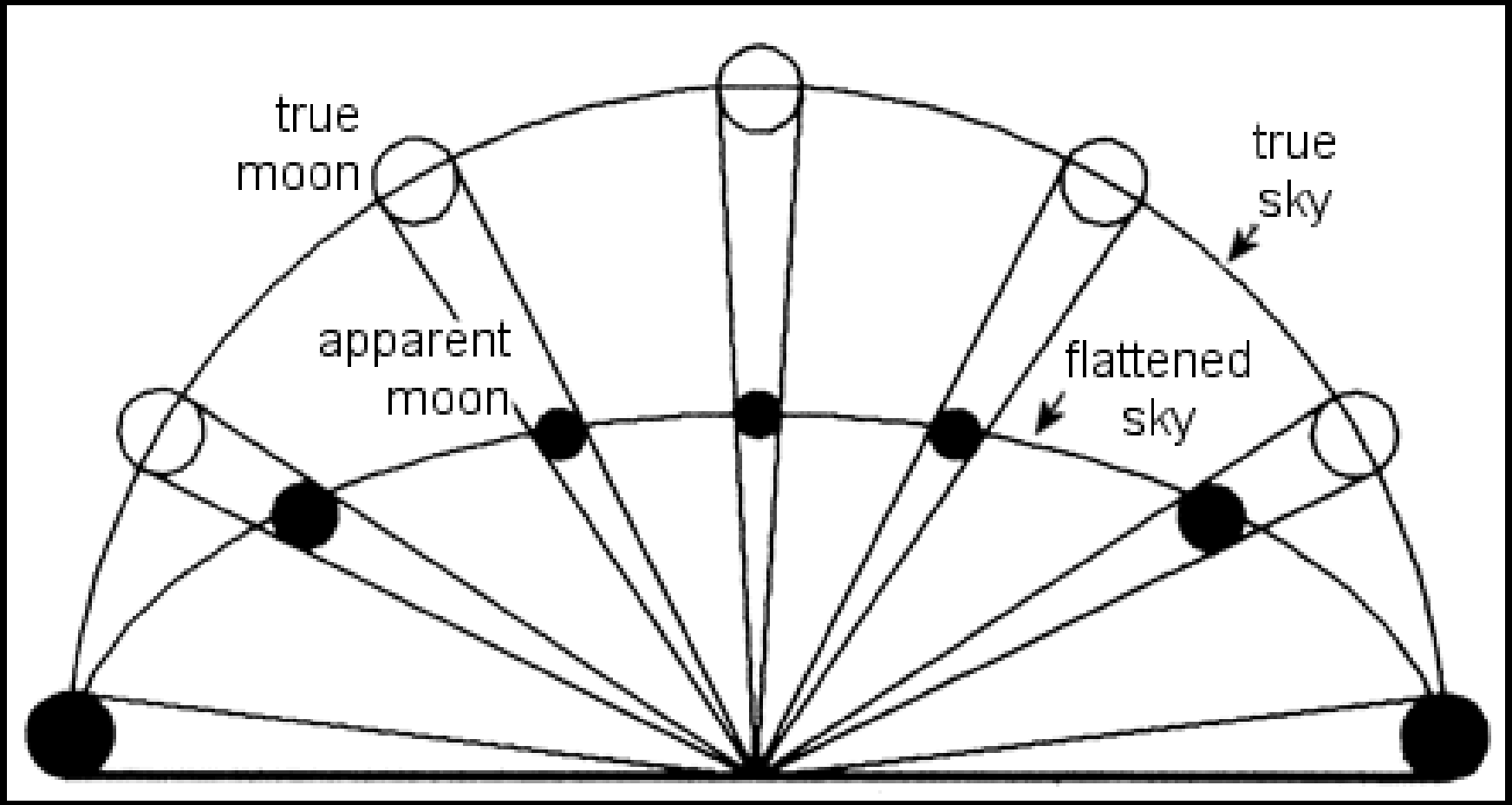


# *“SUPERMOON?”*

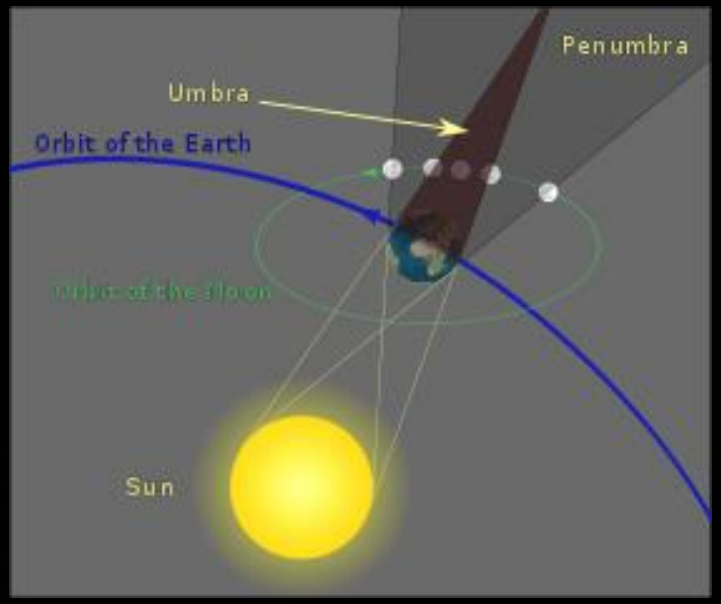
# “The Moon is huge!”

