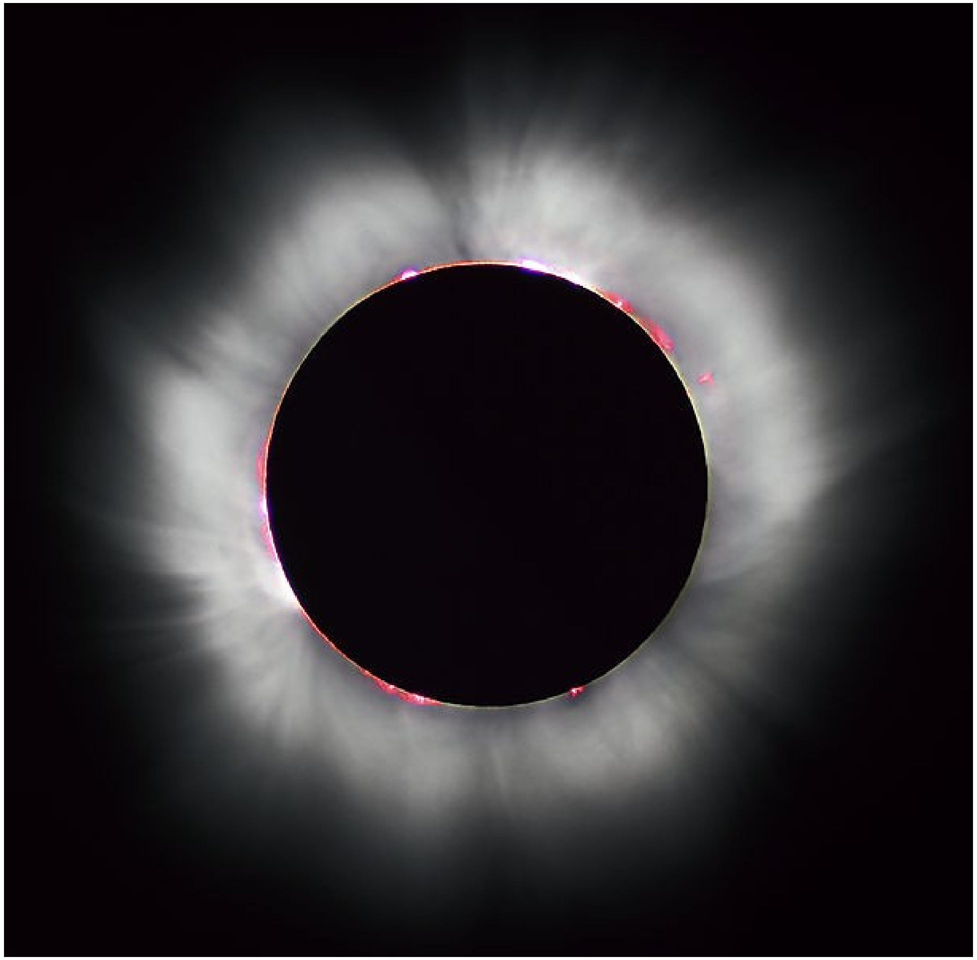
Eclipses!

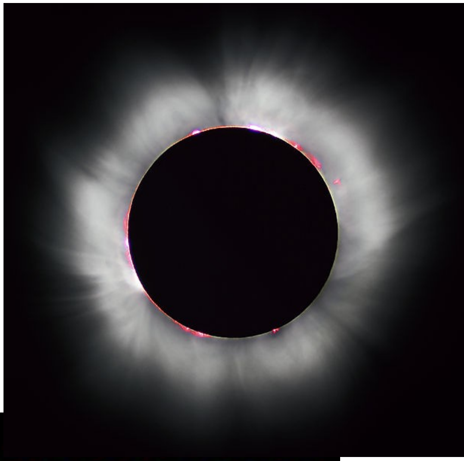


(Total solar eclipse of August 1999)

