



How Eclipses Occur, and the 2017 Great American Solar Eclipse

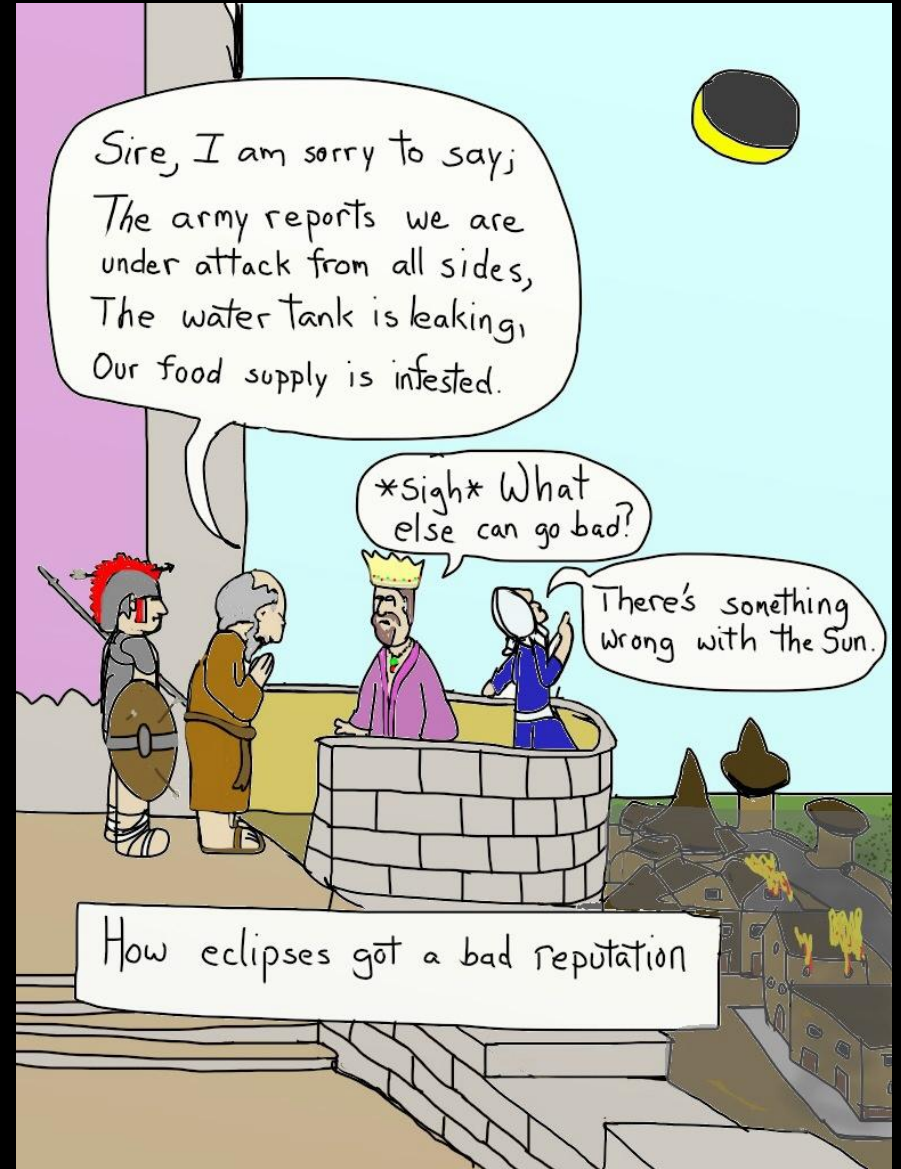
Dr. Bill Blair

JHU Quarknet Presentation

July 25, 2017

(with thanks to the STScI Office of Public Outreach for some of the graphics)

Eclipses through History...

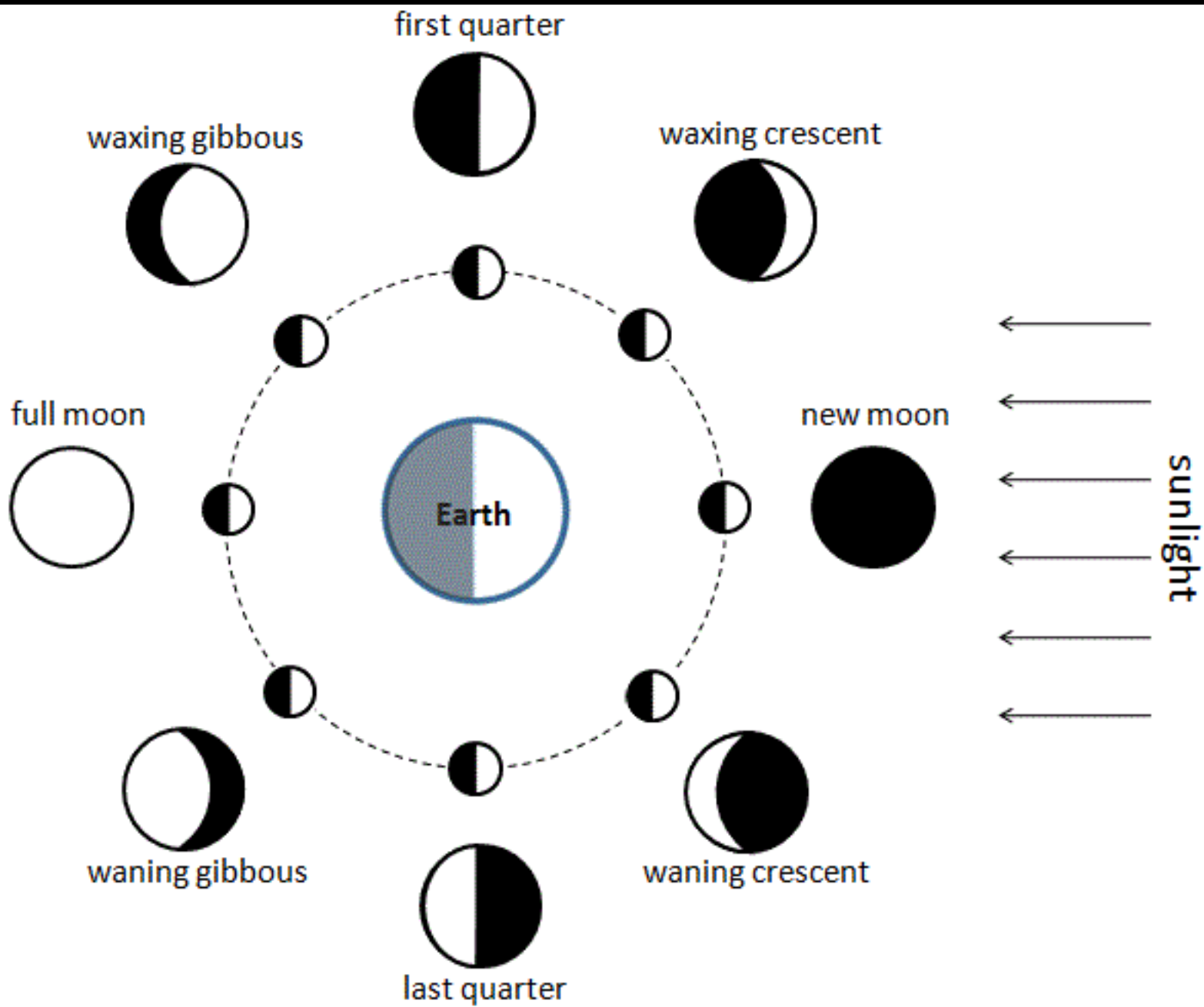




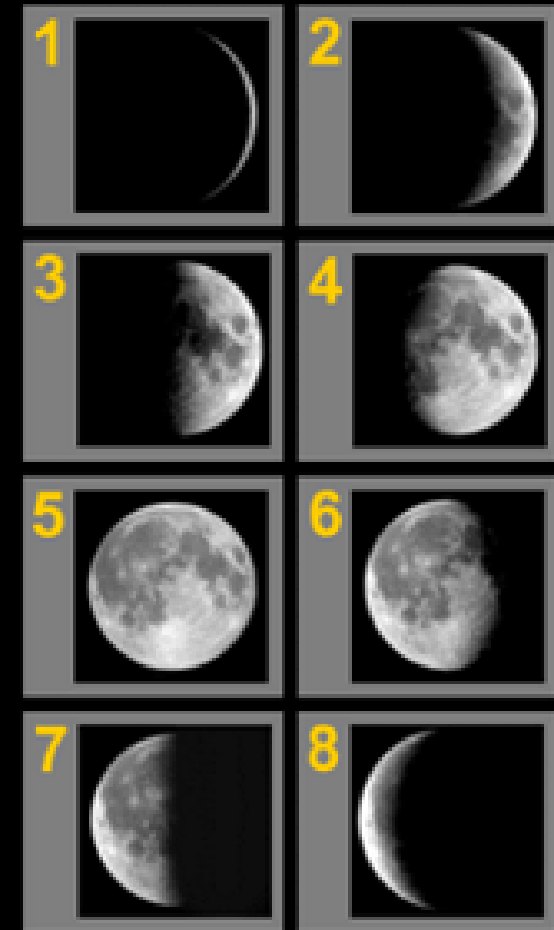
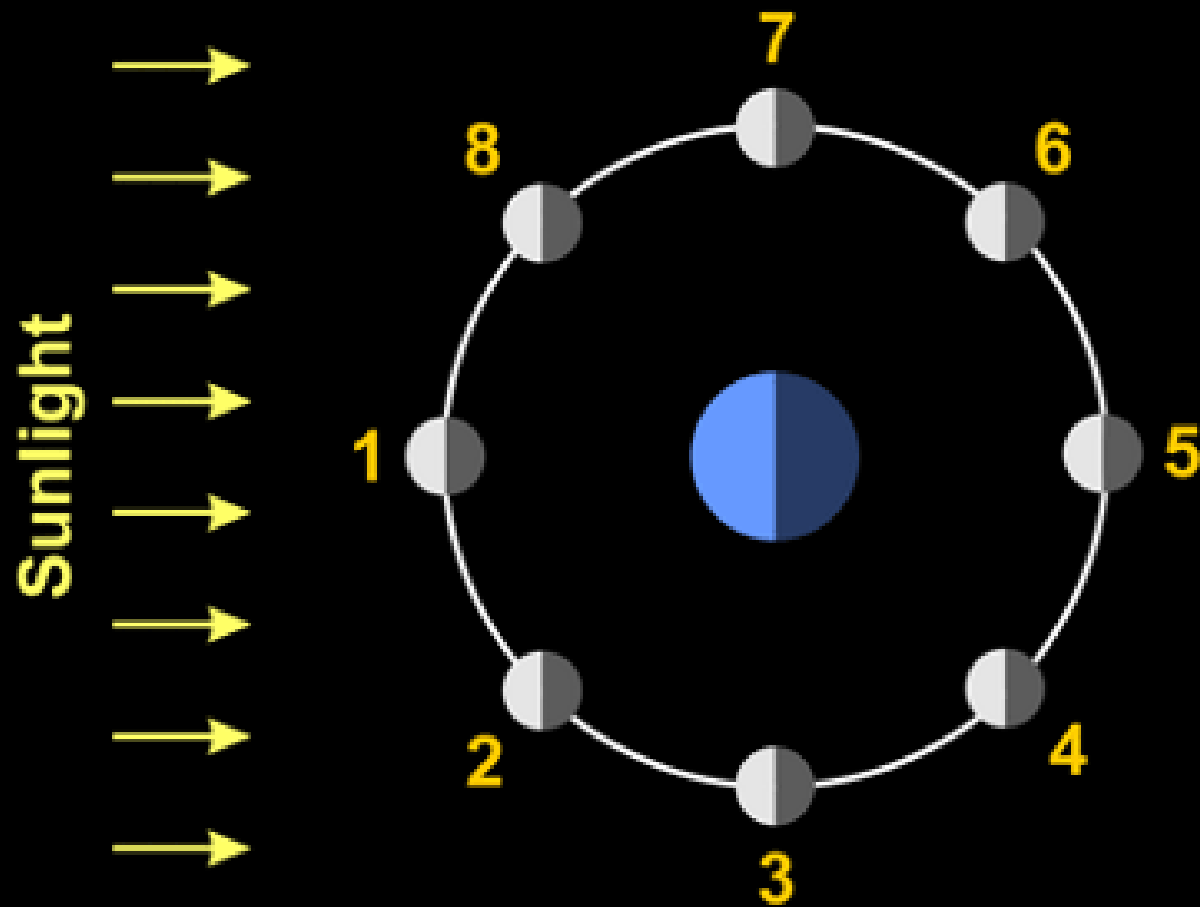
Moon Phases and Orbit