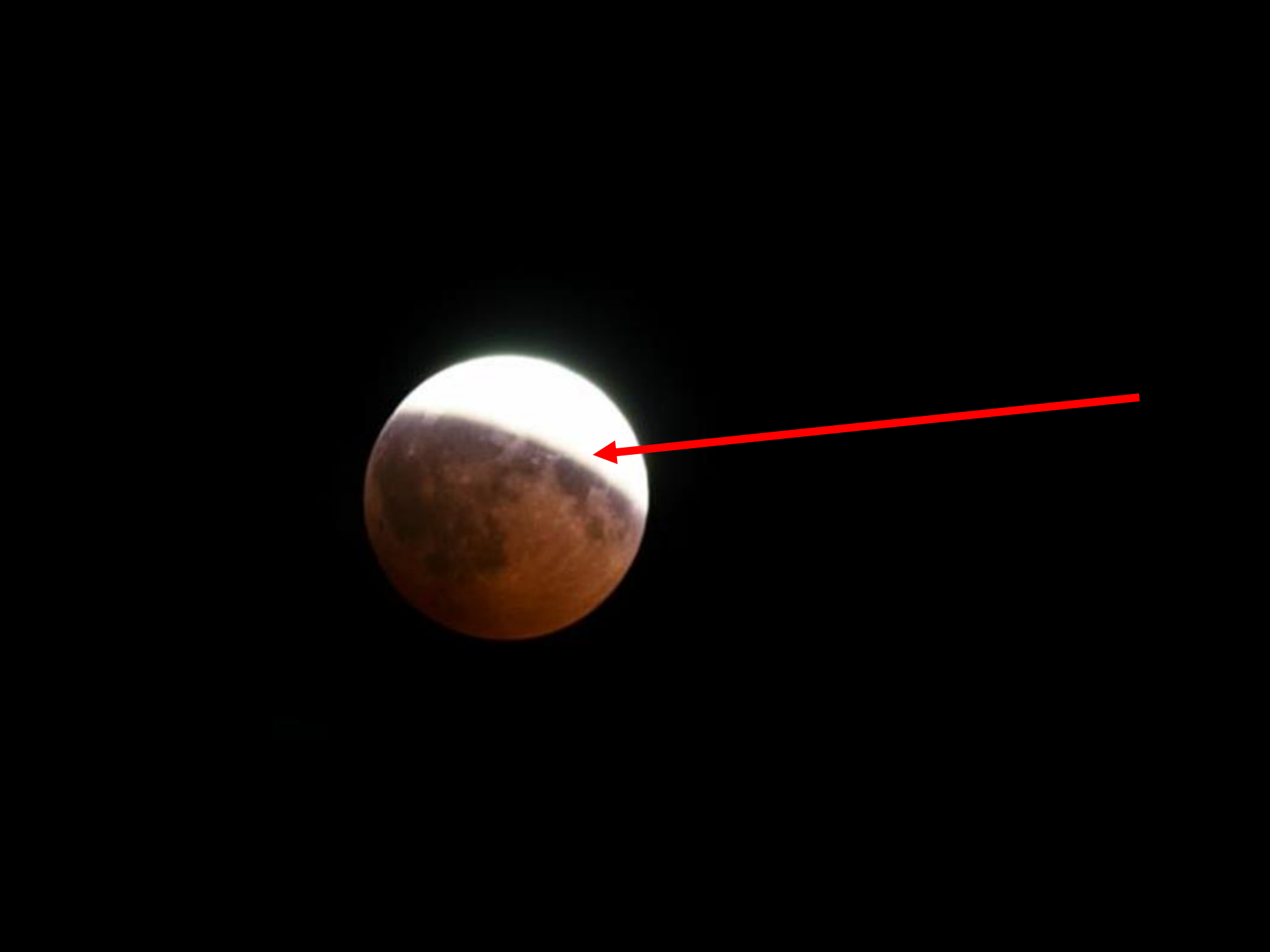


# “Moon illusion”



# Lunar Eclipses





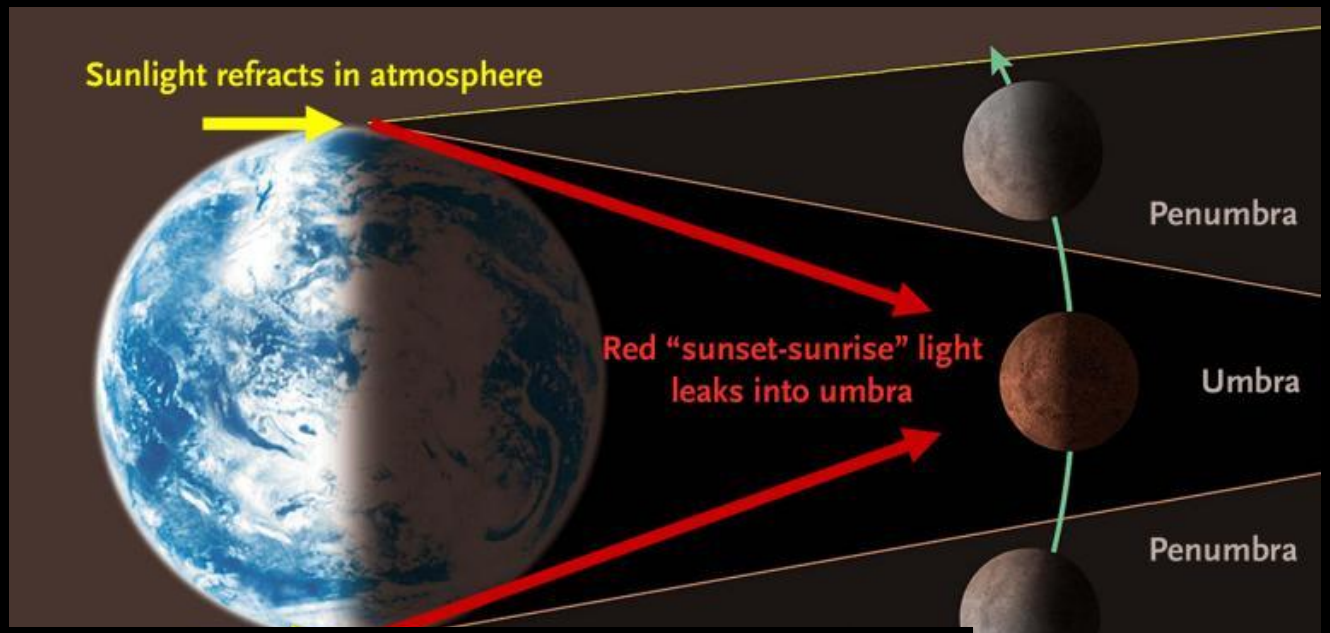
NEW YORK TIMES BEST-SELLING

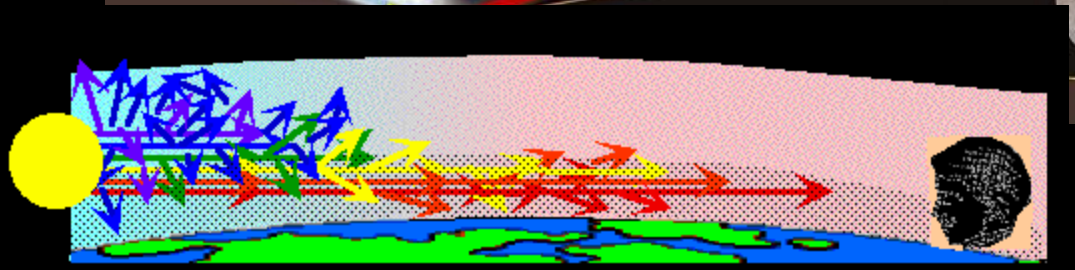
# FOUR BLOOD MOON

SOMETHING IS ABOUT TO CHANGE

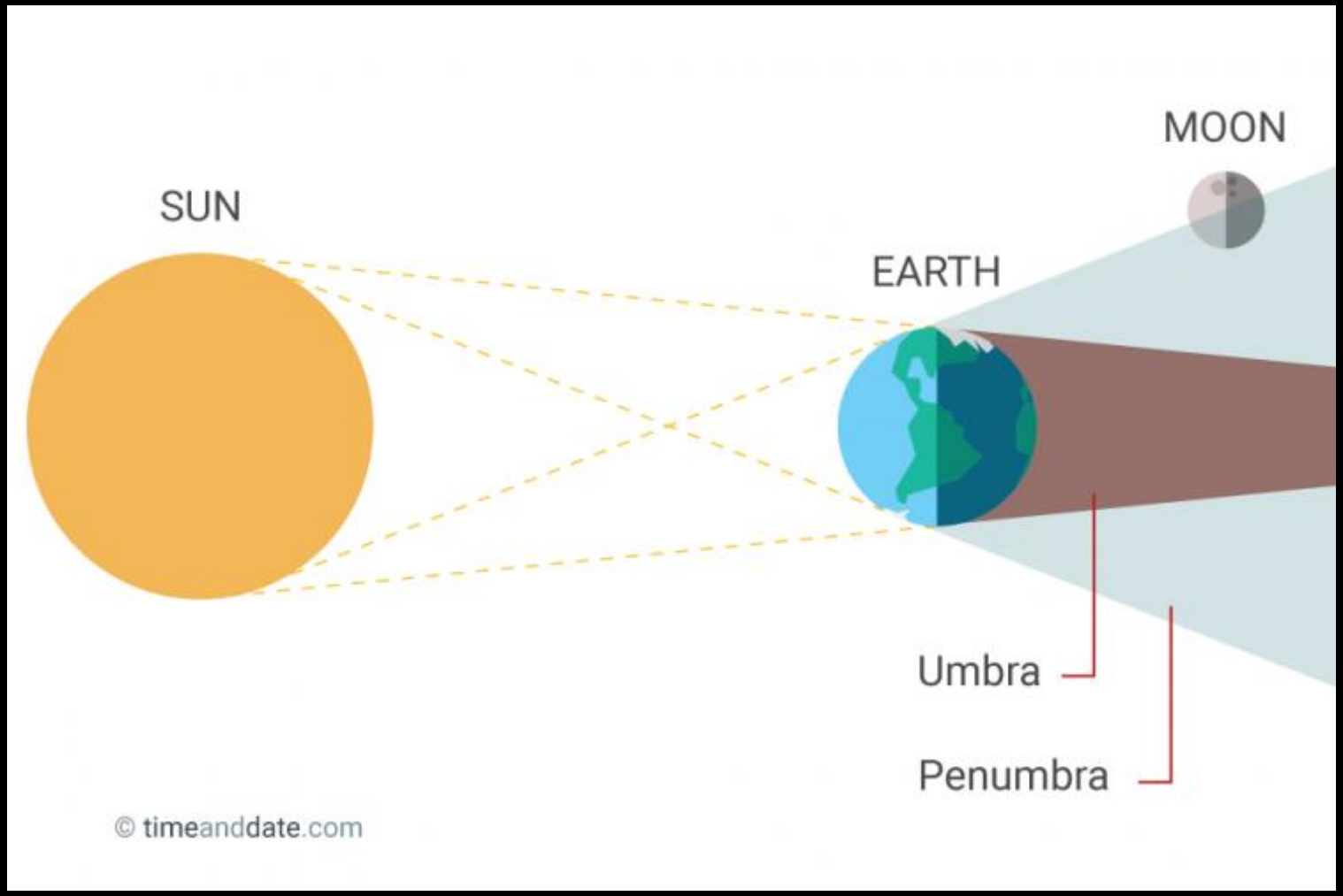
JOHN HAGEE


# *“Blood Moons?”*

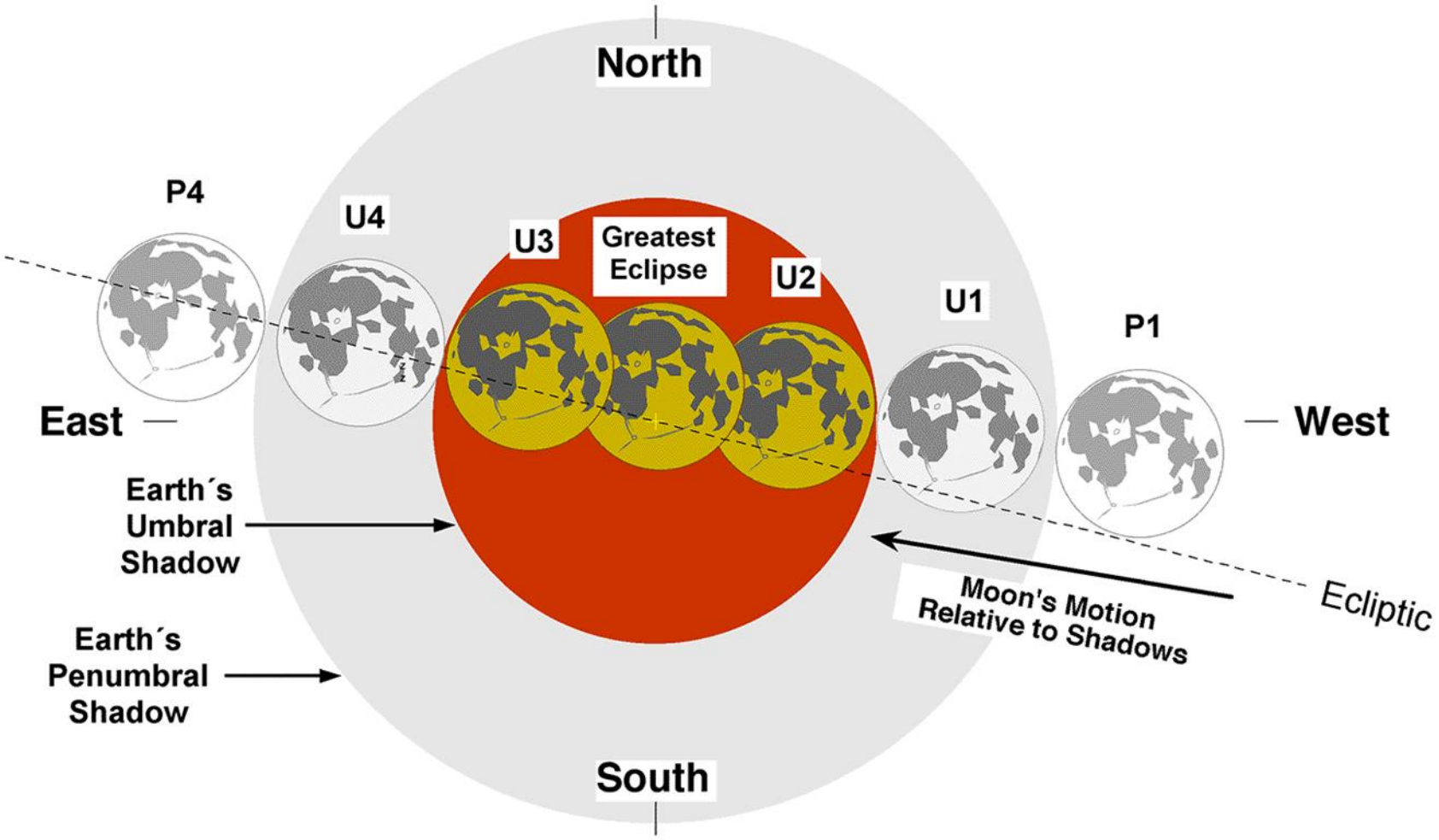

Sunlight refracts in atmosphere
Red “sunset-sunrise” light leaks into umbra
Penumbra
Umbra
Penumbra



# Two parts of a shadow



# Figure 2–1. Lunar Eclipse Contacts




*Courtesy of "Thousand Year Canon of Lunar Eclipses: 1501 – 2500", Fred Espenak, AstroPixels Publishing, 2015.*