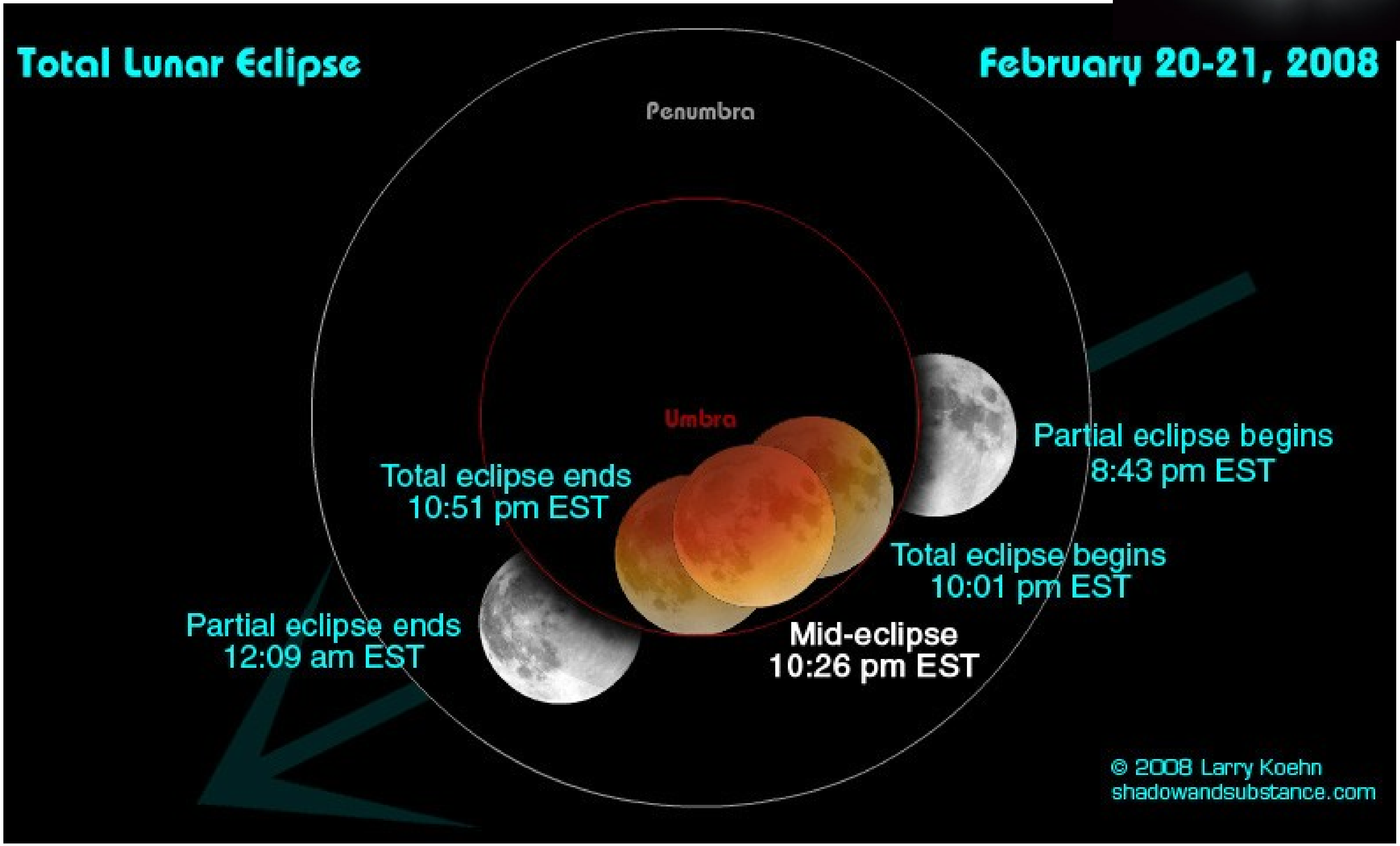
Dr. J. Pinkney June 2023

Eclipses – What are they?

A. Solar Eclipses: the Sun darkens



B. Lunar Eclipses: the Moon darkens



Lunar Eclipse:

My Pics from Jan 20-21, 2019 TLE

Outline

I. What are eclipses?
   A) Solar eclipses
   B) Lunar eclipses
II. Motivation: the upcoming 2024 total solar eclipse!
III. Cool eclipse phenomena
IV. Eclipse basics – shadow cones
V. Simulating eclipses in the classroom.

II. The upcoming 2024 total solar eclipse!

April 8, 2024 – totality can be seen from Ada, OH!

This is a **rare** opportunity!

- A Total Solar Eclipse (TSE) occurs *somewhere on Earth* about 2 times in 3 years (actually, 0.60 times per year on average).
  - BUT you don't experience them unless you're in the path of totality!
- A given spot on Earth experiences a TSE about **once in 360-410 years!**

- Solar eclipses of some type (total + annular + hybrid + partial) occur *somewhere* about 2.4 times per year, on average.
- A minimum of 2 solar eclipses per year (all types).
- Interesting SEs (total + annular + hybrid) occur *somewhere* about 1.4 times per year, on average.

Lunar eclipses occurring *somewhere* have similar frequencies:

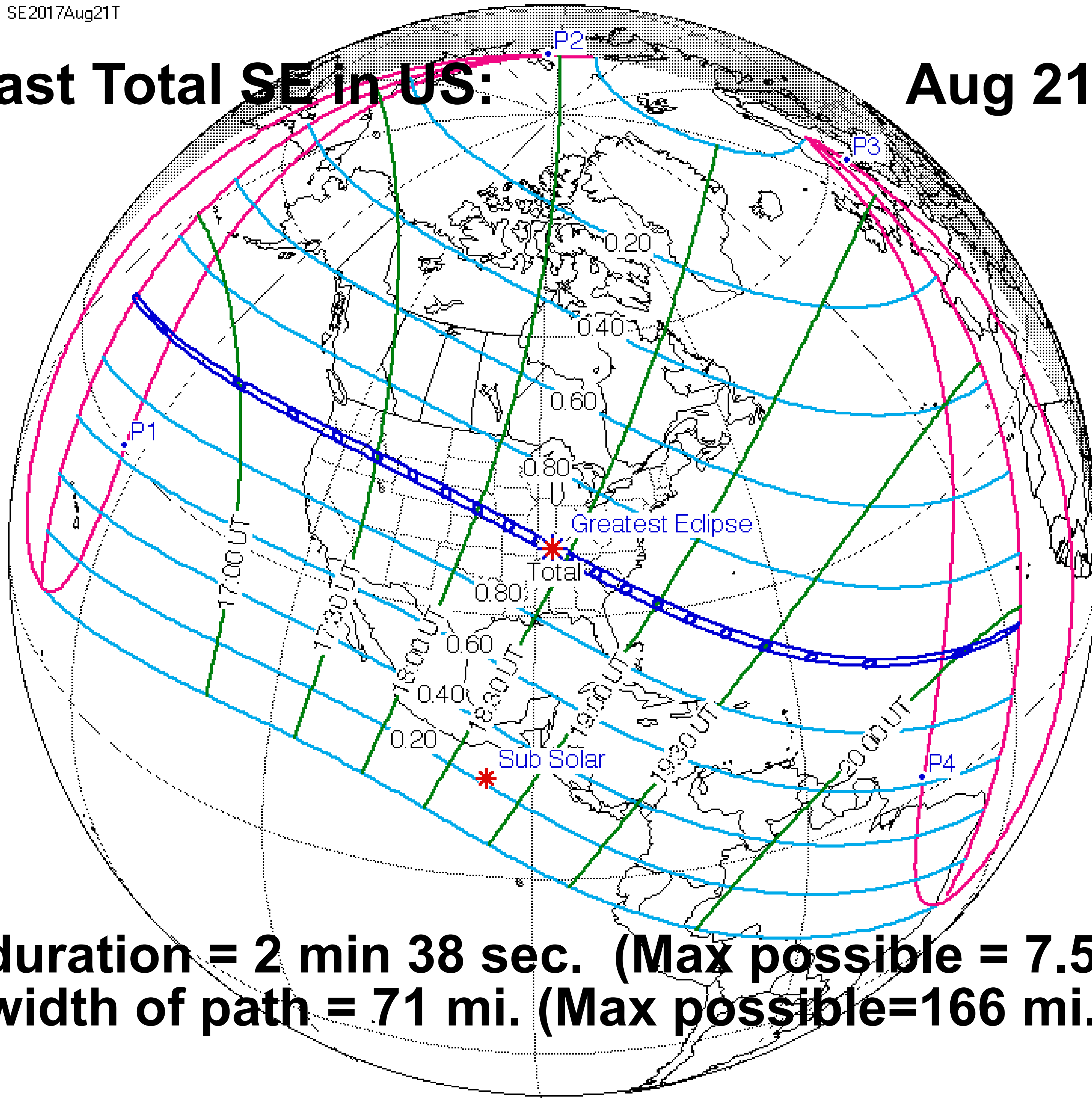
- TLE = 0.9 per yr
- All types of LE (total+penumbral+partial) = 2.3 per yr (minimum 2).
  - BUT, TLEs can be experienced by ½ of the Earth's surface!

II. The upcoming 2024 total solar eclipse!

All solar eclipses 2017-2027, except partials:

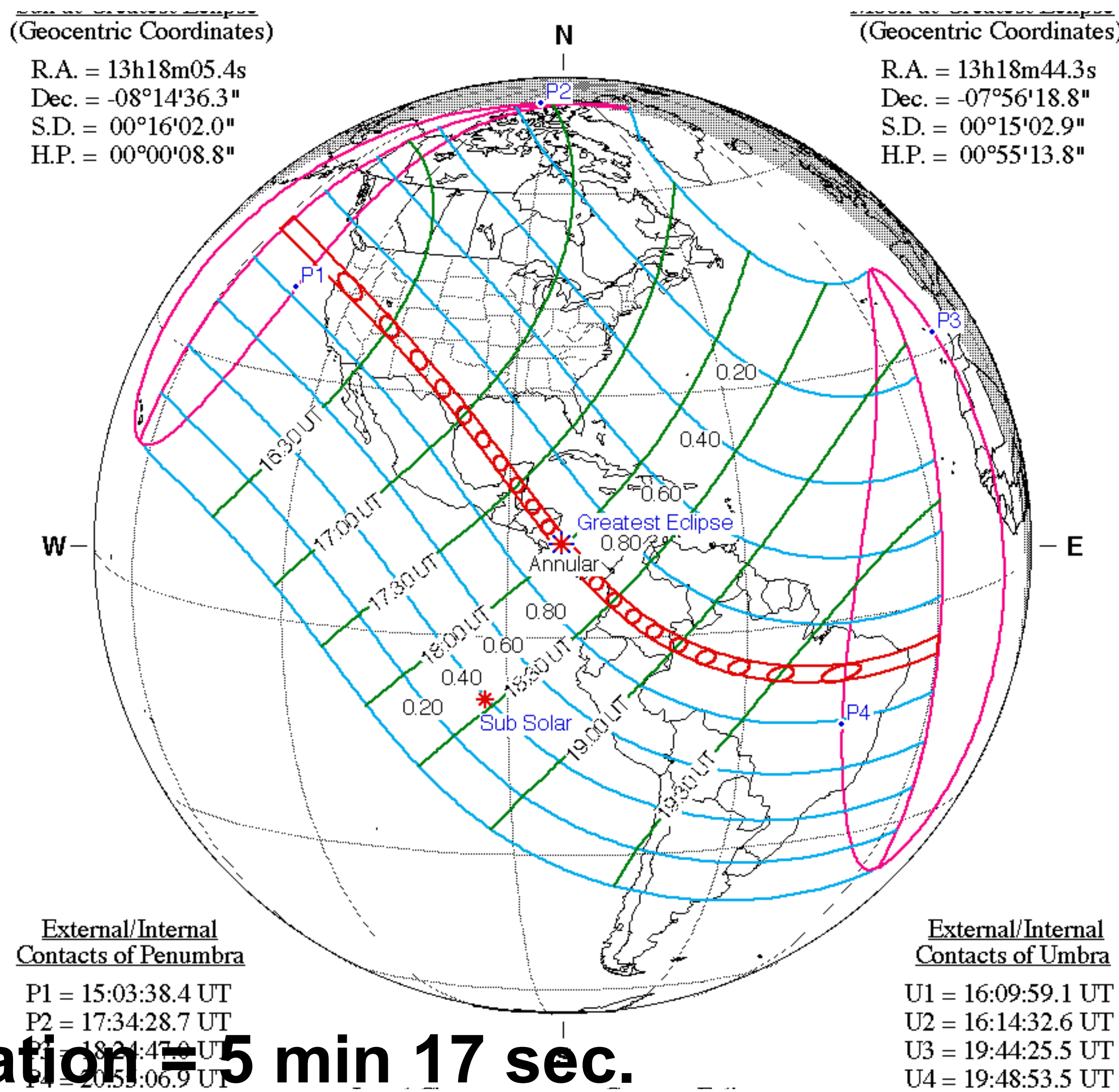
Feb 26, 2017 – Annular (not visible in OH)
Aug 21, 2017 – Total (partial In OH)
July 2, 2019 – Total (not visible in OH)
Dec 26, 2019 – Annular (not visible in OH)
Jan 21, 2020 – Annular (not visible in OH)
Dec 14, 2020 – Total (not visible in OH)
June 10, 2021 – Annular (partial in OH)
Dec 4, 2021 – Total (not visible in OH)
Apr 20, 2023 – Hybrid (not visible in OH)
Oct , 2023 – Annular (partial in OH)
Apr 8, 2024 – Total (Total In OH!)
Oct 2, 2024 – Annular (not visible in OH)
Feb 17, 2026 – Annular (not visible in OH)
Aug 12, 2026 – Total (partial in OH)
Feb 6, 2027 – Annular (not visible in OH)
Aug 2, 2027 – Total (not visible in OH)

The last Total SE in US: Aug 21, 2017



Max duration = 2 min 38 sec. (Max possible = 7.5 min)
Max width of path = 71 mi. (Max possible=166 mi.)