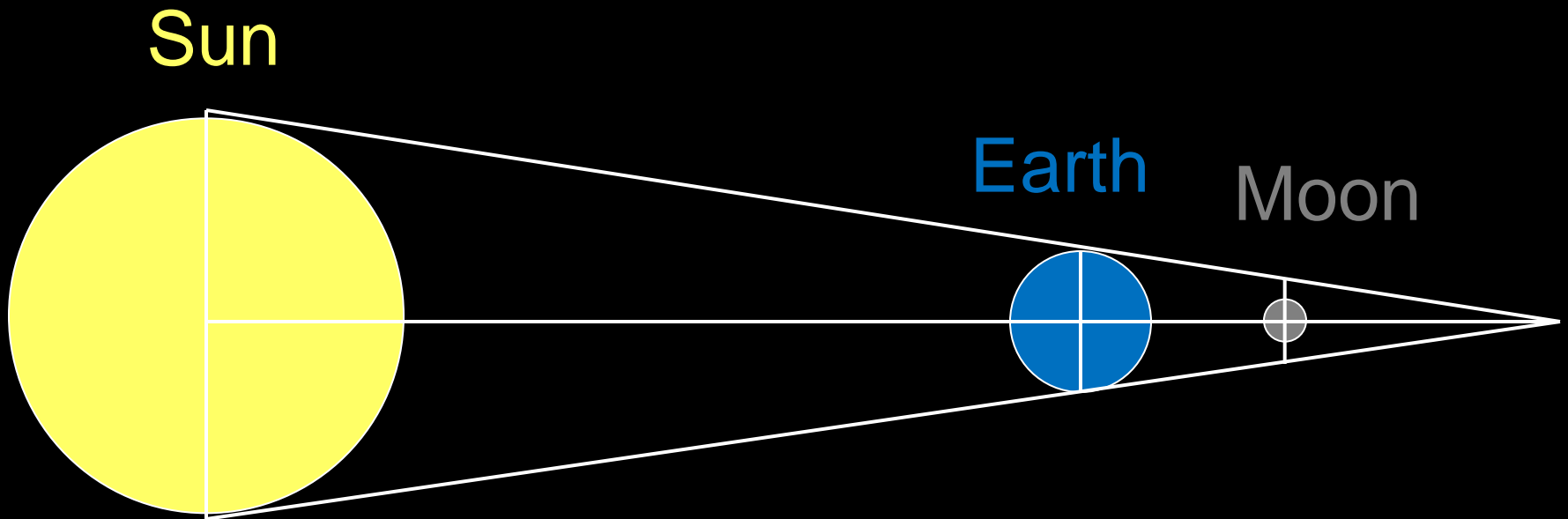
Synodic Month = 29.53059 days



Lunar Phases and Geometry



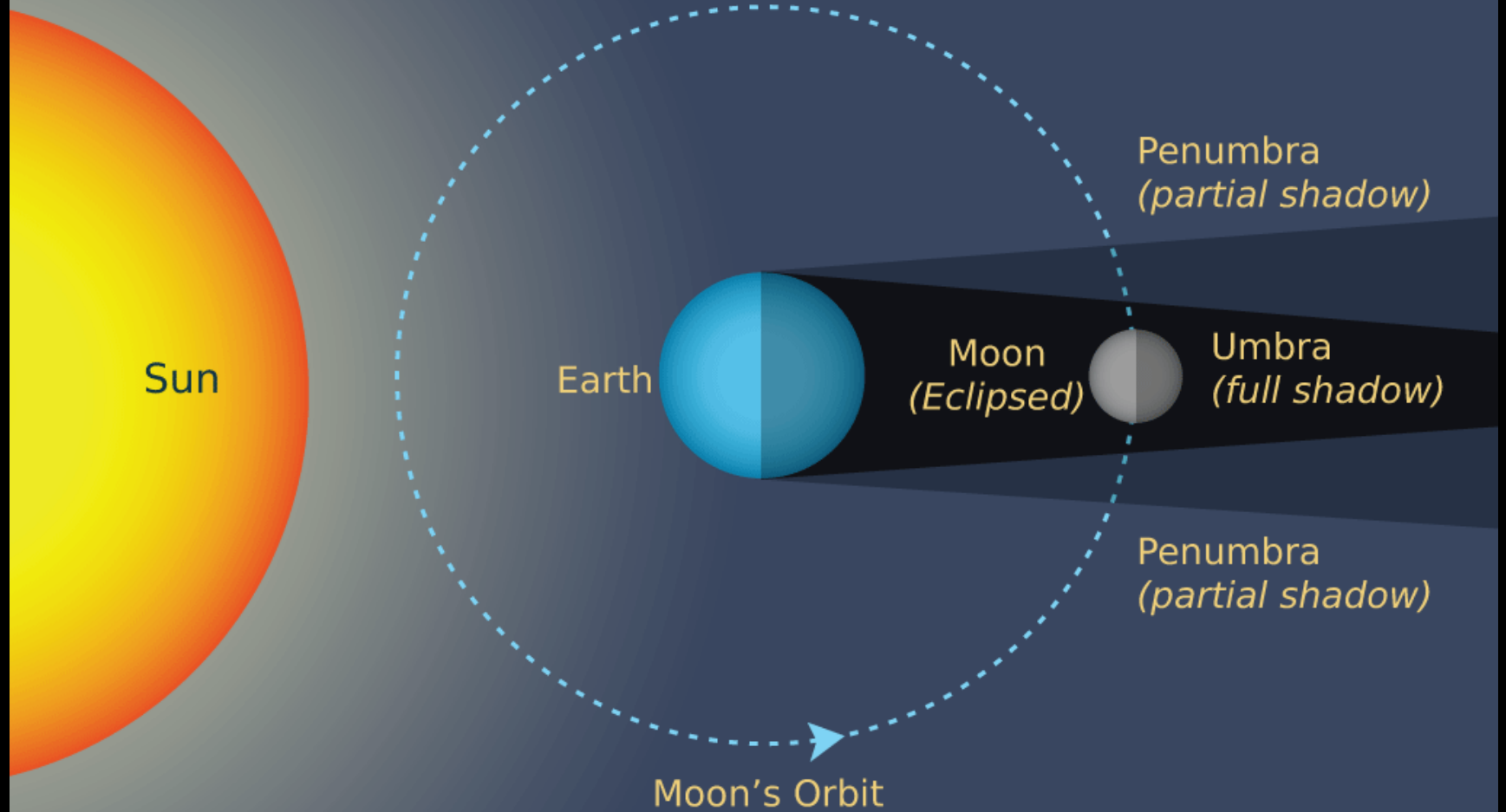
Lunar Eclipse



Approx. Relative Size of Earth and Moon: Moon fits in earth's shadow with room to spare!

Anatomy of a Lunar Eclipse

(Not to scale)