www.EclipseWise.com/eclipse.html

# Partial

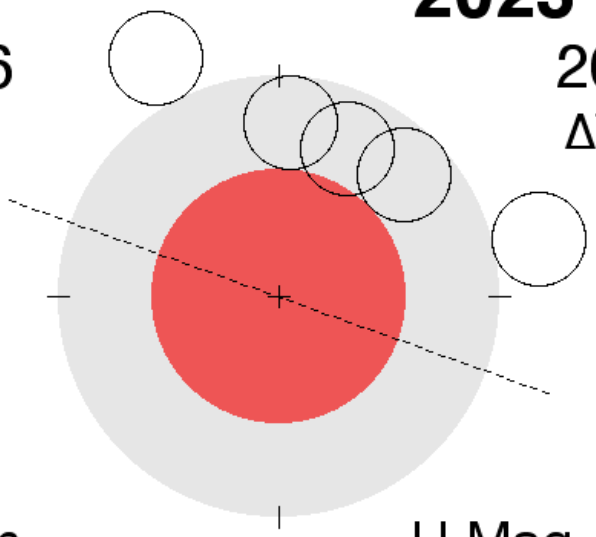
## 2023 Oct 28

Saros 146

20:15 TD

A.Node

ΔT= 71s

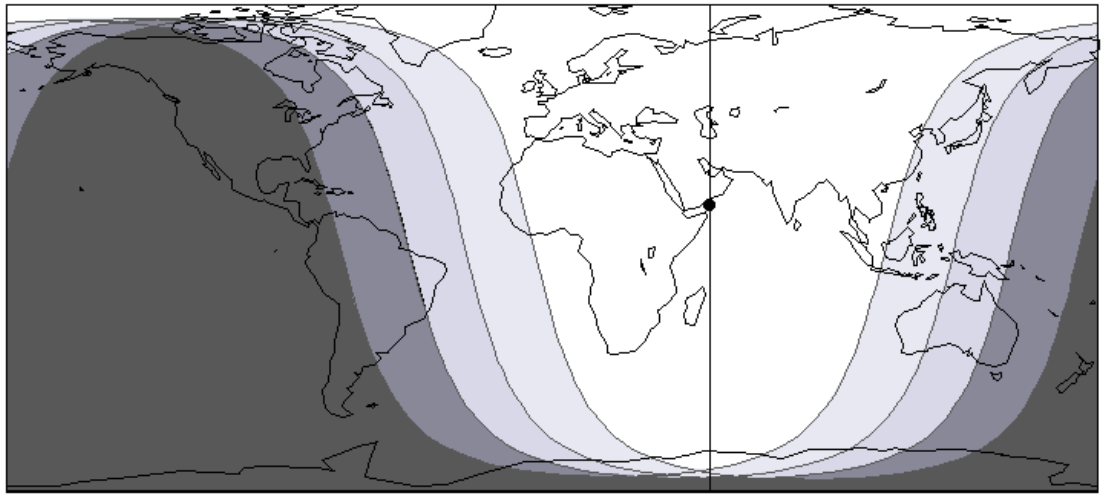


Par. = 77m

U.Mag. = 0.1221

Gam. = 0.9472

P.Mag. = 1.1181



***Thousand Year Canon of Lunar Eclipses***

# Explanation:

- “20:15 TD” – max eclipse in terrestrial dynami time.
- “ΔT = 71sec”- diff between TD and UT
- “Saros” series (stay tuned)
- “ Par = 77m” – duration of partial phase
- “Gam” – gamma (min dist from ctr of Moon to axis of Earth’s umbral shadow cone)
- “U.Mag” – Umbral eclipse magnitude (fract of Moon’s dia immersed in Earth’s shadow)
- “P.Mag” – Penumbral eclipse magnitude

www.EclipseWise.com/eclipse.html

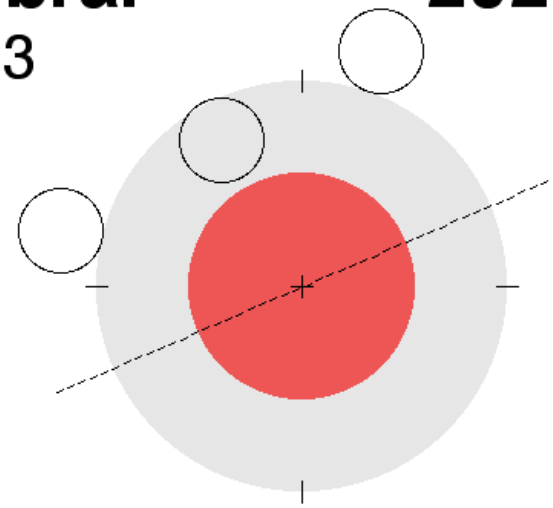
# Penumbral 2024 Mar 25

Saros 113

07:14 TD

D.Node

ΔT= 71s

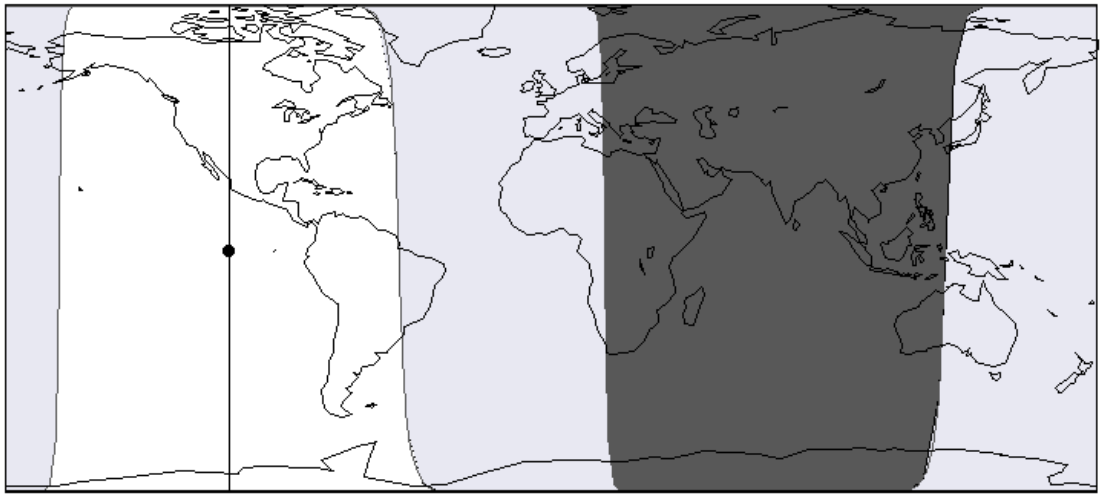


Pen. = 279m

U.Mag. = -0.1324

Gam. = 1.0610

P.Mag. = 0.9557



***Thousand Year Canon of Lunar Eclipses***

www.EclipseWise.com/eclipse.html

# Total

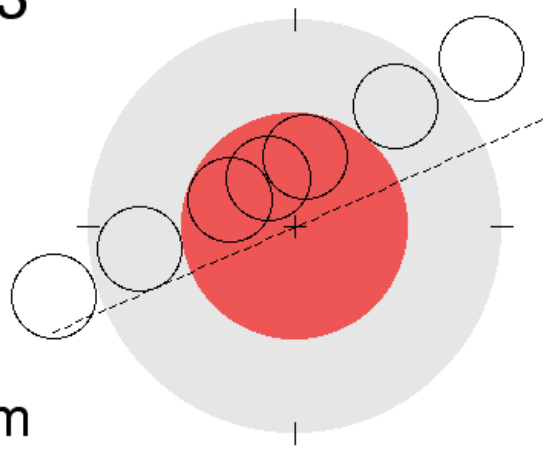
## 2025 Mar 14

Saros 123

07:00 TD

D.Node

ΔT= 72s



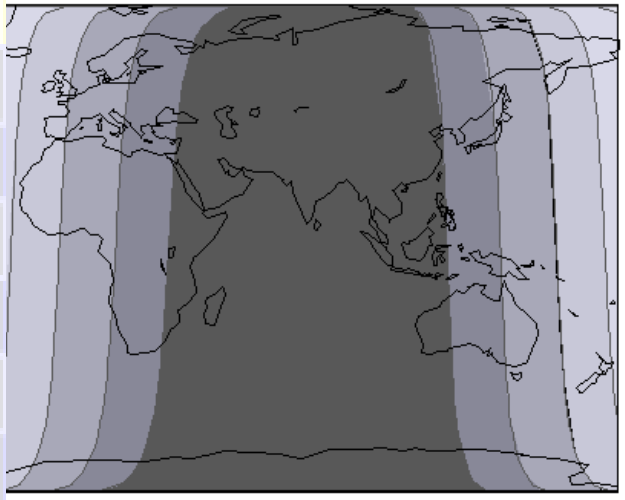
Tot. = 65m

Par. = 218m

U.Mag. = 1.1784

P.Mag. = 2.2595

| Eclipse Event | Contact | Time TD |
|---|---|---|
| *Penumbral Begins* | P1 | 03:58:21.1 |
| *Partial Begins* | U1 | 05:10:34.3 |
| *Total Begins* | U2 | 06:27:09.2 |
| *Greatest Eclipse* | Greatest | 06:59:56.2 |
| *Total Ends* | U3 | 07:33:13.1 |
| *Partial Ends* | U4 | 08:49:30.1 |
| *Penumbral Ends* | P4 | 10:01:43.5 |



***Canon of Lunar Eclipses***

# *A note about "time" . . . .*

- Solar time = based on the position of the Sun
- Local Mean Time/Standard time = based on an "average Sun" (time on your phone)
- Universal Time = Time at prime meridian

CST = UT – 6 hours

CDT = UT – 5 hours

Ex 1) Sept 3, 10 hrs UT = Sept 3, 5am CST

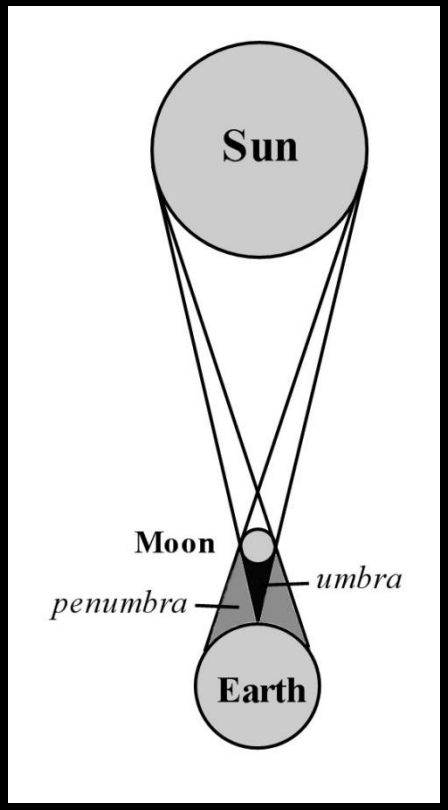
Ex 2) Sept 3, 23 hrs UT = Sept 3, 6pm CST