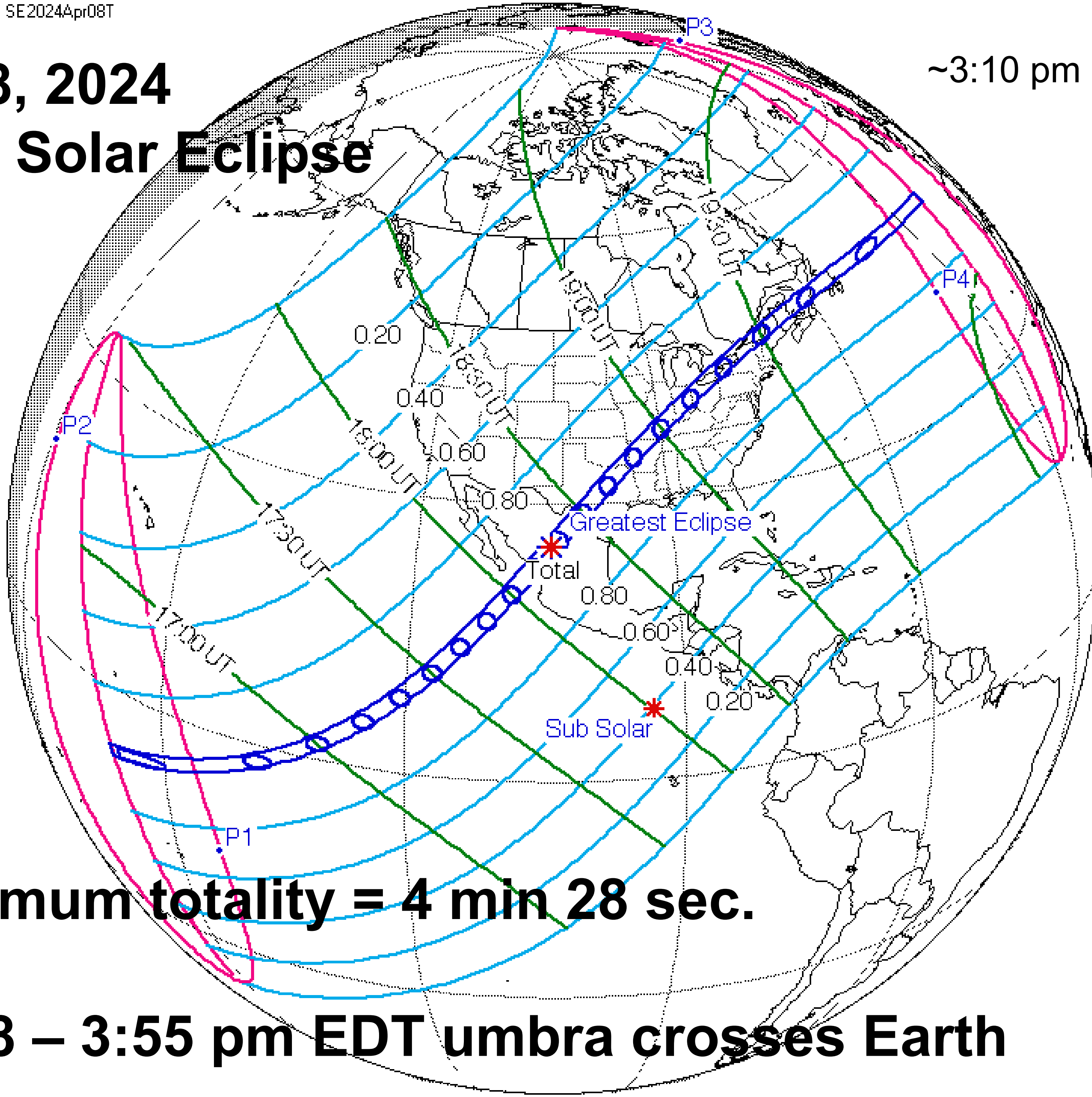
The next Annular SE: Oct 14, 2023



Max duration = 5 min 17 sec.
Max width of path = 116 mi.