Lunar eclipse – visible from anywhere on the night-side of earth



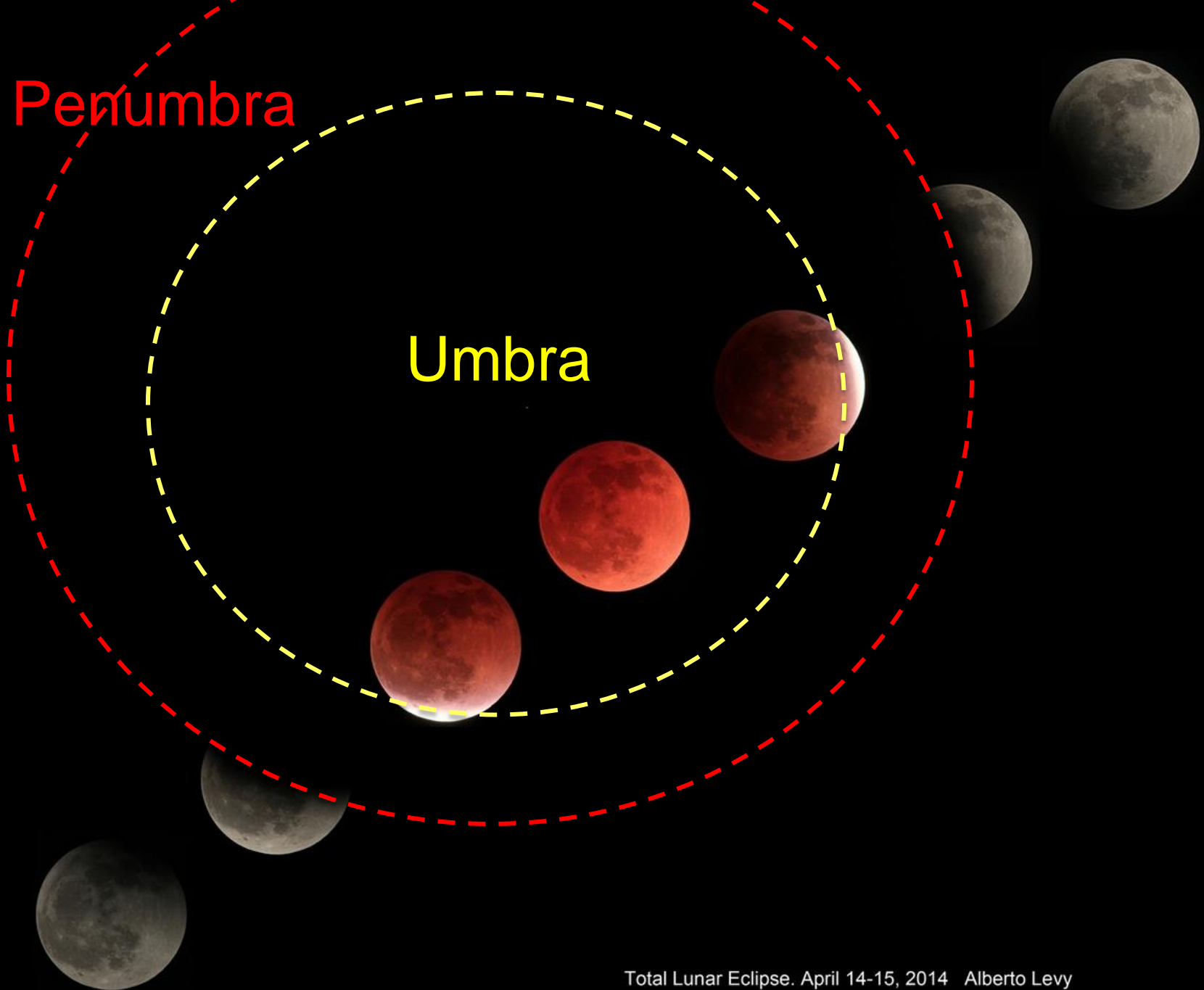
Lunar Eclipse Time Series



Total Lunar Eclipse. April 14-15, 2014 Alberto Levy

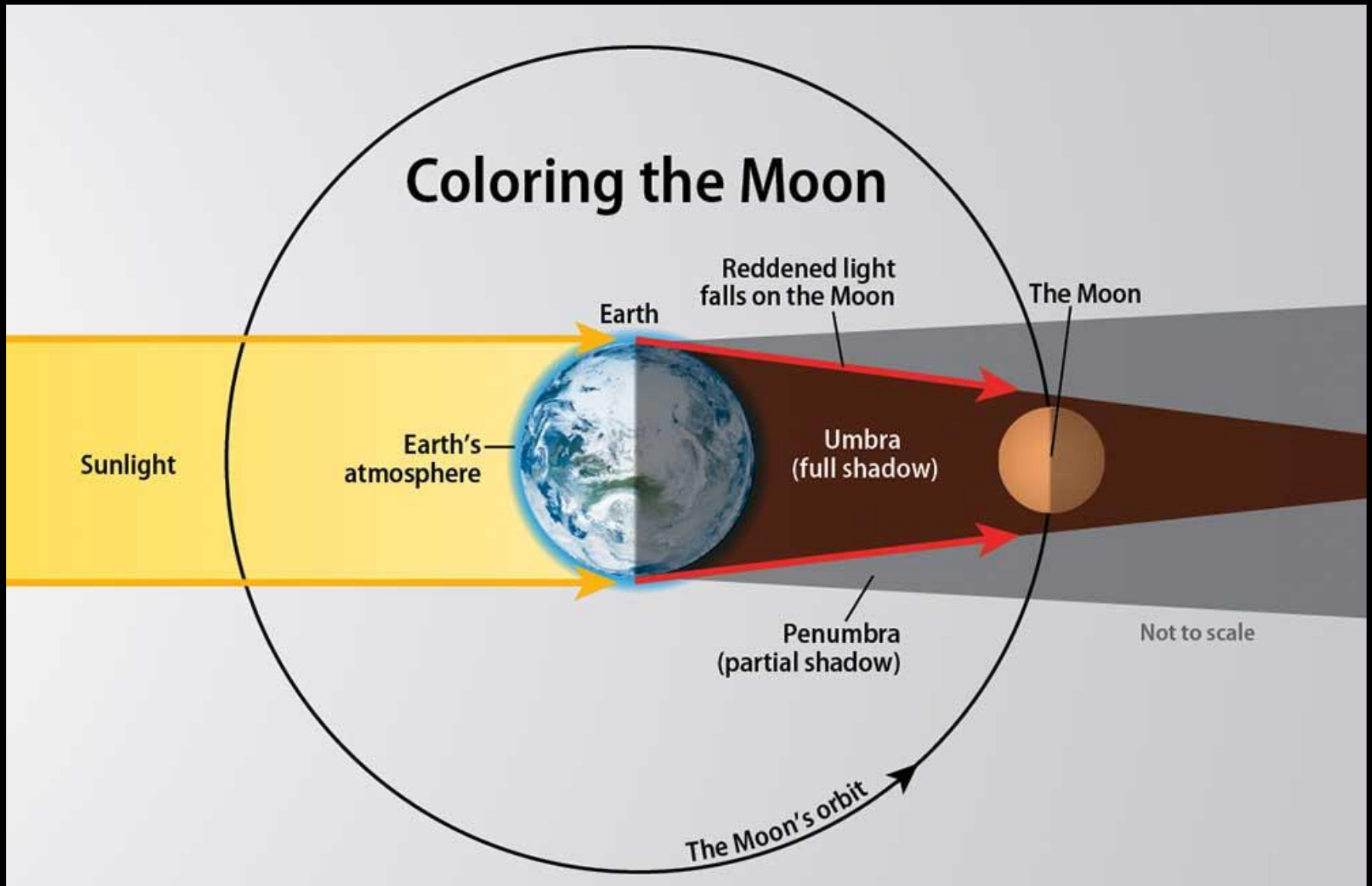
Penumbra

Umbra

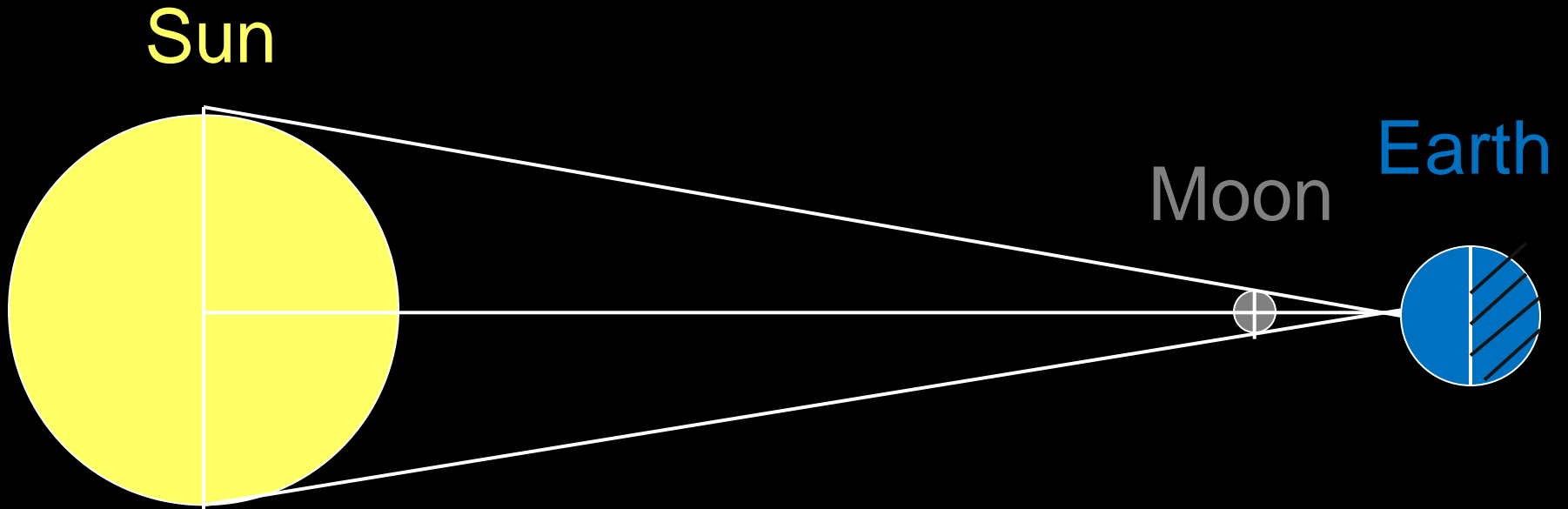


Why is the moon red in Lunar Eclipse?

Coloring the Moon



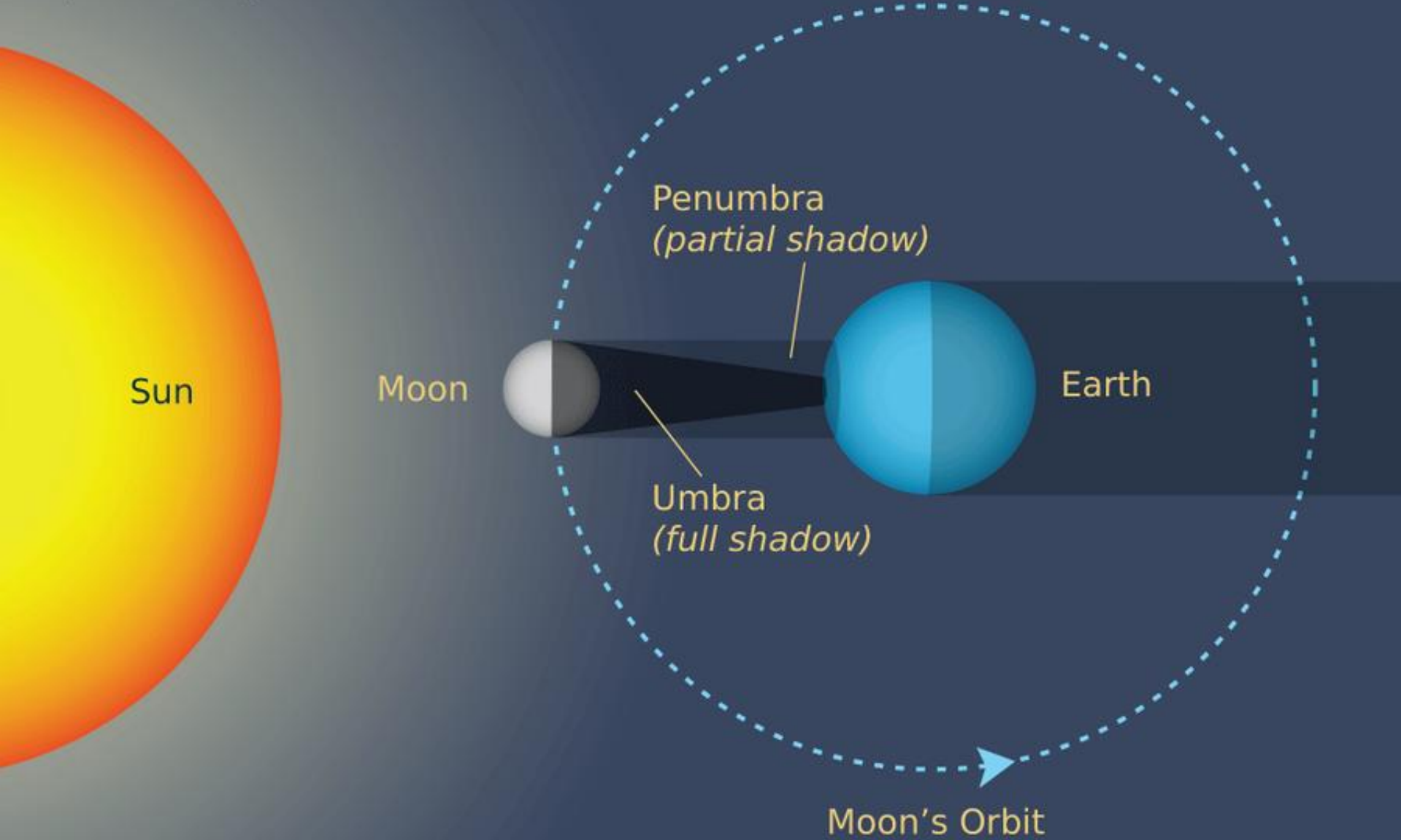
Solar Eclipse



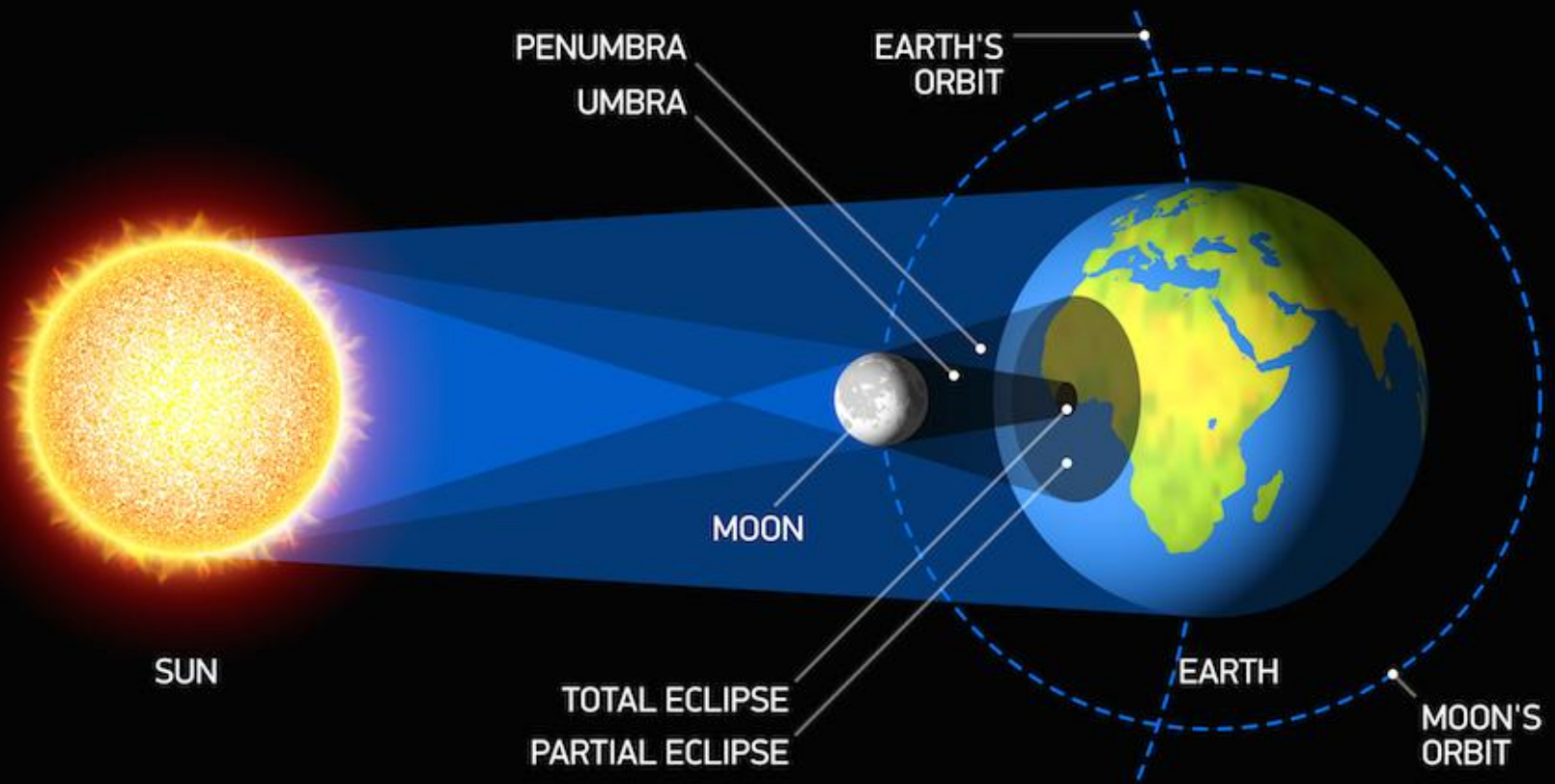
Angular Size of Sun and Moon are nearly the same! (Only a small portion of the sunlit side of earth can see, however.)