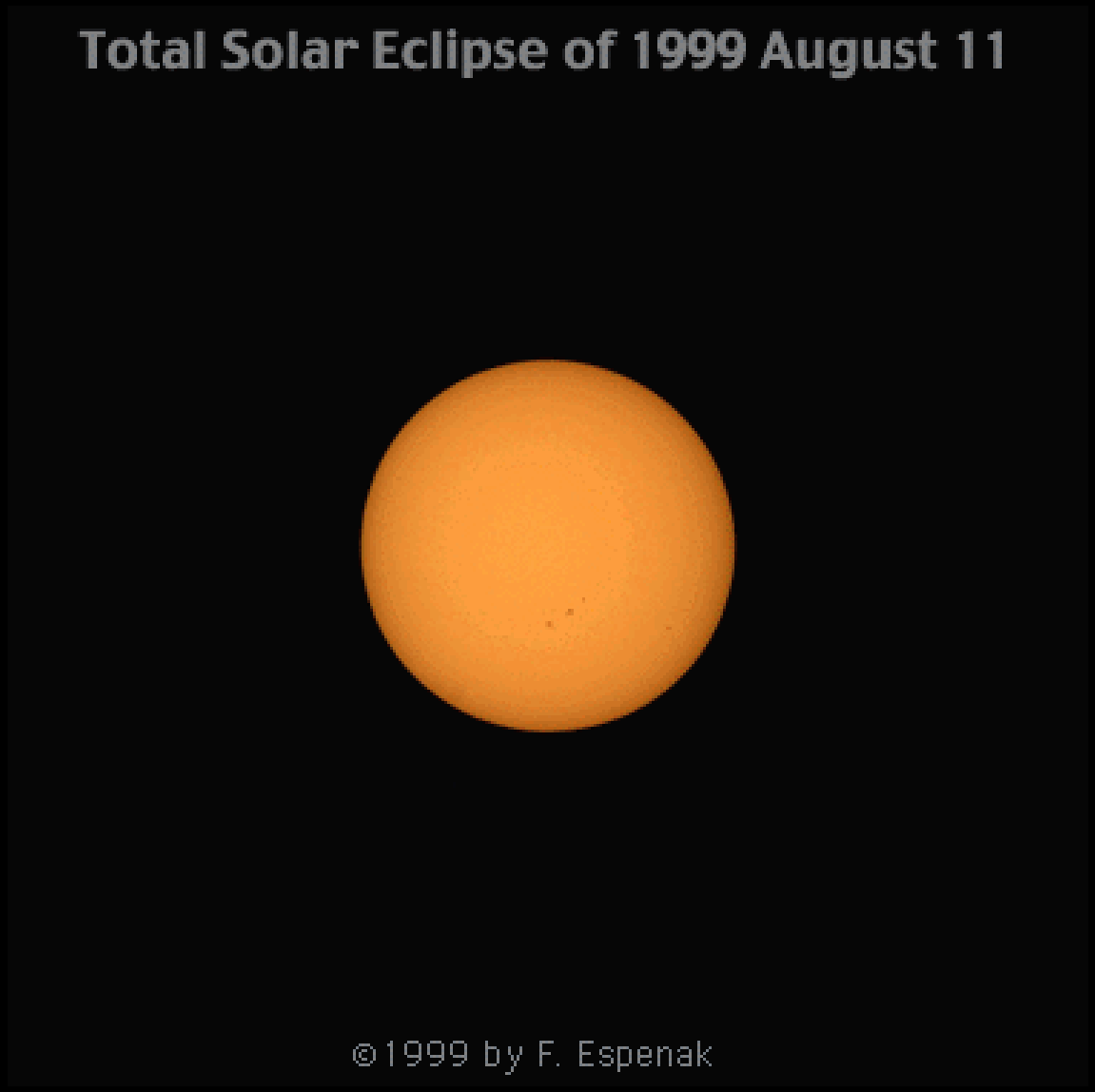
Ex 3) Sept 3, 2 hrs UT = Sept 2, 9pm CST

| Eclipse Event | Contact | Time TD |
|---|---|---|
| *Penumbral Begins* | P1 | 03:58:21.1 |
| *Partial Begins* | U1 | 05:10:34.3 |
| *Total Begins* | U2 | 06:27:09.2 |
| *Greatest Eclipse* | Greatest | 06:59:56.2 |
| *Total Ends* | U3 | 07:33:13.1 |
| *Partial Ends* | U4 | 08:49:30.1 |
| *Penumbral Ends* | P4 | 10:01:43.5 |