Apr 8, 2024
Total Solar Eclipse

~3:10 pm EDT - Ada

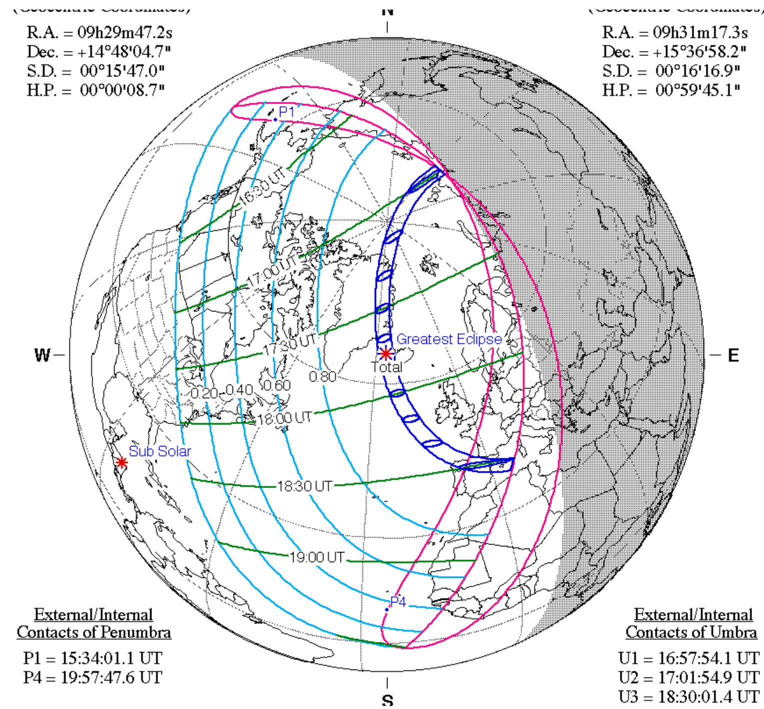


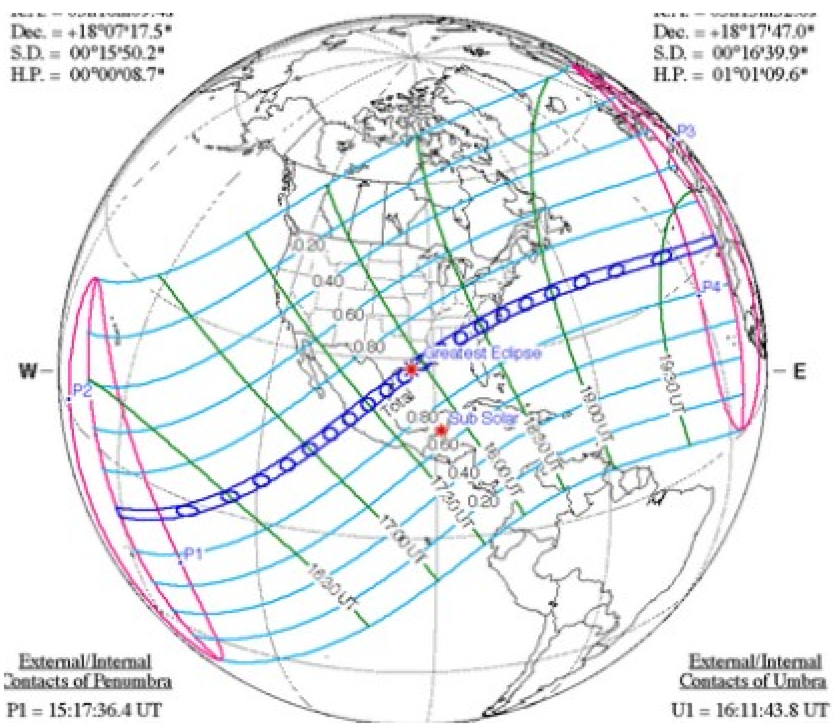
Maximum totality = 4 min 28 sec.

12:38 – 3:55 pm EDT umbra crosses Earth

Future eclipses for OH

2026, Aug 12 Total SE (Partial for OH)



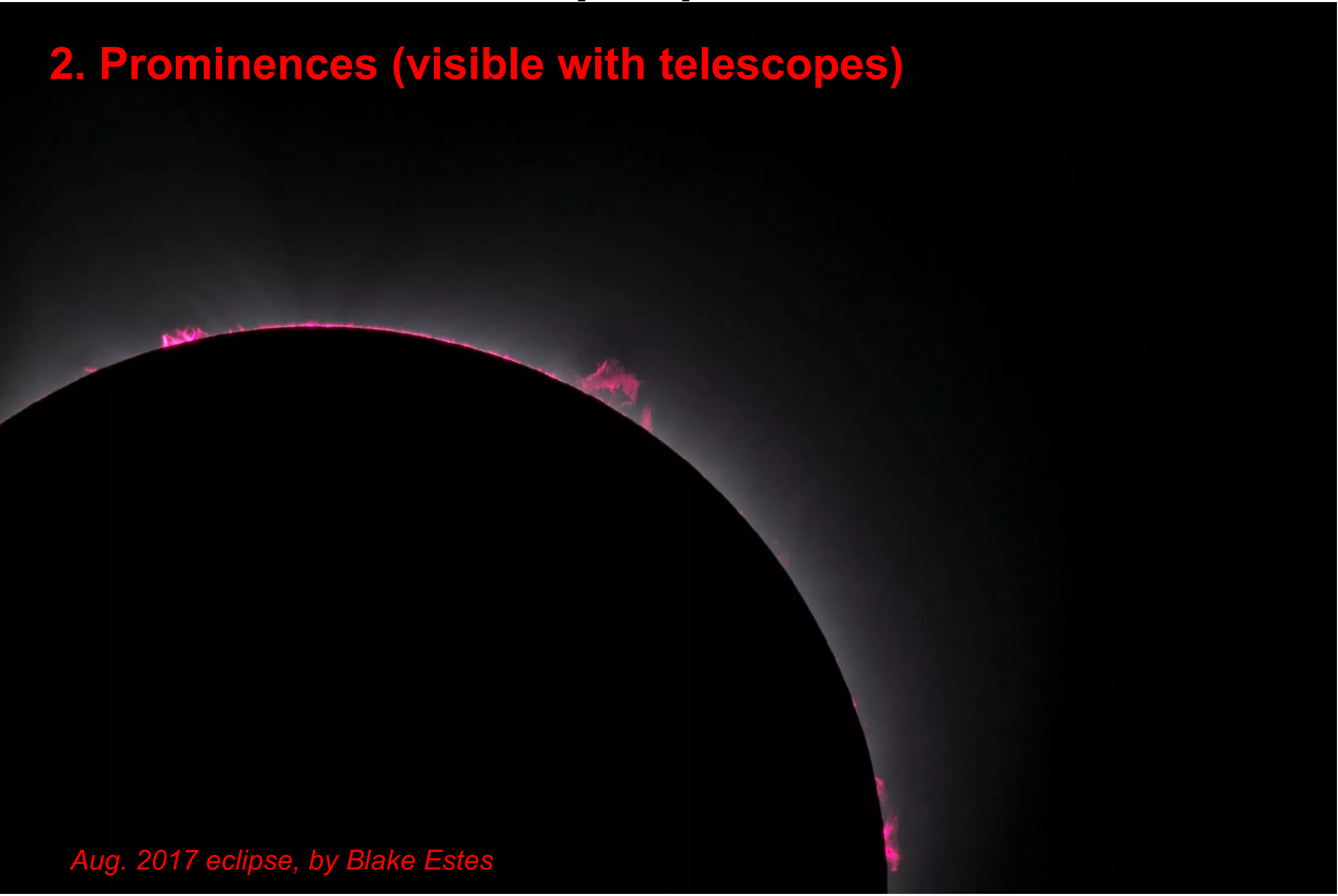


2078, May 11 (1 *exeligmos* after the 2024 eclipse)