Anatomy of a Solar Eclipse

(Not to scale)



This is the geometry...



...but of course not to scale!



Earth's diameter (8000 miles) is about 4 times the Moon's diameter (2200 miles)

The Moon is located about 240,000 miles
(30 Earth diameters) away.



(Now think about the shadows needed to
cause eclipses!)

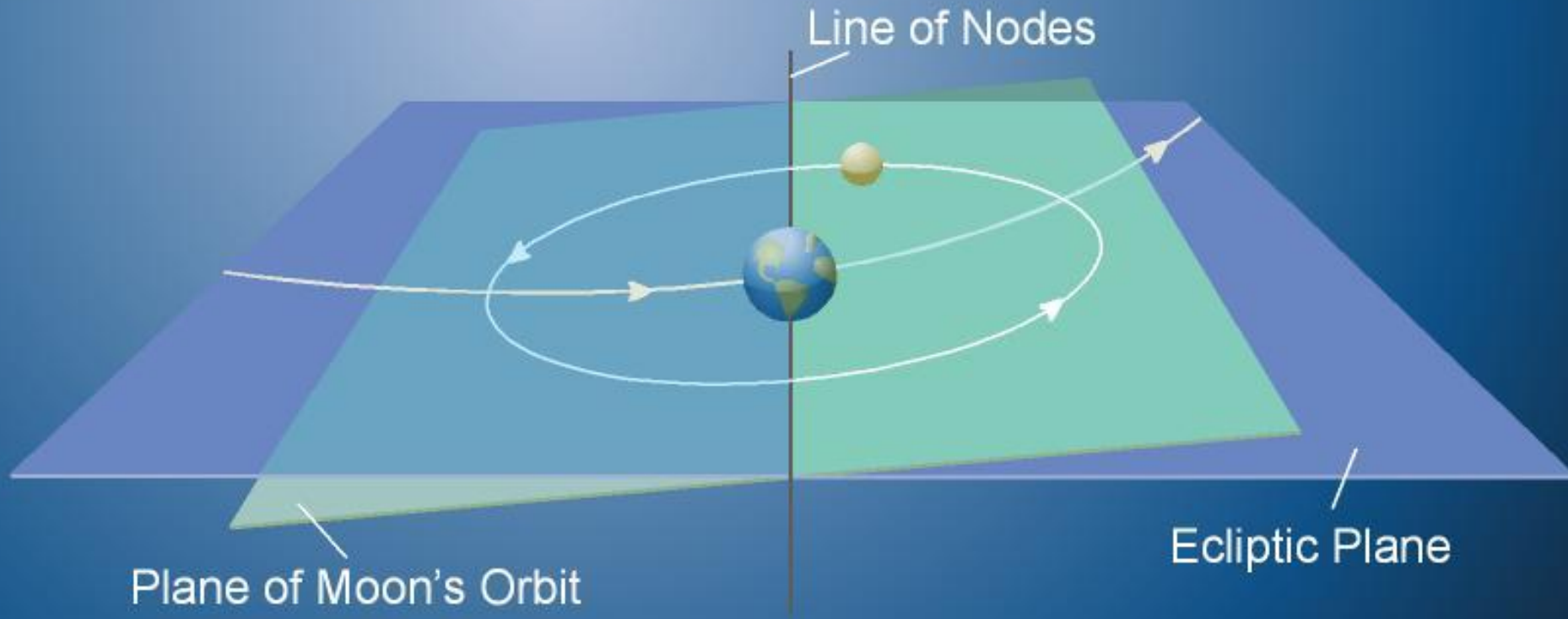
(Yardstick demo)

(sun)

Why Not Eclipses Every Month?

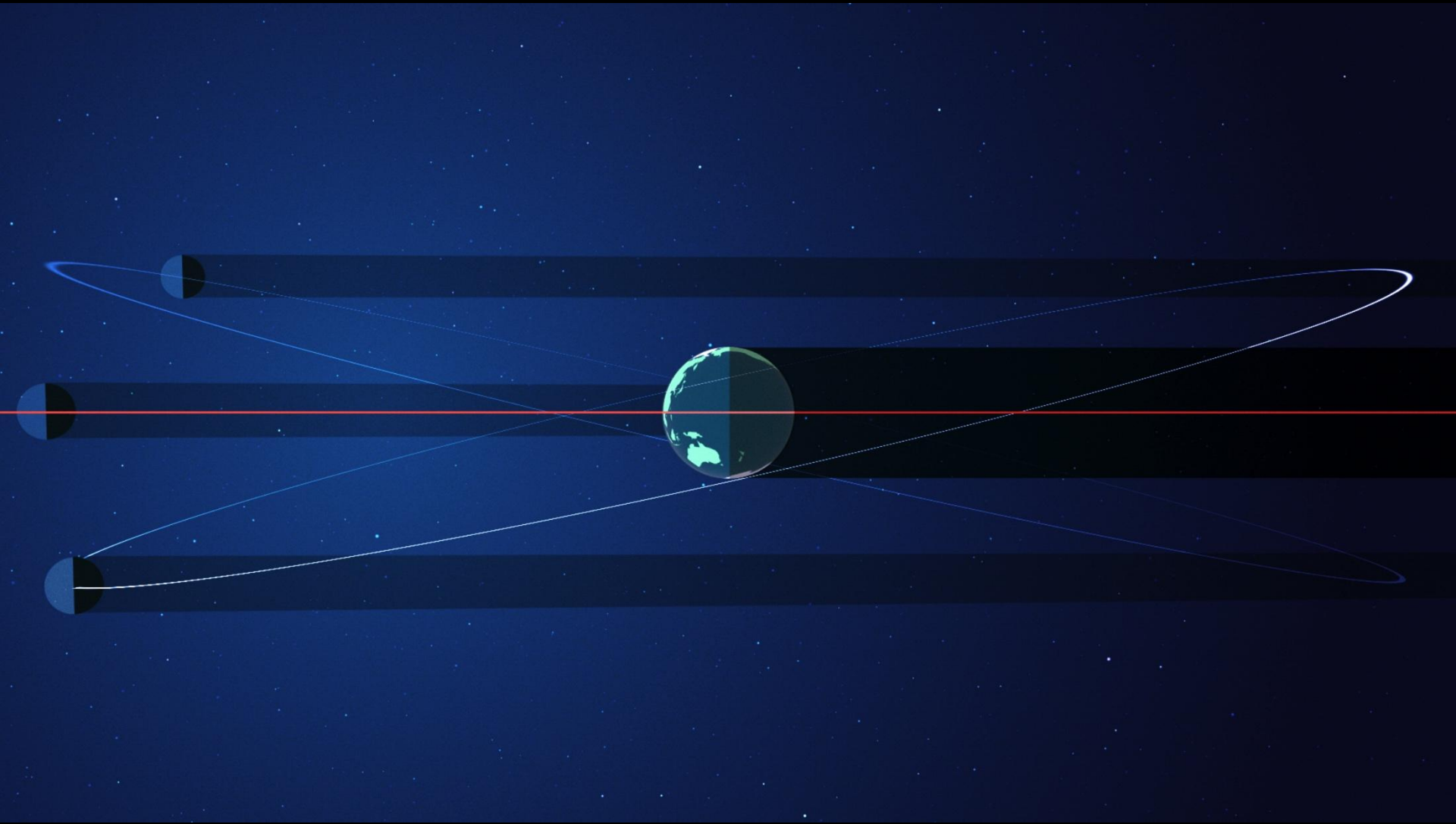
- Eclipse Ingredients
 - Moon Phase
 - Full moon (lunar) or new moon (solar)
 - Orbital plane alignment
 - Moon crossing Earth-Sun plane
 - Earth-Moon Distance (apogee, perigee, or inbetween)
 - Affects apparent (angular) size of moon

Moon's orbital plane is tipped $\sim 5^\circ$ to Earth's

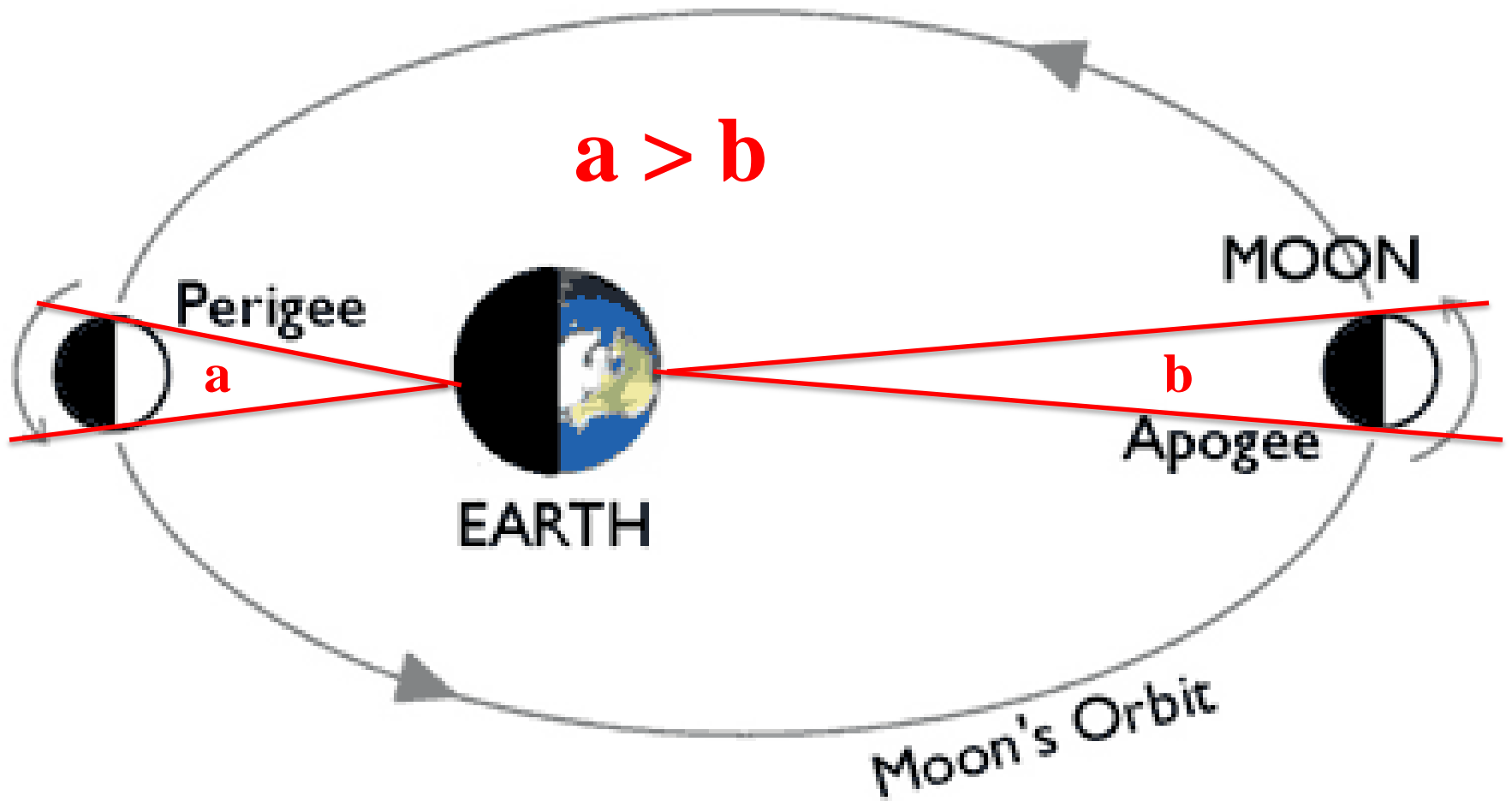


Need full or new moon to occur along the intersection of the orbit planes for eclipses!