- 10:58pm Mar. 13
- 12:10am Mar. 14
- 1:27am
- 1:59am
- 2:33am
- 3:49am

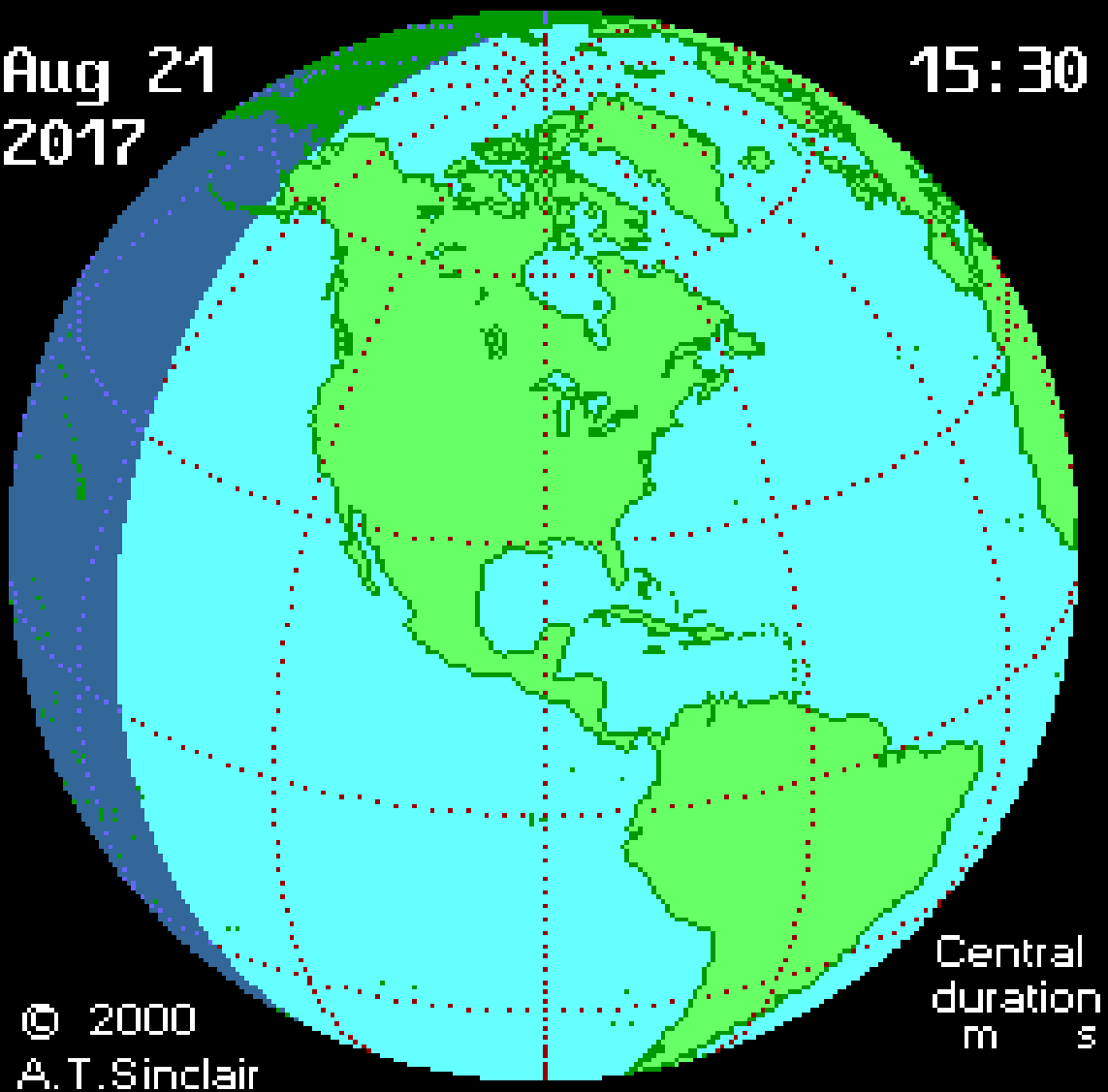
# Solar Eclipses



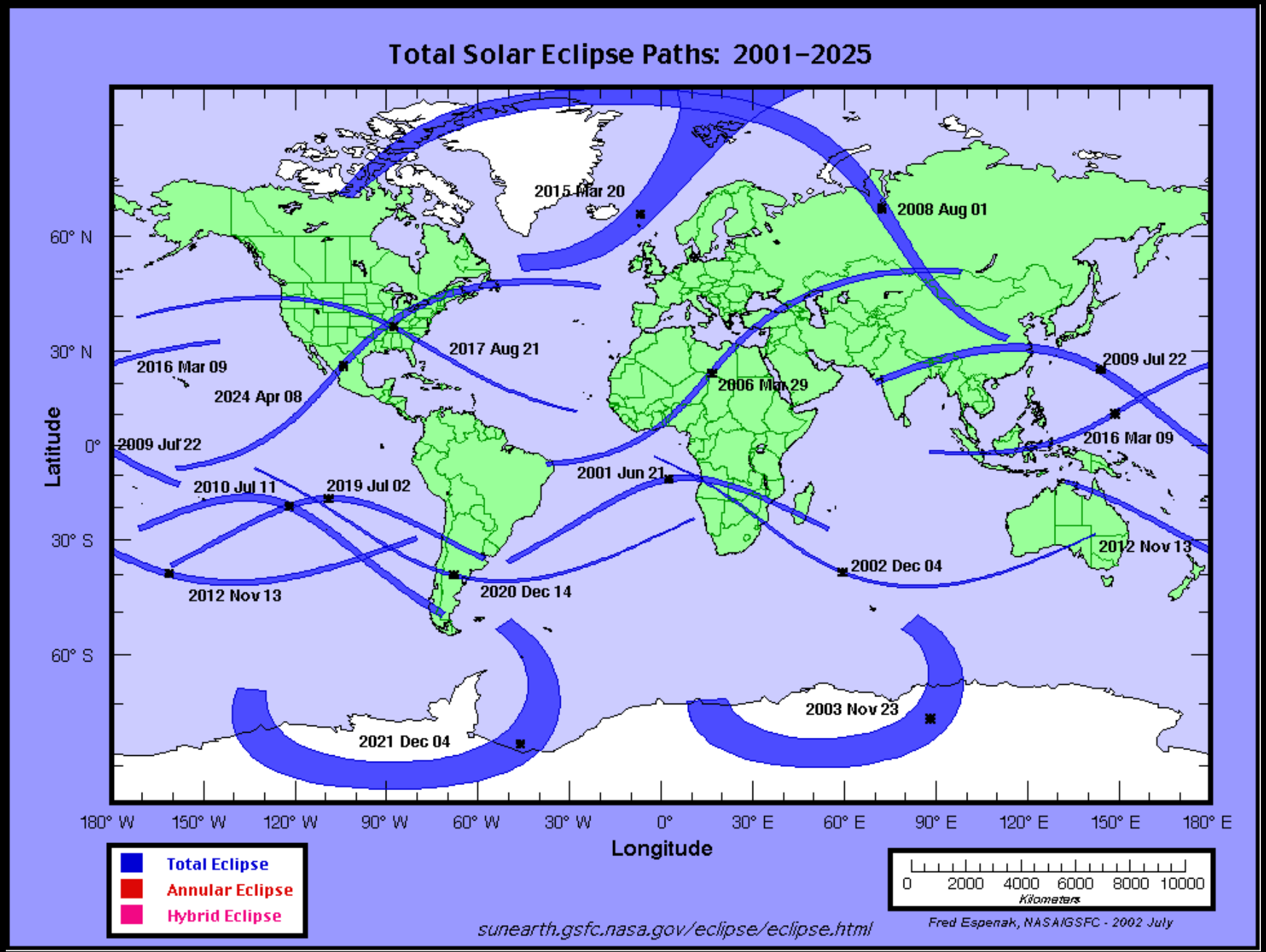



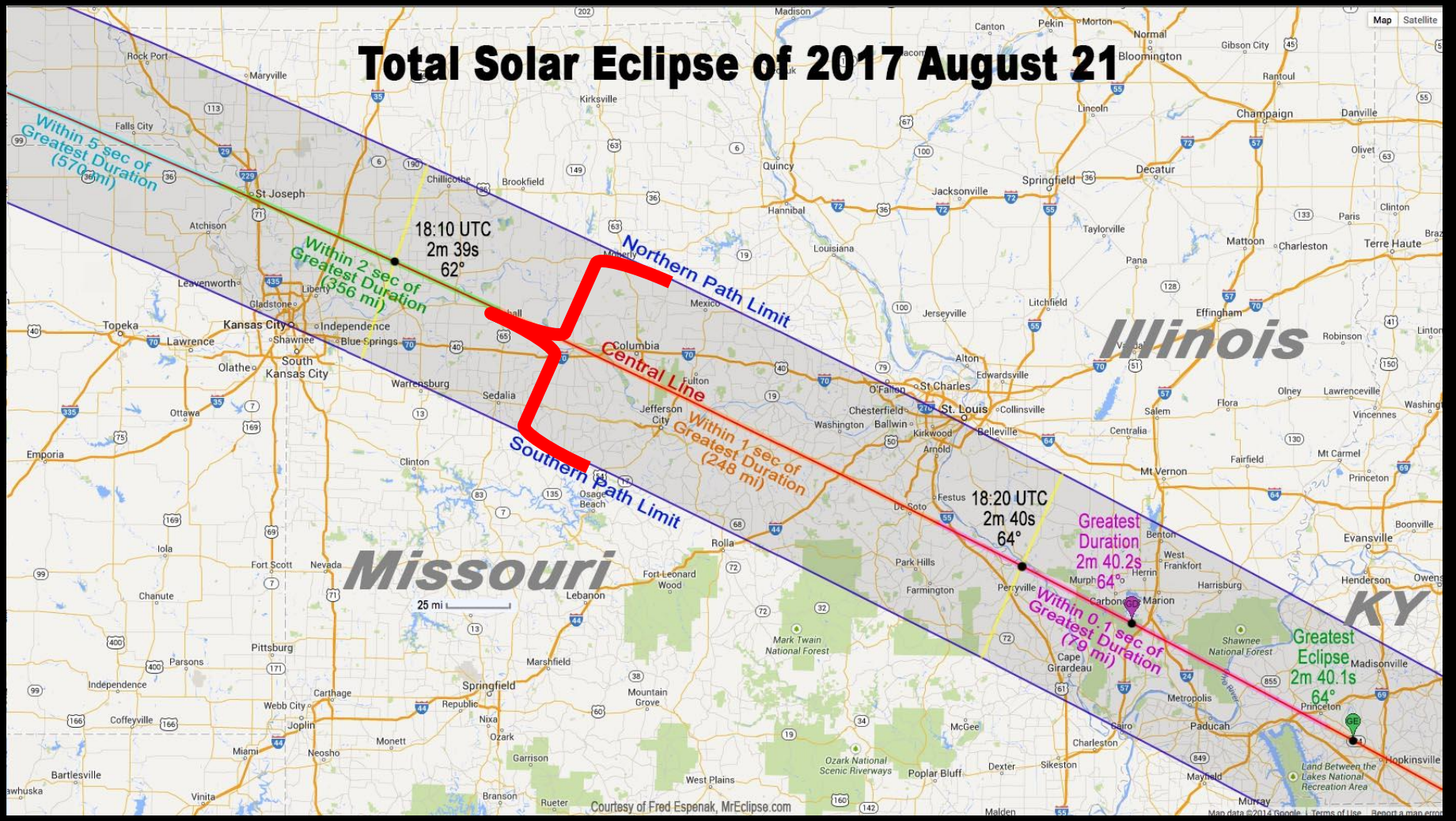
# Lunar Perigee vs Apogee

Image by Jeff Bryant




sunearth.gsfc.nasa.gov/eclipse

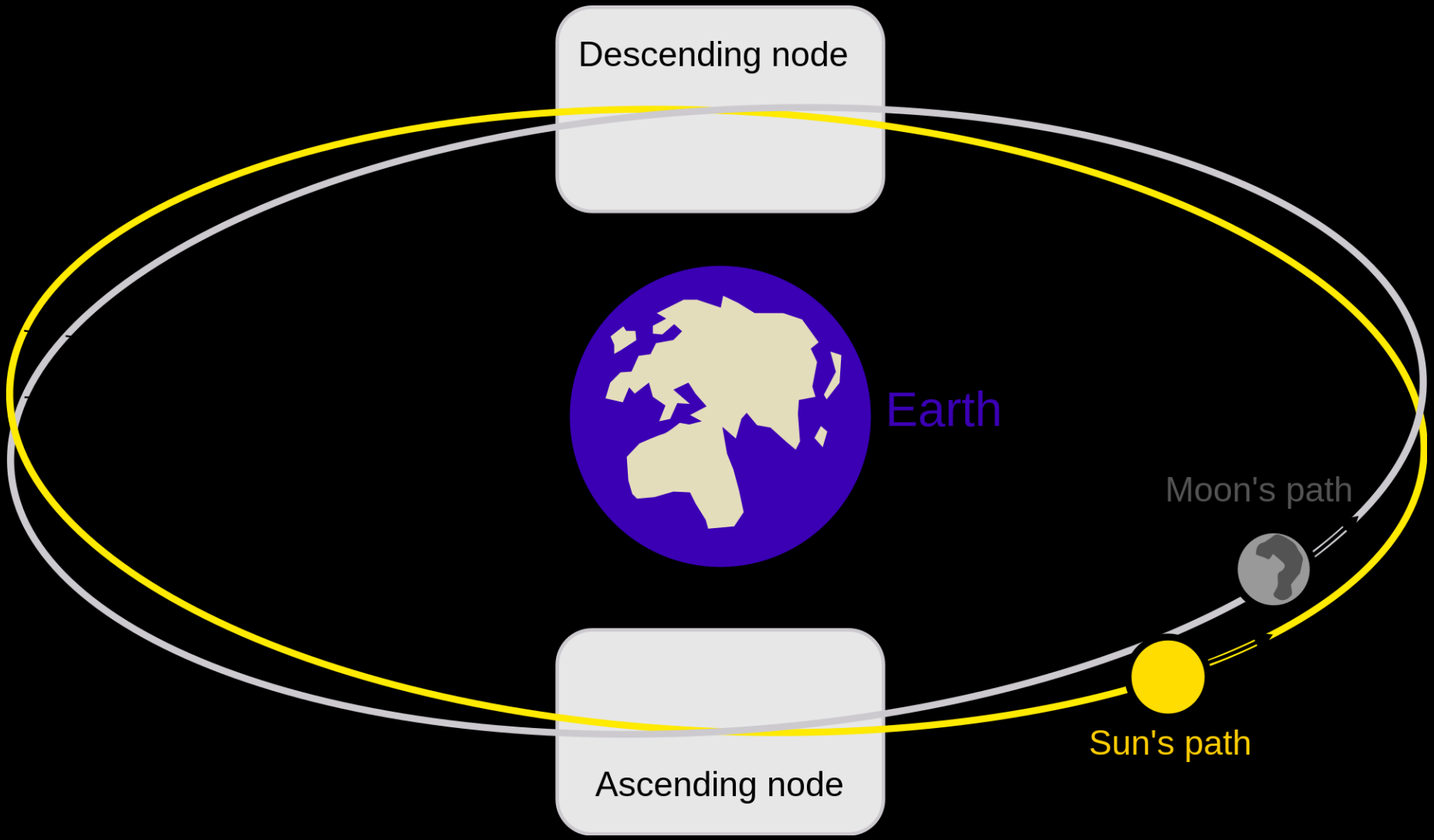

Total Solar Eclipse Paths: 2001–2025
2015 Mar 20
2008 Aug 01
2017 Aug 21
2016 Mar 09
2024 Apr 08
2009 Jul 22
2006 Mar 29
2009 Jul 22
2016 Mar 09
2001 Jun 21
2010 Jul 11
2019 Jul 02
2012 Nov 13
2002 Dec 04
2012 Nov 13
2020 Dec 14
2003 Nov 23
2021 Dec 04
60° N
30° N
0°
30° S
60° S
Latitude
180° W
150° W
120° W
90° W
60° W
30° W
0°
30° E
60° E
90° E
120° E
150° E
180° E
Longitude
Total Eclipse
Annular Eclipse
Hybrid Eclipse
0
2000
4000
6000
8000
10000
Kilometers
sunearth.gsfc.nasa.gov/eclipse/eclipse.html
Fred Espenak, NASA/GSFC - 2002 July




**Shadow width in Illinois = 71 miles, moving 1425 mph!!**

# Regression of nodes

- Where the Moon crosses the ecliptic a bit westward each time
- Due to gravitational pull of other bodies
- Full trip around ecliptic = 18.6 years