III. Cool solar eclipse phenomena

Cool eclipse phenomena

Cool eclipse phenomena



Cool eclipse phenomena

Cool eclipse phenomena

Cool eclipse phenomena

6. The planets and stars come out!

This is for the Aug 2017 TSE. *Src: astroashville.org*

Cool eclipse phenomena

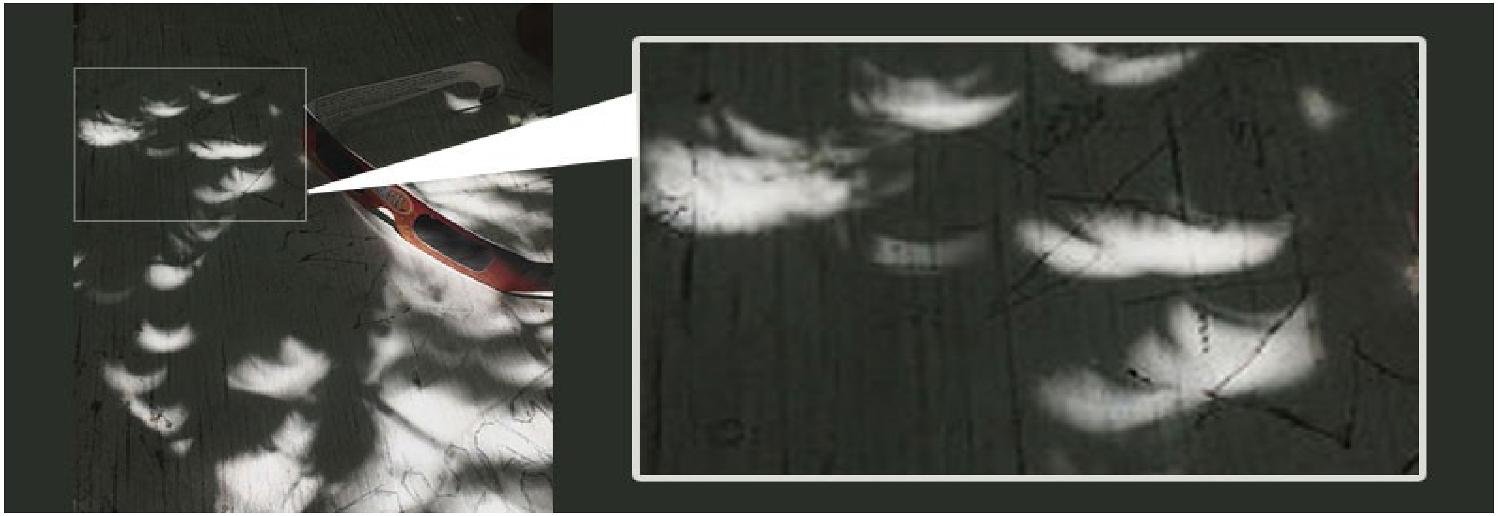
What’s happens around you!?

7. Wrap-around sunset!
8. The temperature drops!
9. People whoop and holler!
10. See *shadow bands* just before and after totality.
***More* shadow bands.**

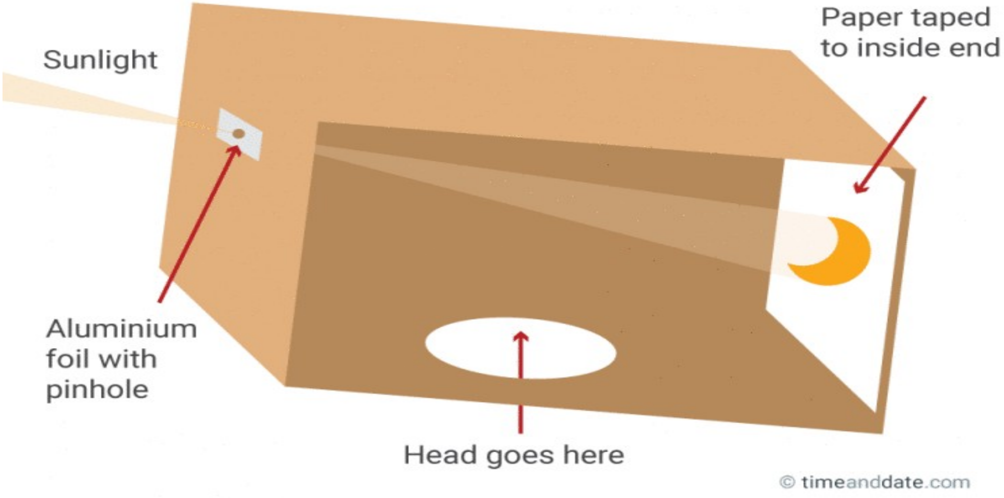
11. Animals think its sunset or get confused.
Bugs, bats, llamas, even *chickens!*