Otherwise the shadows miss their targets!

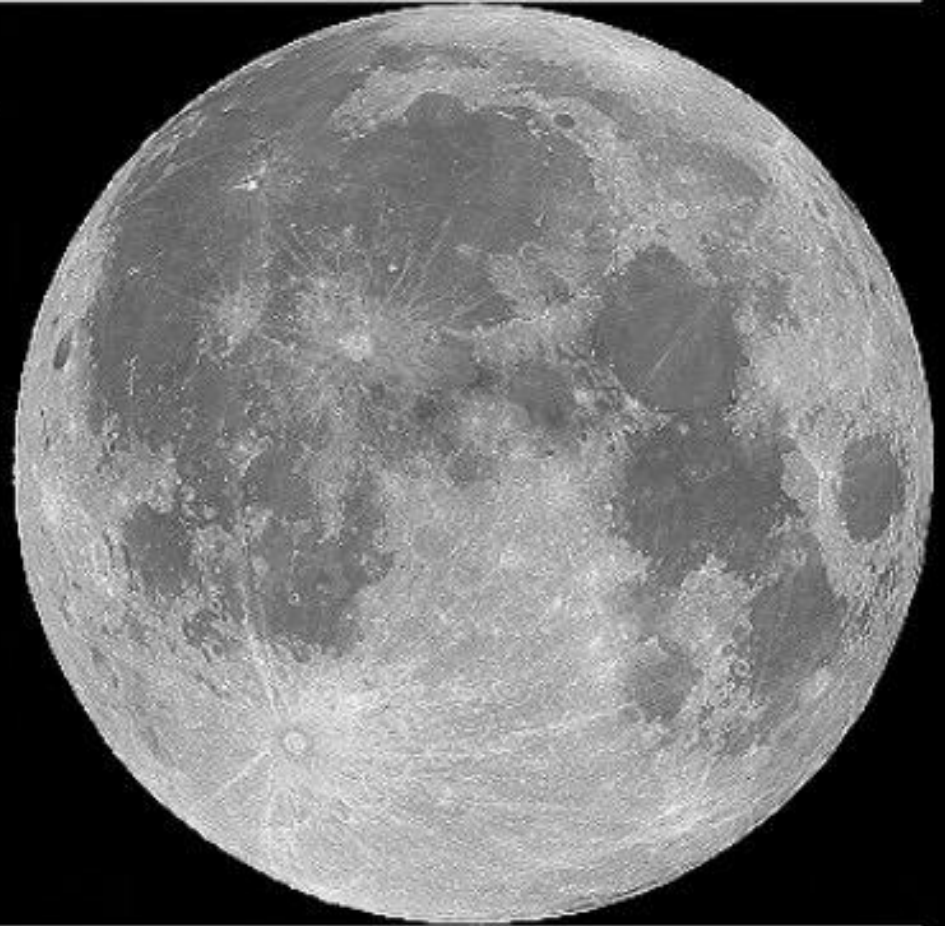


Moon's orbit is slightly elliptical, so its angular size changes during its orbit.



Apogee

Perigee



2006-02-13
405,978 km
29.87 arc-mins

2006-09-08
357,210 km
33.89 arc-mins

Anthony Ayiomamitis



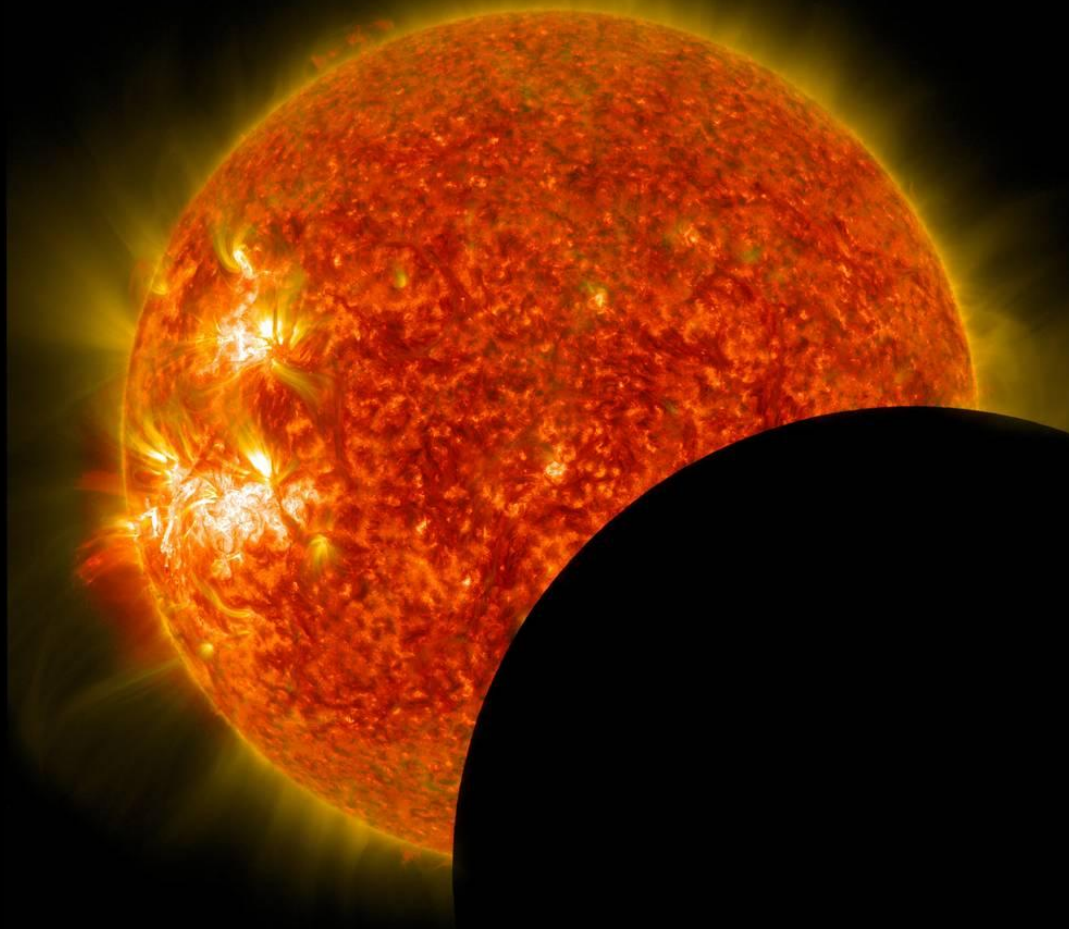
Annular Eclipse (February 2017)



Annular Solar Eclipse Views

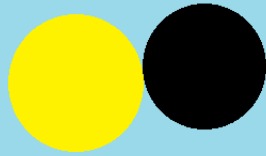


Solar Eclipse Phenomenology



NASA

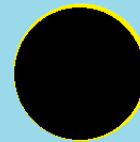
Total Solar Eclipse contacts



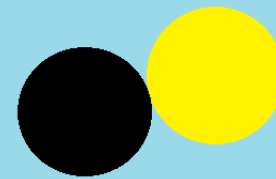
Contact 1



Contact 2



Contact 3

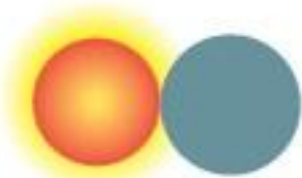


Contact 4

Contact 1: Partial Eclipse begins.
Contact 2: Total Solar Eclipse begins.
Contact 3: Total Solar Eclipse ends.
Contact 4: Partial eclipse ends.