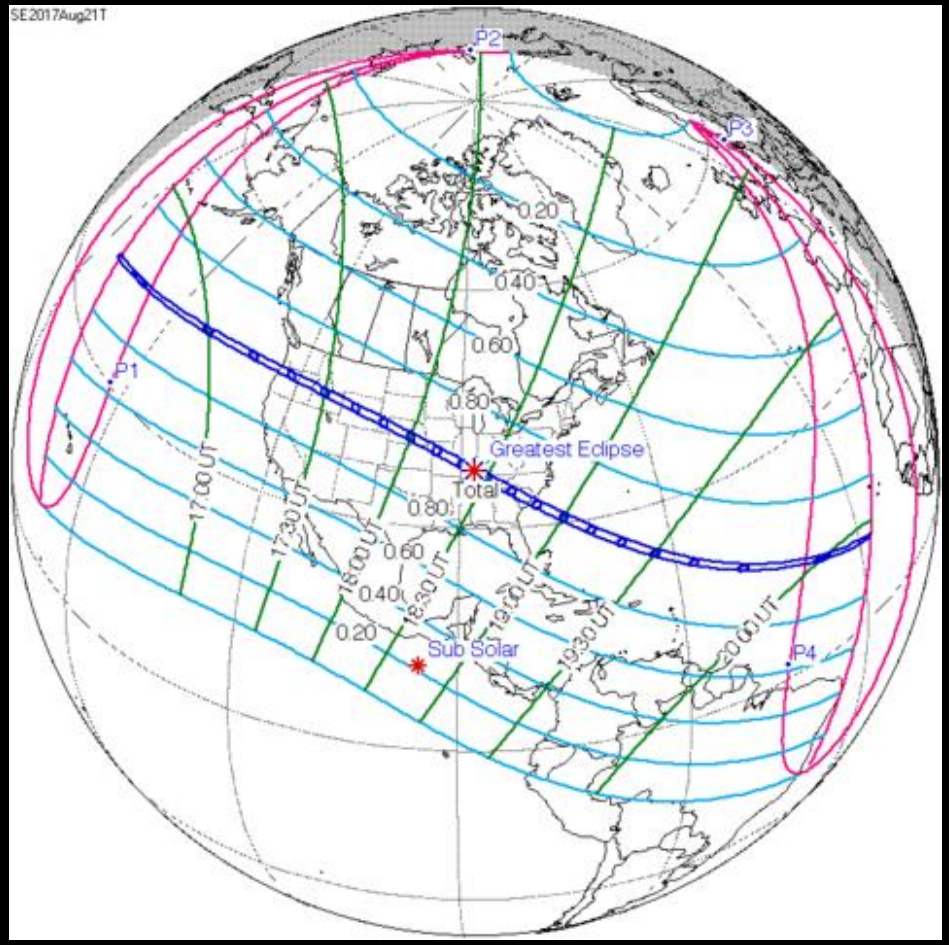

Descending node
Earth
Moon's path
Sun's path
Ascending node

# “Saros Cycle”

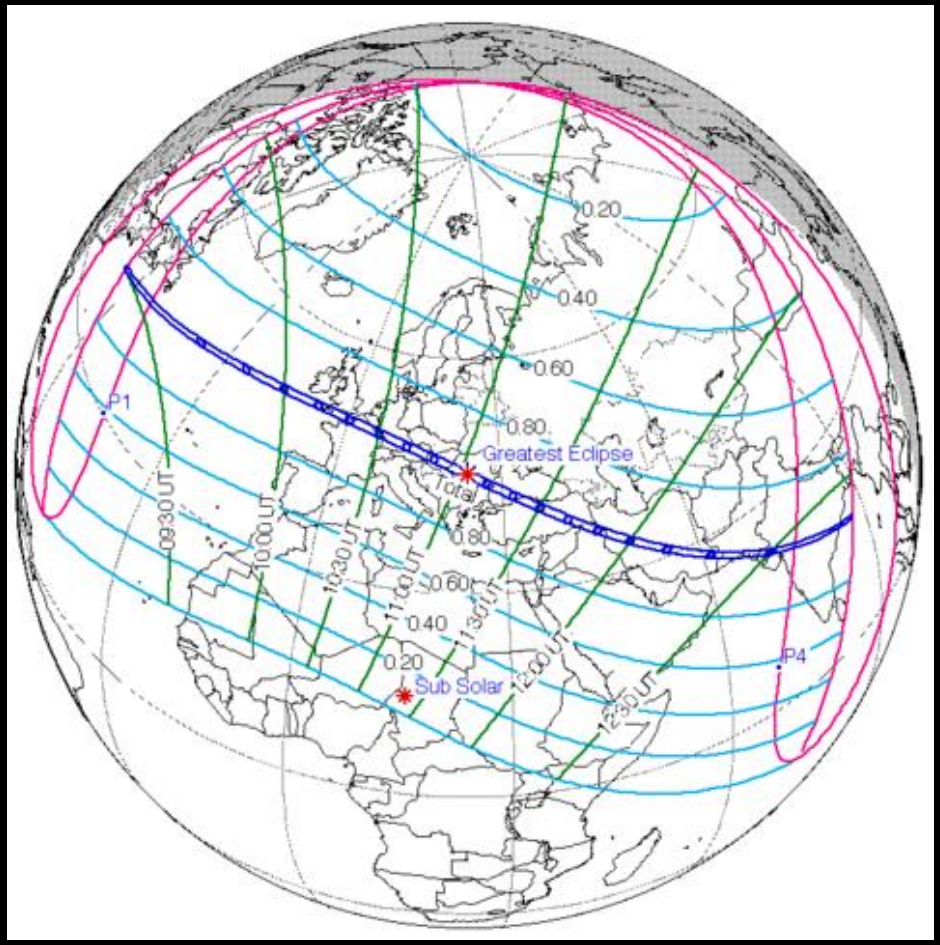
- Exactly 223 synodic months, or
- approximately 6585.3211 days, or 18 years, 10, 11, or 12 days (depending on the number of leap years), *and* 8 hours
- Sun, Moon & Earth return to same geometry
- Applied to eclipses by Hally (1686)
- Three cycles must coincide for an eclipse. . . . .

# 3 “months” . . .

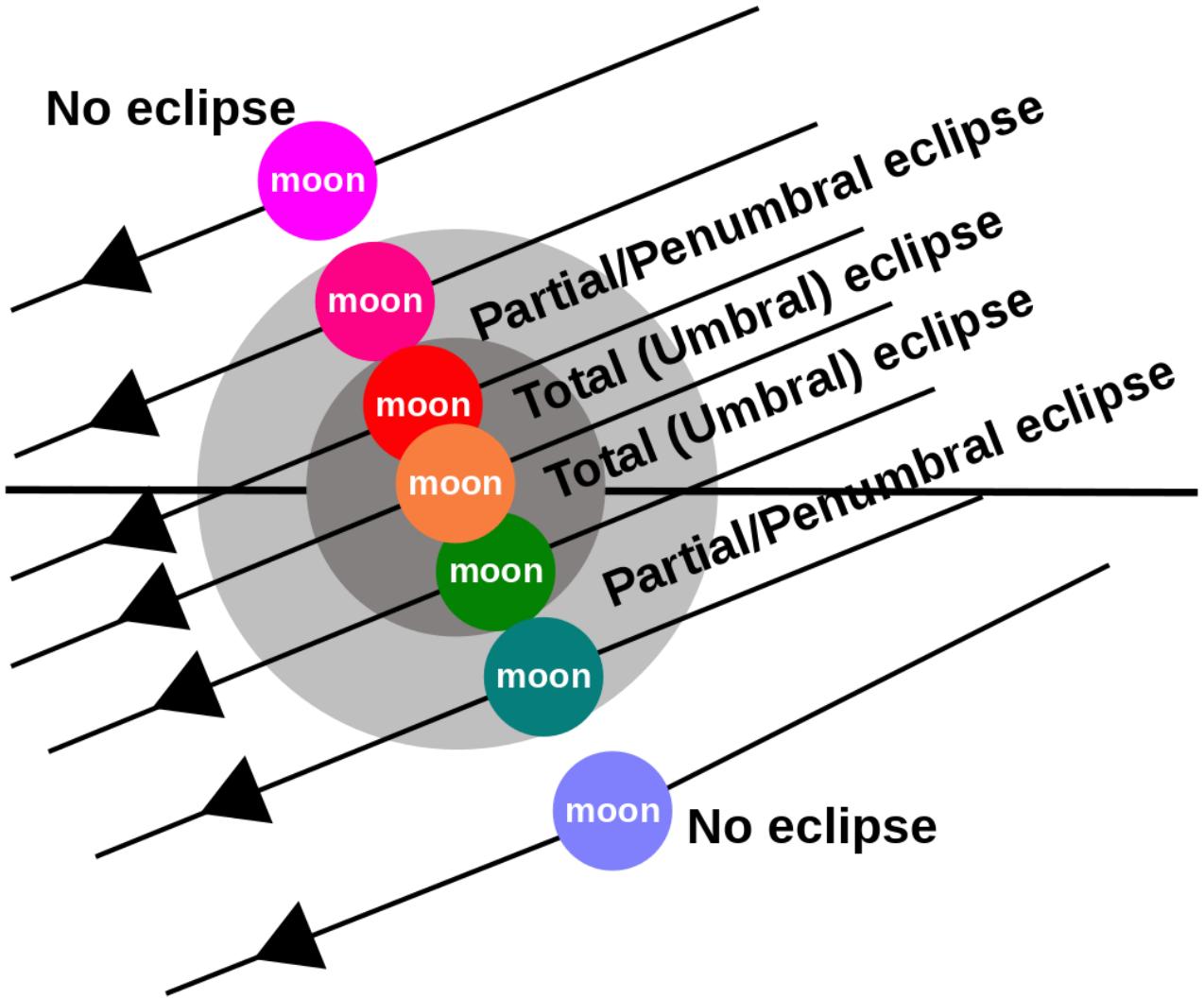
- “Synodic Month” – lunar phases (29.53059 days)
- “Draconian Month” – Moon returns to same node (27.2122 days)
- “Anomalistic Month” – perigee to perigee (27.53455 days)



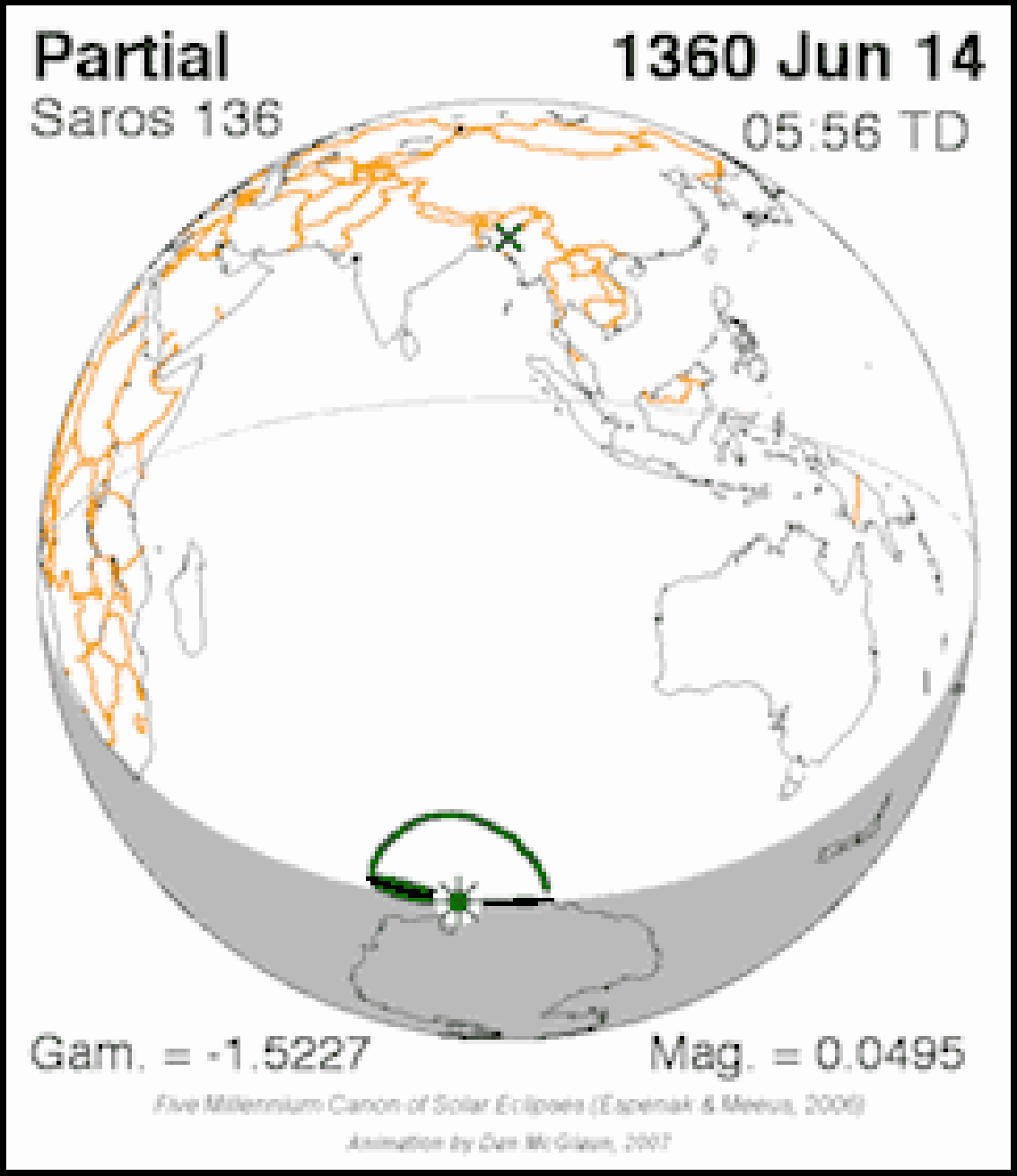

August 21, 2017




August 11, 1999




Descending node lunar eclipse paths


Partial
1360 Jun 14
Saros 136
05:56 TD
Gam. = -1.5227
Mag. = 0.0495
Five Millennium Canon of Solar Eclipses (Espenak & Meeus, 2006)
Animation by Dan McGlaun, 2007

# Do we live in “special times?”

- Moon receding at a rate of 1.5 inches (3.8 cm) each year!
- “Angular Momentum” L = r x m x v = const.
- Max distance reached in 50 billion years!
- *Last total solar eclipse = 600 million years!*

# *Do other planets have eclipses?*

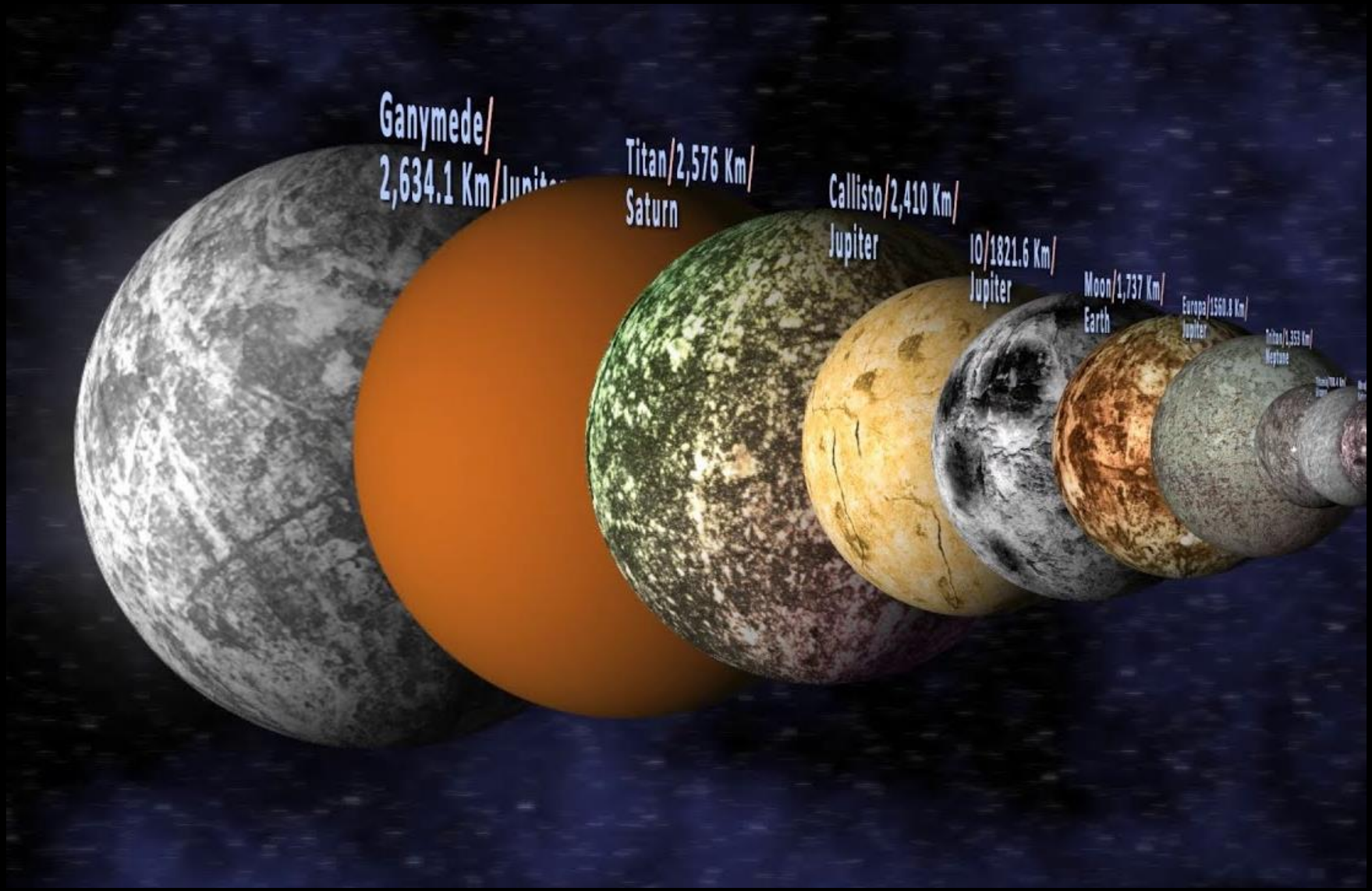
- 2004 – Jupiter from HST

- Phobos from *Curiosity* rover (August 2013)

# A quick inventory . . . .

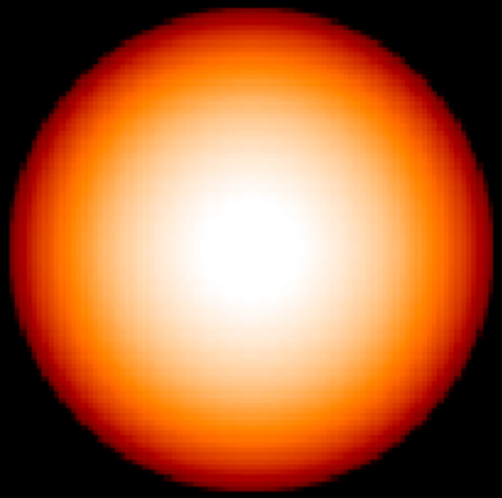

- 8 planets
- 5 dwarf planets
- 1,278,134 asteroids
- 4,724 Kuiper Belt Objects
- 8,007 comets
- 288 planetary moons
- 9 dwarf planet moons
- 378 moons surrounding asteroids
- 119 KBO moons
- 6 objects with rings (4 planets, 1 dwarf)
  - (as of July 8, 2023)

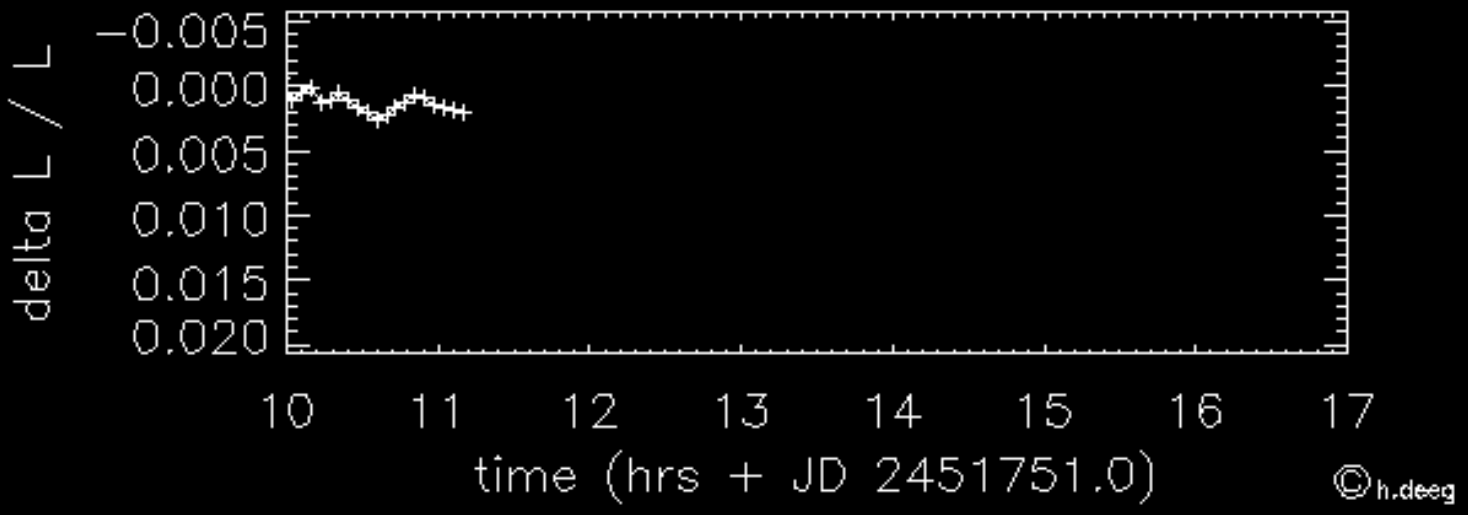
# Moon is 5th largest in solar system



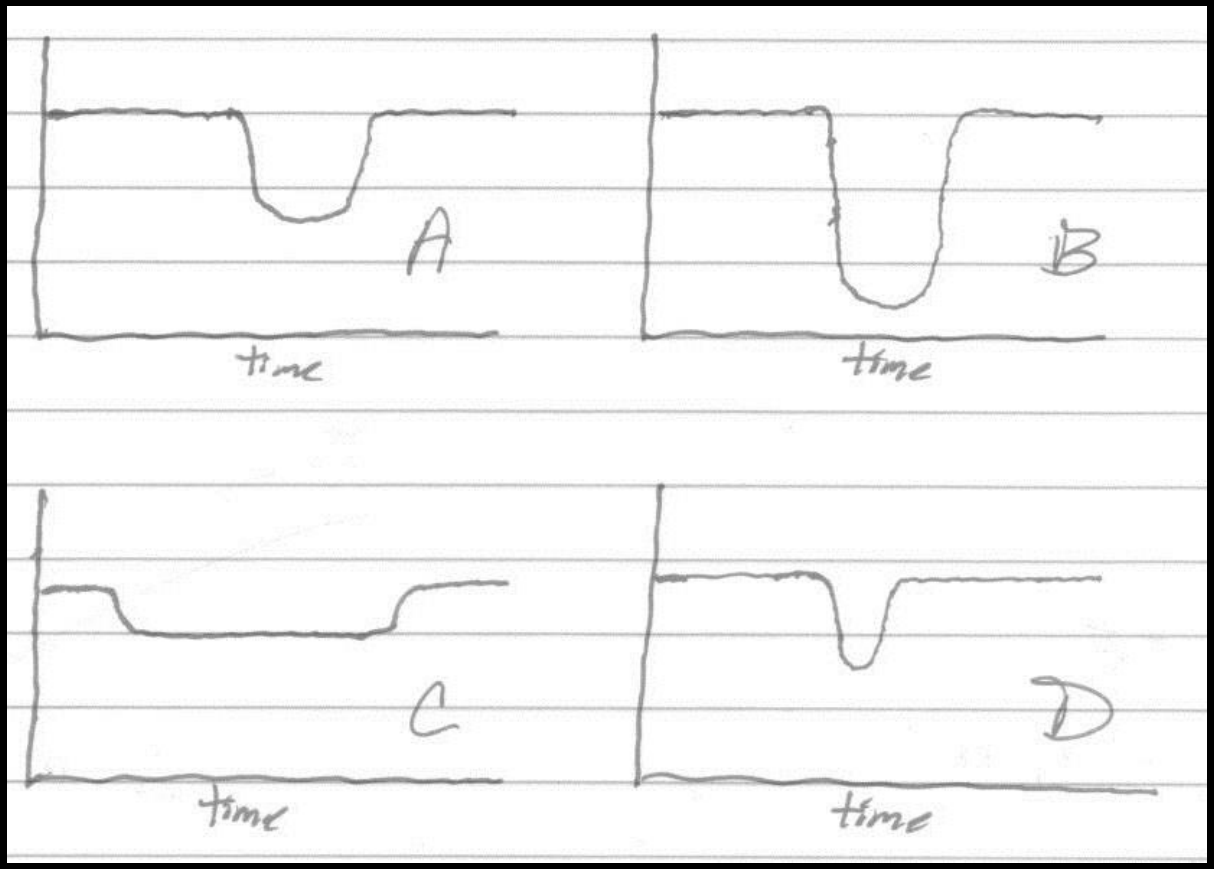
*“What about other Suns?”*

# Transits



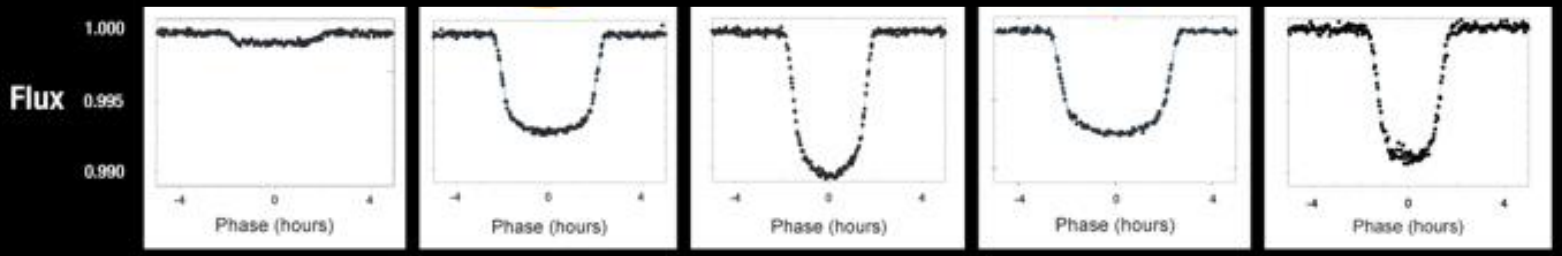

delta L / L
−0.005
0.000
0.005
0.010
0.015
0.020
10
11
12
13
14
15
16
17
time (hrs + JD 2451751.0)
©h.deeg