EclipseGeeks.com © 2015

Total eclipse



(1) first contact



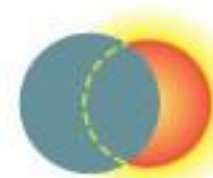
(2) partial phase



(3) second contact,
beginning
of totality



(4) third contact,
end of
totality

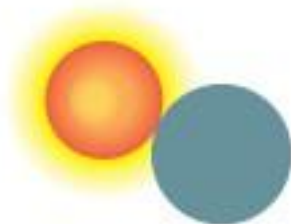


(5) partial phase

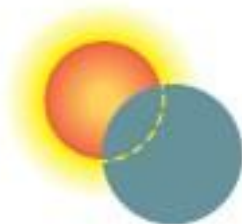


(6) fourth contact

Partial eclipse



(1) first contact



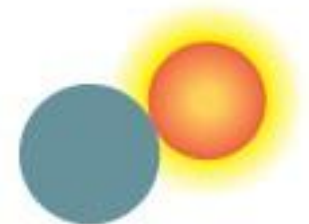
(2) partial phase



(3) maximum phase



(4) partial phase



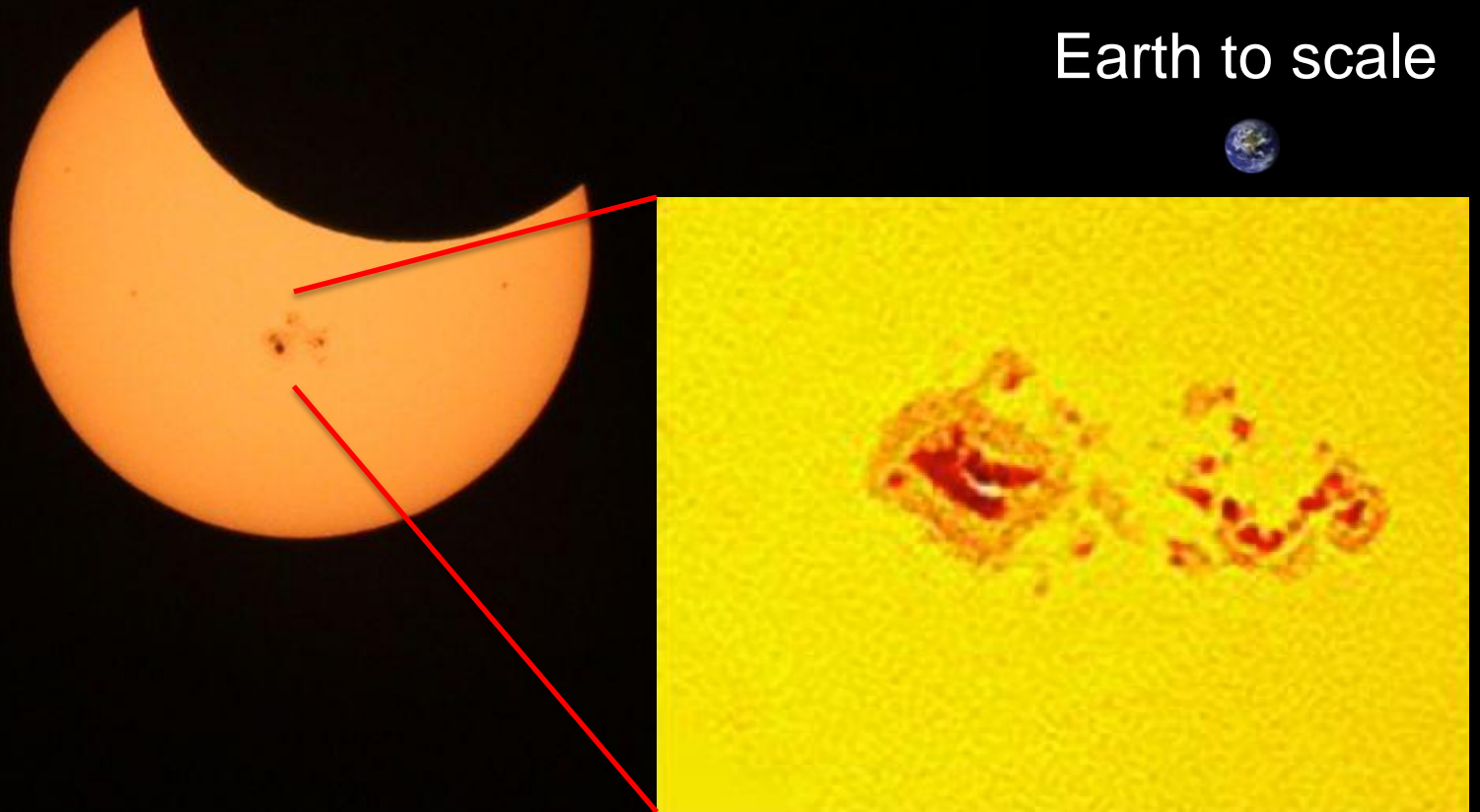
(5) last contact

Partial eclipse showing large sunspot group



Partial phases last about 3 hours total. (Totality is in the middle of this time if you are on the center line.)

Partial eclipse showing large sunspot group



Diamond Ring Effect



“Baily’s Beads”



(Sunlight passing through lunar valleys on the moon's limb)

Pierre Arpin

Baily's Beads Time Series



Total Eclipse showing solar corona



Coronal structure depends
on solar activity level



Solar Chromosphere and Prominences



A Realistic Naked Eye View...



Solar Eclipse Viewed from Space



DSCOVER / NASA



DSCOVR / NASA



DSCOVR / NASA



DSCOVN / NASA



DSCOVR / NASA



DSCOVR / NASA



DSCOVR / NASA



DSCOVR / NASA



DSCOVR / NASA

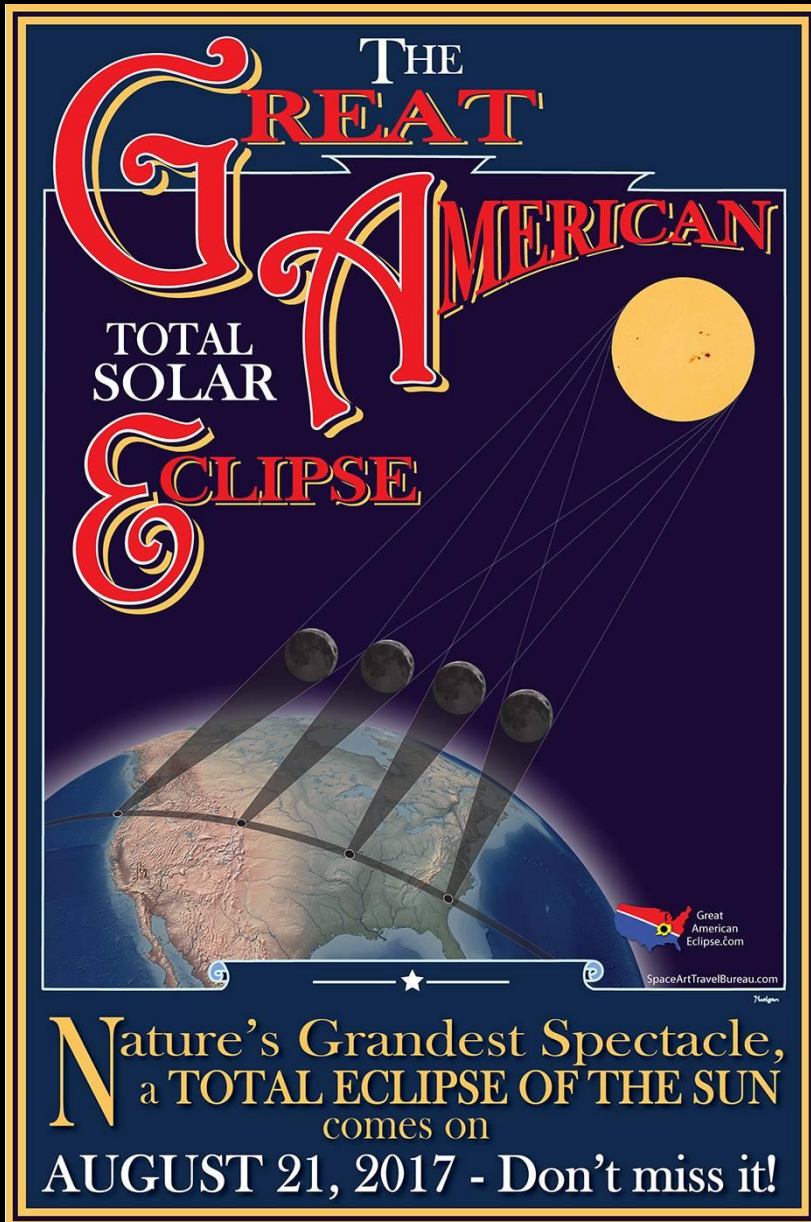


DSCOVR / NASA



DSCOVR / NASA

August 21, 2017 – Where Will You Be?



The poster features a dark blue background with a yellow sun in the upper right. A map of the United States is shown in the lower left, with a path of totality indicated by a line of four small sun icons. Lines radiate from the sun to the path of totality. The text 'THE GREAT AMERICAN TOTAL SOLAR ECLIPSE' is written in a stylized, red and yellow font. At the bottom, it says 'Nature's Grandest Spectacle, a TOTAL ECLIPSE OF THE SUN comes on AUGUST 21, 2017 - Don't miss it!'. A small logo for 'Great American Eclipse.com' and 'SpaceArtTravelBureau.com' is visible in the bottom right corner of the poster.

THE GREAT AMERICAN
TOTAL SOLAR
ECLIPSE

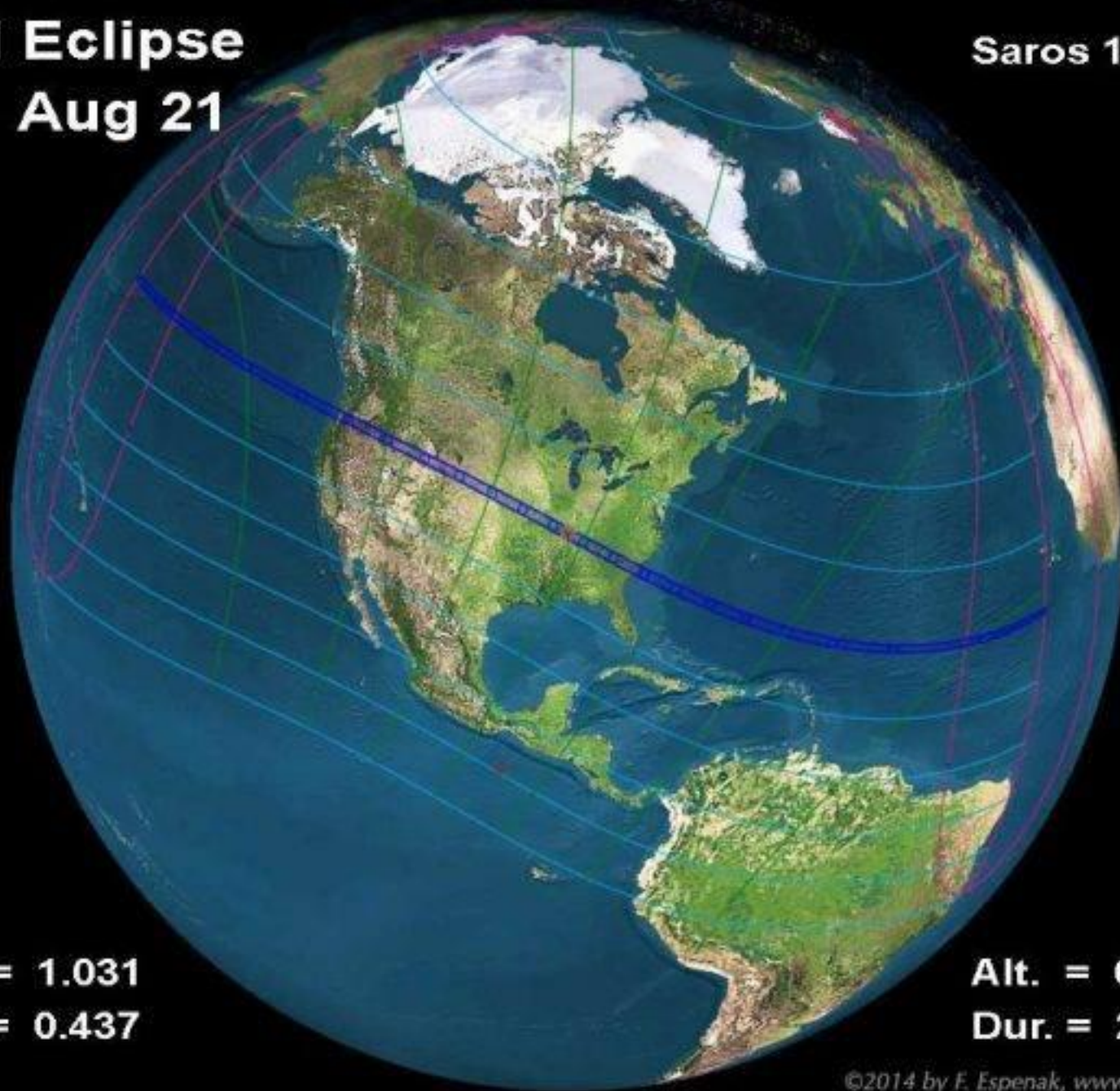
Nature's Grandest Spectacle,
a TOTAL ECLIPSE OF THE SUN
comes on
AUGUST 21, 2017 - Don't miss it!

Great American Eclipse.com
SpaceArtTravelBureau.com



**Total Eclipse
2017 Aug 21**

Saros 145



Mag. = 1.031
Gam. = 0.437

Alt. = 64°
Dur. = 2^m 40^s

Total Solar Eclipse – August 21, 2017



Greatest eclipse at 18:25 UT
Duration 2 min 40 sec
Totality path is 71 miles wide
Partial eclipse across North America



Observing the Eclipse

[Sun Calculator](#) | [Moon Calculator](#) | [Moon Phases](#) | [Eclipses](#) | [Seasons](#) | [Day and Night Map](#) | [Moon Light Map](#) | [Astronomy Articles](#) |

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Eclipse Calculator – Eclipses in USA

Search for a city's next eclipse:

Total, partial, annular solar, and lunar eclipses...