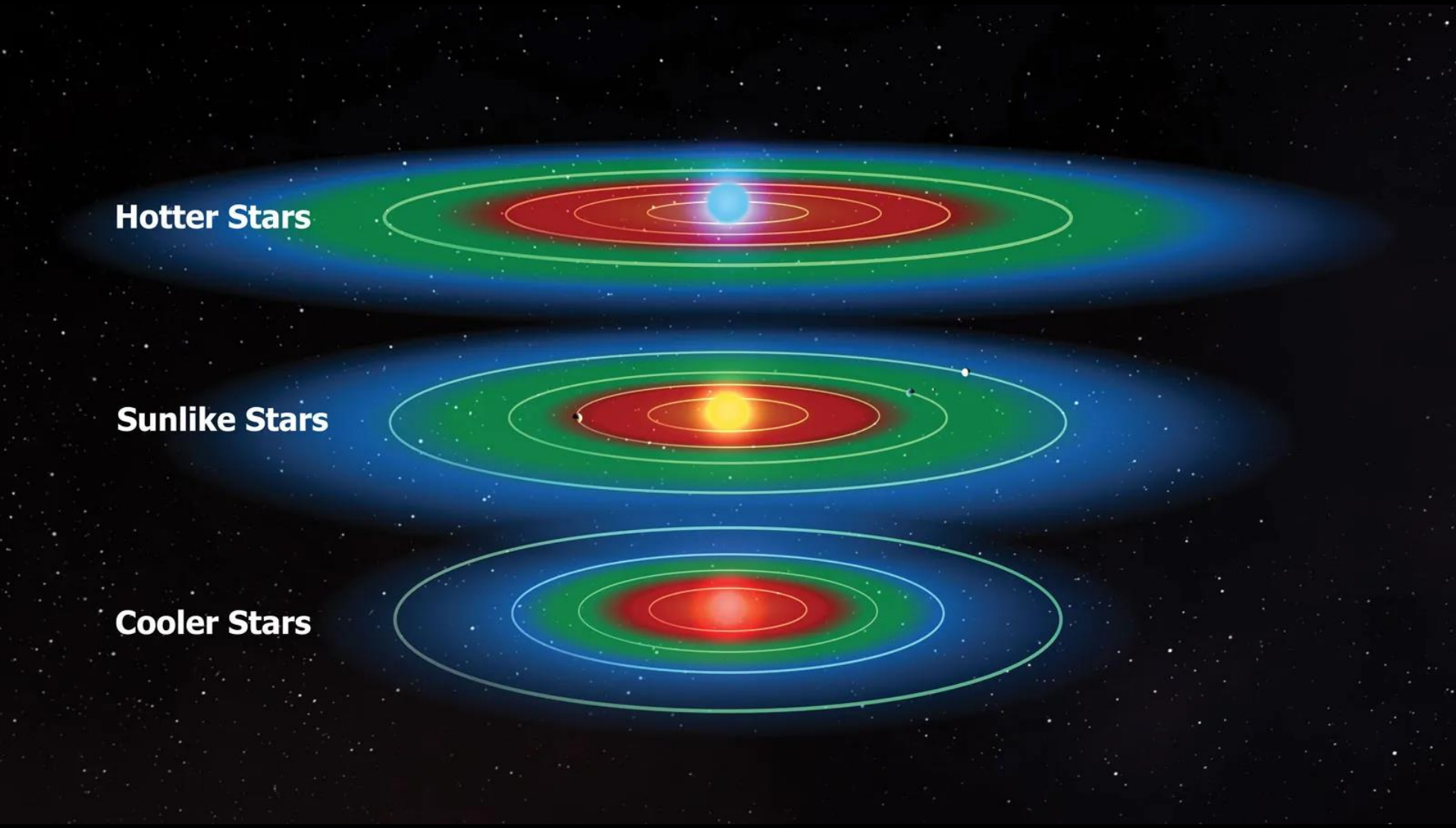
# So . . .how does this work?




1. **Which star system has the largest planet?**
2. **Which planet moves the fastest?**
3. **Which planet is farthest from the star?**

# Transit Light Curves

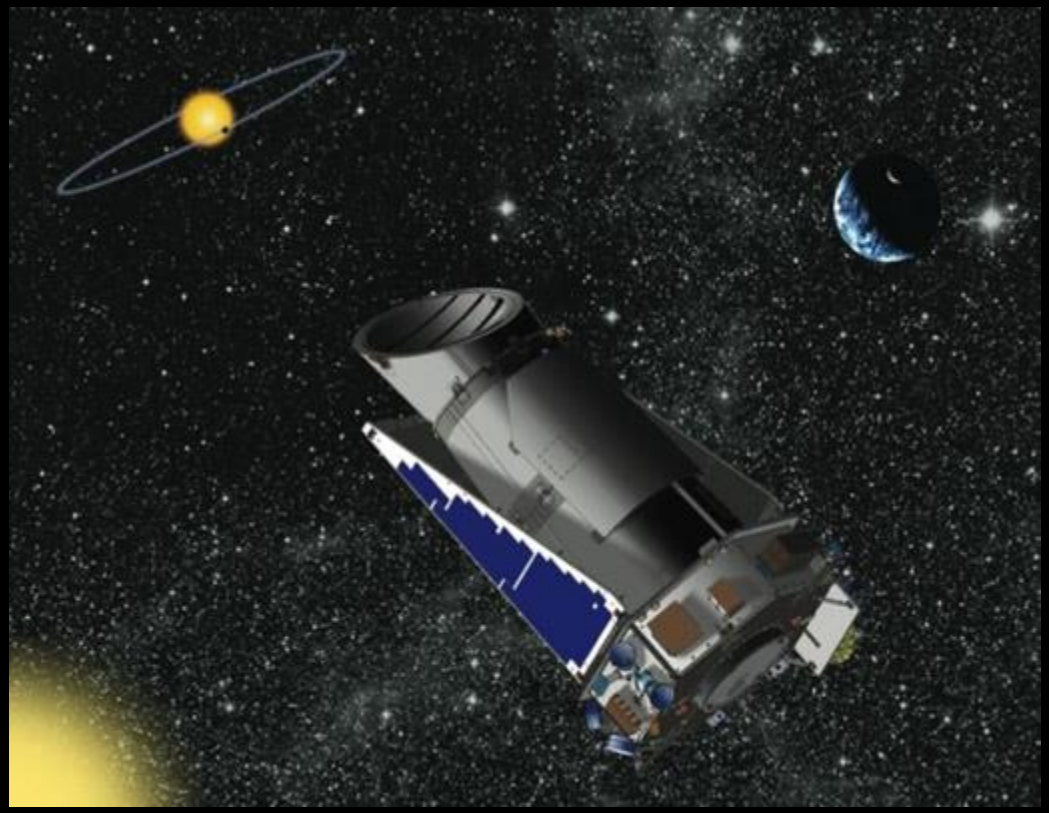


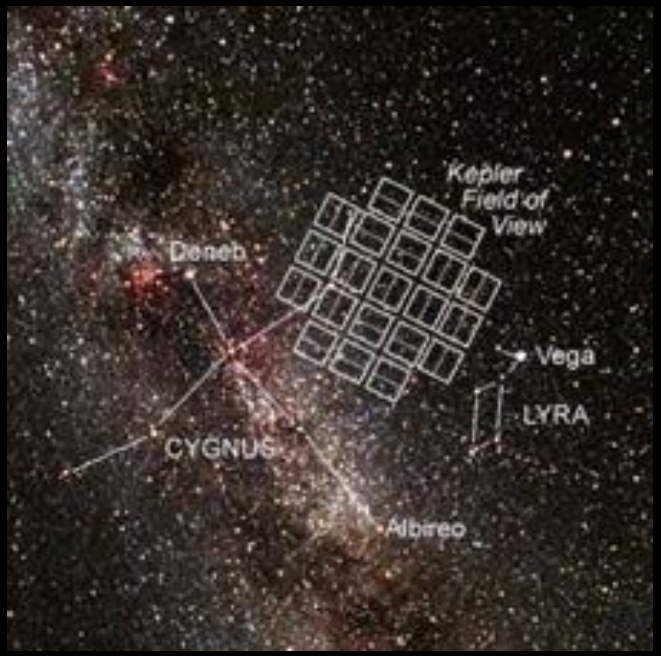

Hotter Stars
Sunlike Stars
Cooler Stars

Kepler 22b  (???)

# Kepler

## A Search for Terrestrial Planets






2009

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# Catalog

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Status | Detection | Filter

Showing 5502 planets / 4063 planetary systems / 877 multiple planet systems

All fields

Show 100 entries

Planet Search

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| Planet | Mass ($M_{Jup}$) | Radius ($R_{Jup}$) | Period (day) | *a* (AU) | *e* | *i* (deg) | Ang. dist. (arcsec) | Discovery | Update |
|---|---|---|---|---|---|---|---|---|---|
| 55 Cnc e | 0.02703 | 0.1737 | 0.7365478 | 0.015439 | 0.028 | 90.36 | 0.001264 | 2004 | 2023-08-22 |
| HD 175679 b | 59.9 | — | 1366 | 3.38 | 0.38 | — | — | 2012 | 2023-08-21 |
| TYC 3318-01333-1 b | — | — | 562 | 1.414 | 0.1 | — | — | 2018 | 2023-08-21 |
| TOI-561 b | 0.00705 | 0.1267 | 0.4465688 | 0.0106 | 0 | 88.12 | — | 2020 | 2023-08-21 |
| Kepler-1660 (AB) b | 4.89 | — | 239.48 | — | 0.055 | 84.7 | — | 2017 | 2023-08-21 |
| HD 140901 c | — | — | 7417.5 | 7.421 | 0.6 | — | — | — | 2023-08-18 |
| HD 140901 b | — | — | 9.02378 | 0.085 | 0.47 | — | — | 2022 | 2023-08-18 |
| HD 16905 b | 9.065 | — | 6707.49126 | 6.443 | 0.665 | 19.657 | — | 2022 | 2023-08-17 |
| OGLE-2019-BLG-0825 b | 50 | — | — | 0.06 | — | — | — | 2023 | 2023-08-17 |

*Questions?*