Suggestions: [Baltimore](#) | [Chestertown](#) | [Annapolis](#) | [Greenbelt](#) | [Takoma Park](#)

[World Clock](#) | [Weather](#) | [Time Differences](#) | [Seasons](#) | [Eclipses](#) | [Sunrise & Sunset](#) | [Moonrise & Moonset](#) | [Moon Phases](#) | [Moon Distances](#)

Location Name	State	Country
Auburn	Alabama	USA
Birmingham	Alabama	USA
Brewton	Alabama	USA

Eclipse calculator by city: fractional coverage and timing:
<https://www.timeanddate.com/eclipse/in/usa>

Observing the Eclipse

[Sun Calculator](#) | [Moon Calculator](#) | [Moon Phases](#) | [Eclipses](#) | [Seasons](#) | [Day and Night Map](#) | [Moon Light Map](#) | [Astronomy Articles](#)

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Eclipses in Baltimore, Maryland, USA

Max View in Baltimore



Monday, August 21, 2017 at
2:42 pm

Global Type: [Total Solar Eclipse](#)
Baltimore: [Partial Solar Eclipse](#)

Begins: Mon, Aug 21, 2017 at 1:18 pm [Countdown](#)
Maximum: Mon, Aug 21, 2017 at 2:42 pm
Ends: Mon, Aug 21, 2017 at 4:01 pm

Duration: 2 hours, 43 minutes
Magnitude: [0.83](#)

[Time/General](#) | [Weather](#) | [Time Zone](#) | [DST Changes](#) | [Sun & Moon](#)

Eclipse calculator by city: fractional coverage and timing:
<https://www.timeanddate.com/eclipse/in/usa>

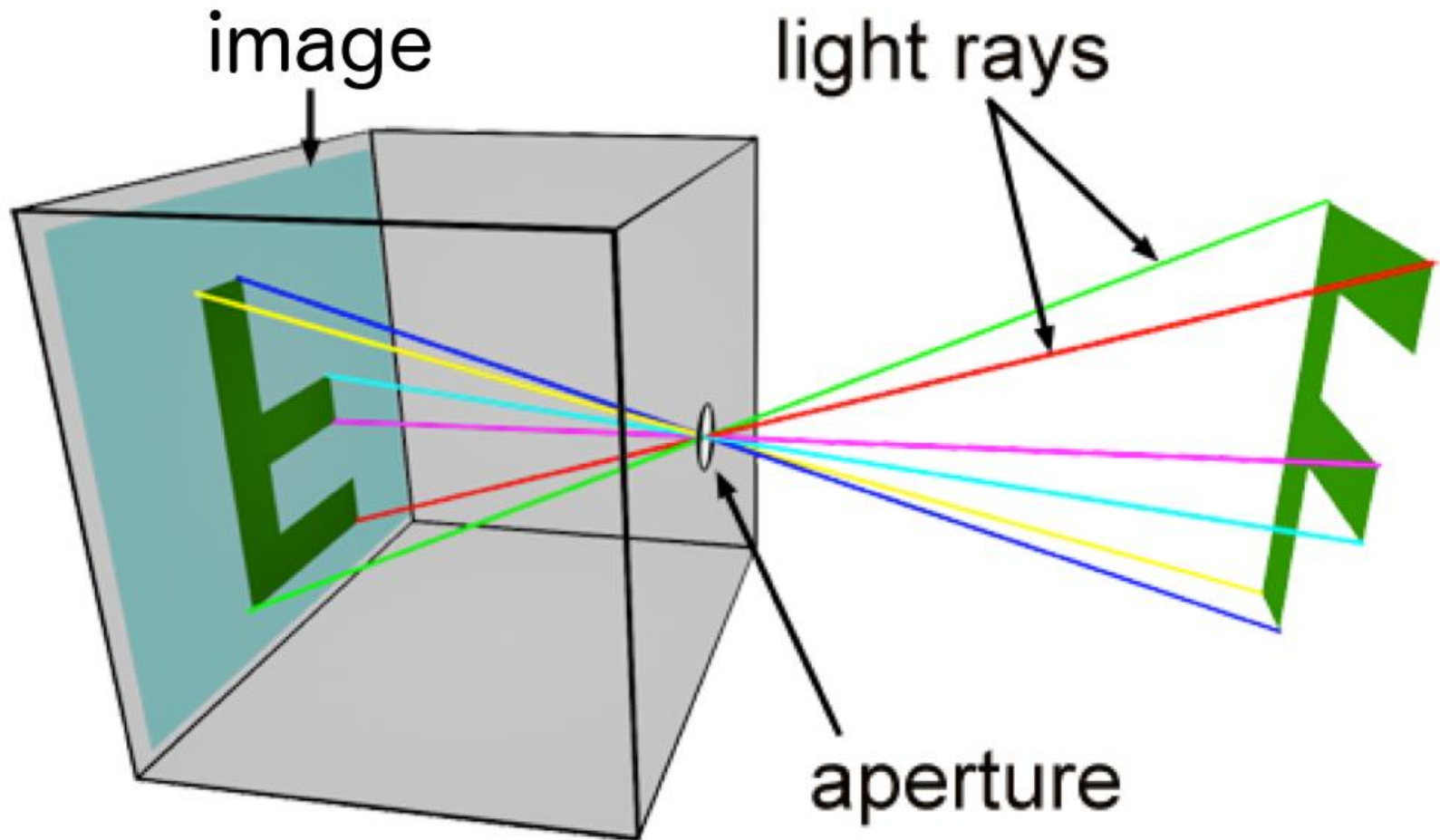
Safety First

- Looking directly at the Sun is unsafe!
 - Use certified solar filters, or eclipse glasses
 - **SUNGLASSES ARE NOT ENOUGH!**
- Only one exception
 - Can look directly at Sun during total eclipse
 - Don't look directly at Sun during partial eclipse!



Indirect Viewing (Partial phases)





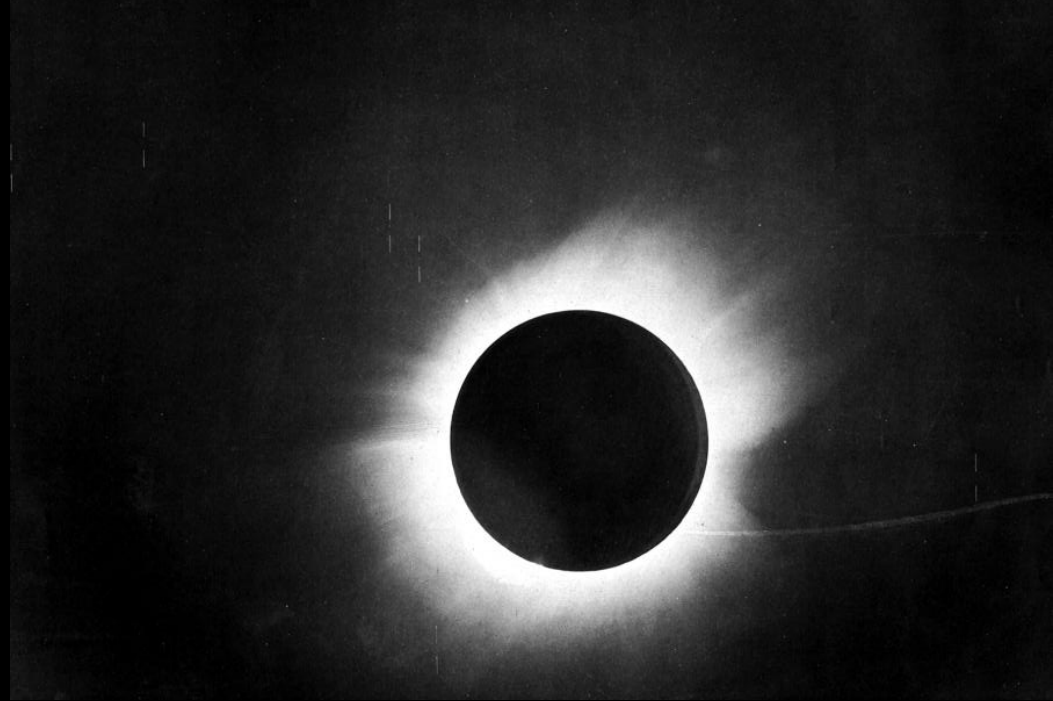
© www.scratchapixel.com

For pinhole cameras, the image is inverted.

Use what you have available to create your own pinhole cameras....



Lucia Garcia

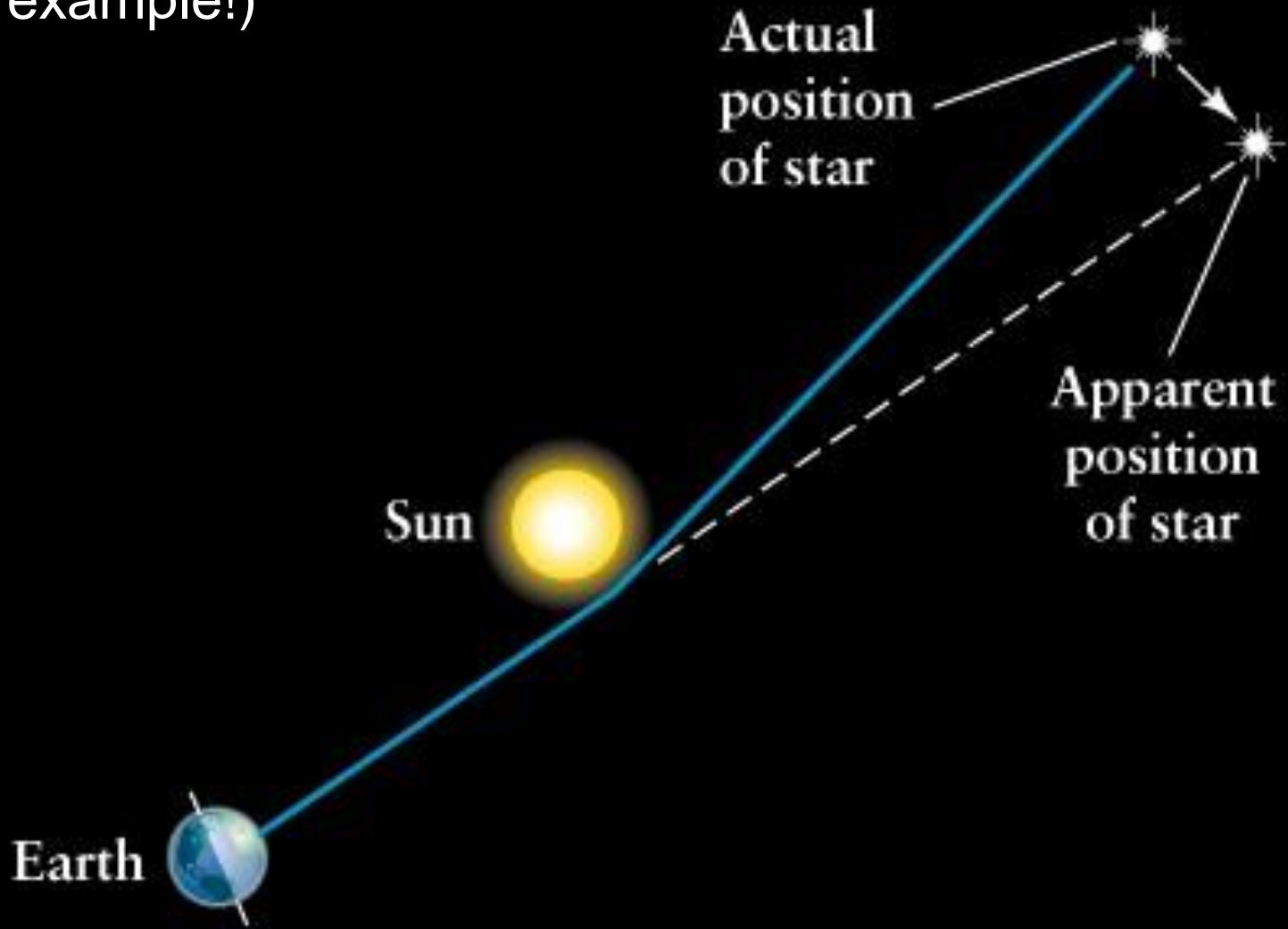


The Eclipse of 1919 and General Relativity

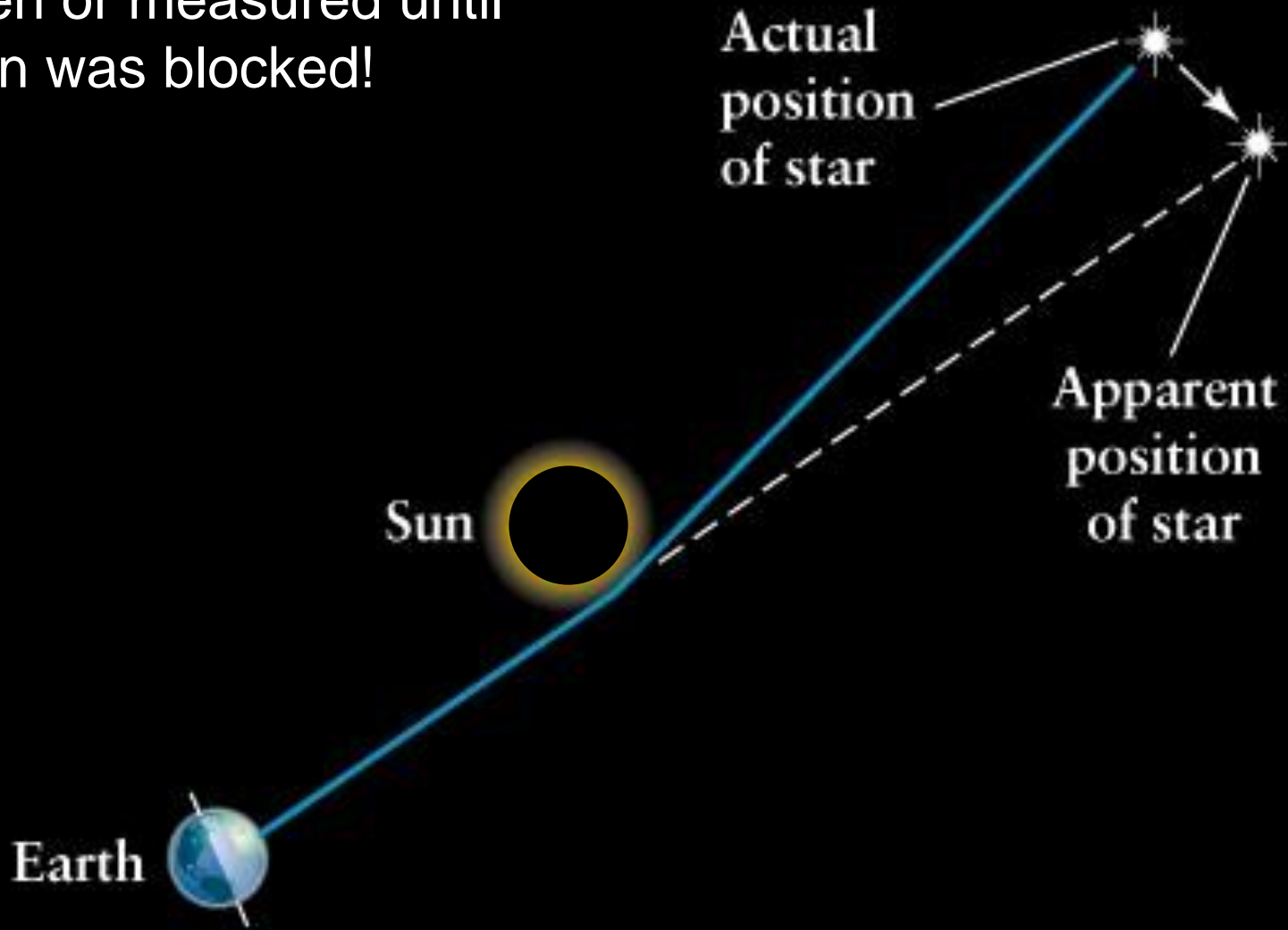
General Relativity

- 1915 – Einstein: “mass warps space”
- Light that passes near the Sun will bend
- Background star positions should shift slightly due to the mass of the sun

(Effect is greatly exaggerated in this example!)

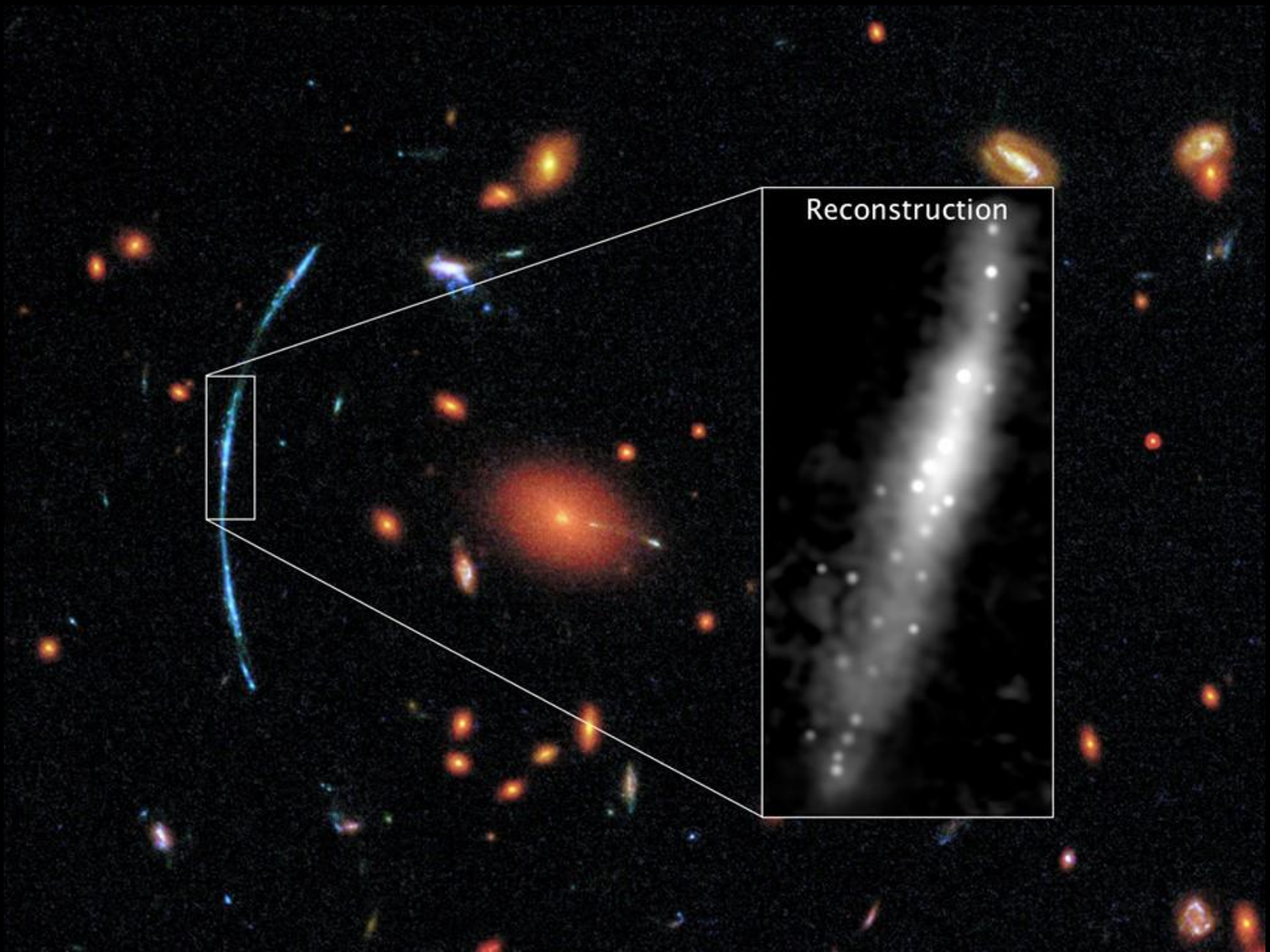


Background stars could not be seen or measured until the sun was blocked!



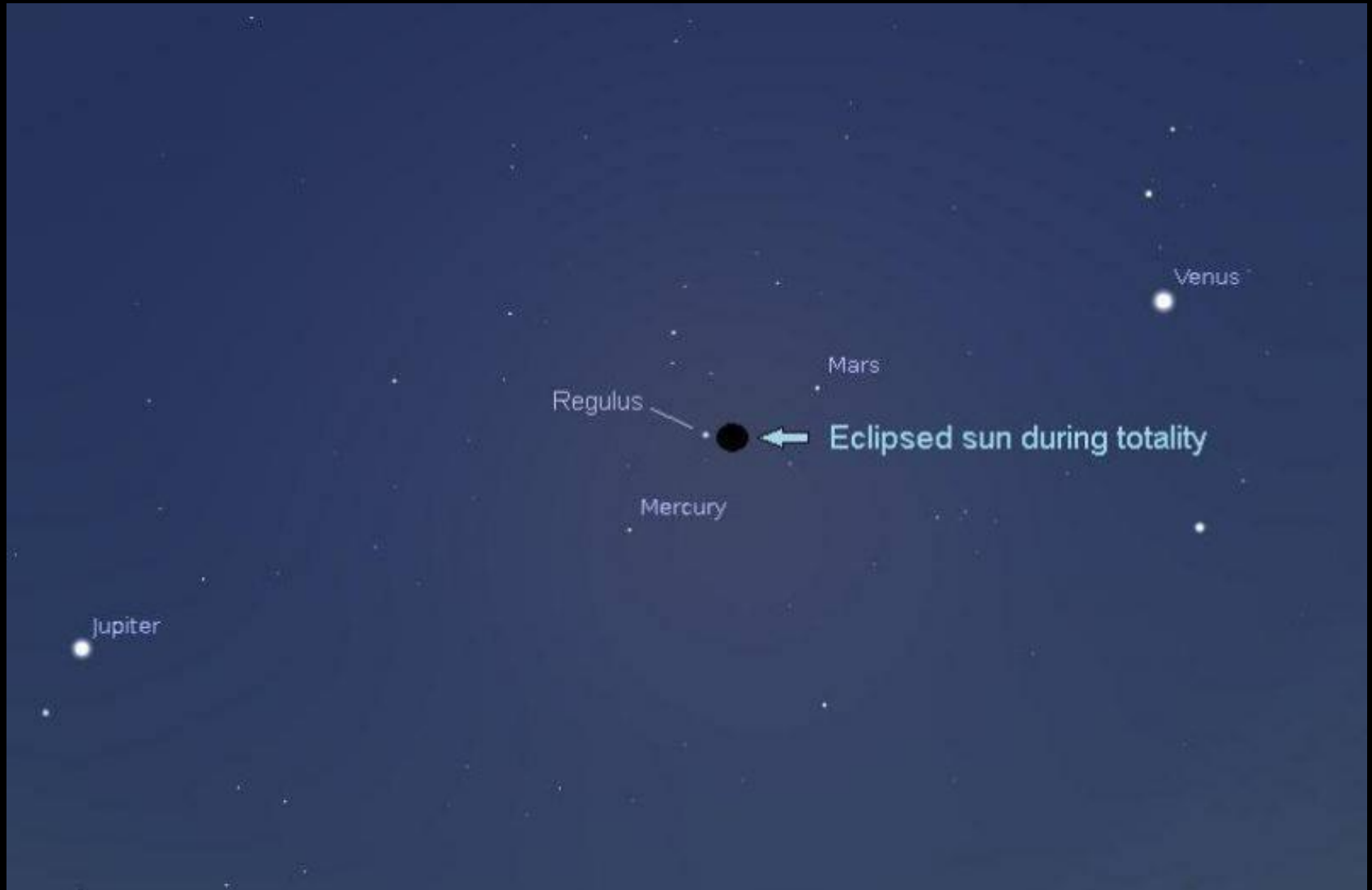
General Relativity Tested

- 1915 – Einstein “mass warps space”
- Light that passes near the Sun will bend
- 1919 – Expeditions to measure star positions during total solar eclipse and compare to earlier pictures of the field.
- Result: Deviations matched predictions
 - General Relativity passed eclipse test!



Gravitational lens example as observed with Hubble

August eclipse planets and stars





Questions?