Cool eclipse phenomena

12. Crescent shadows under trees

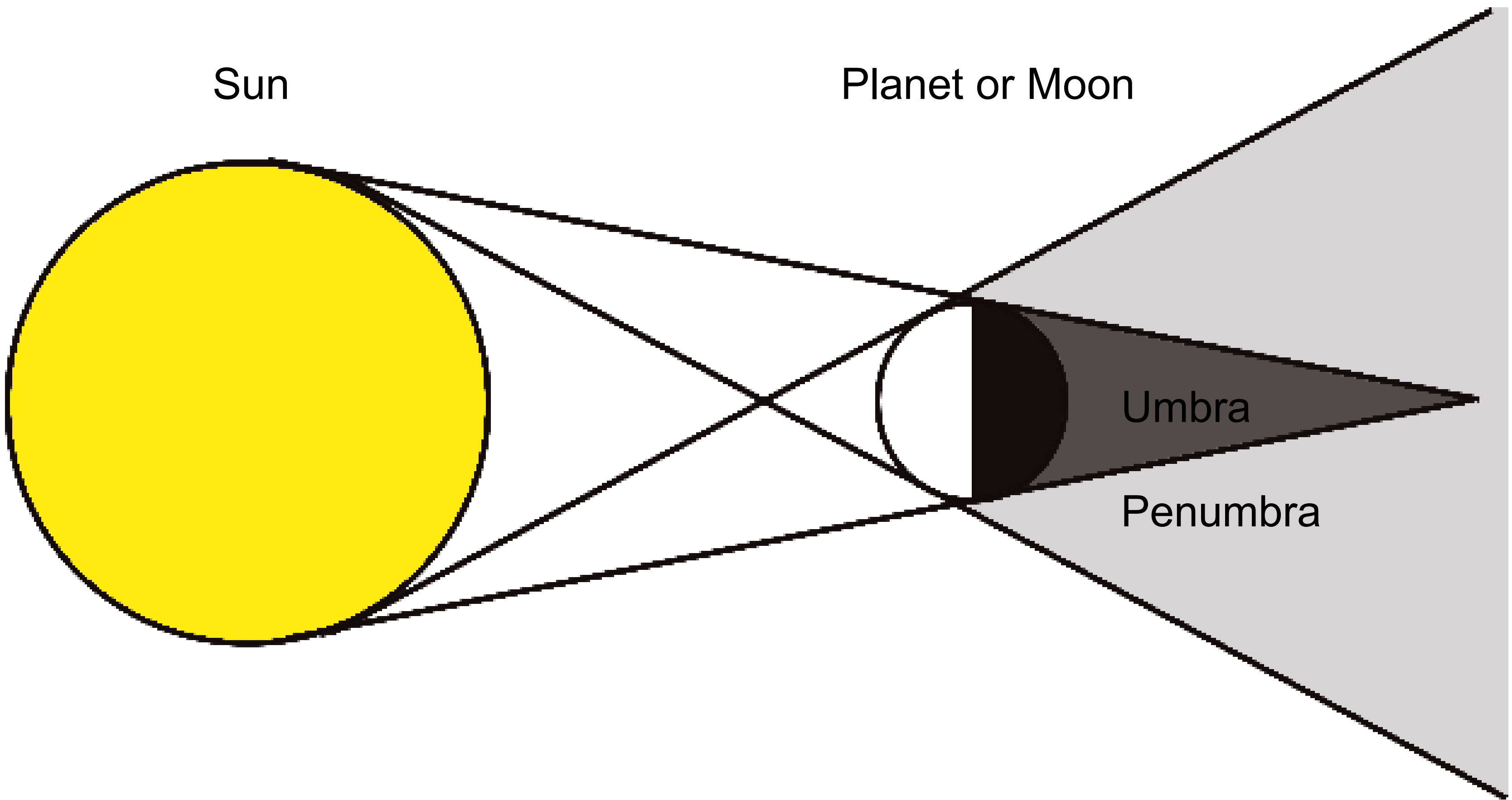


Trees act like *pinhole cameras* ...



V. Eclipse Basics - Shadow cone geometry

Eclipse Basics – the shadow cone geometry.



The Sun is actually about 110 times the Earth in diameter, and 400 times the Moon in diameter!

Eclipse Basics.

Solar Eclipses – the shadow of the Moon falls on the Earth. We (on Earth) see the Sun get obscured.

TYPES: Partial
Annular
Hybrid or mixed
Total

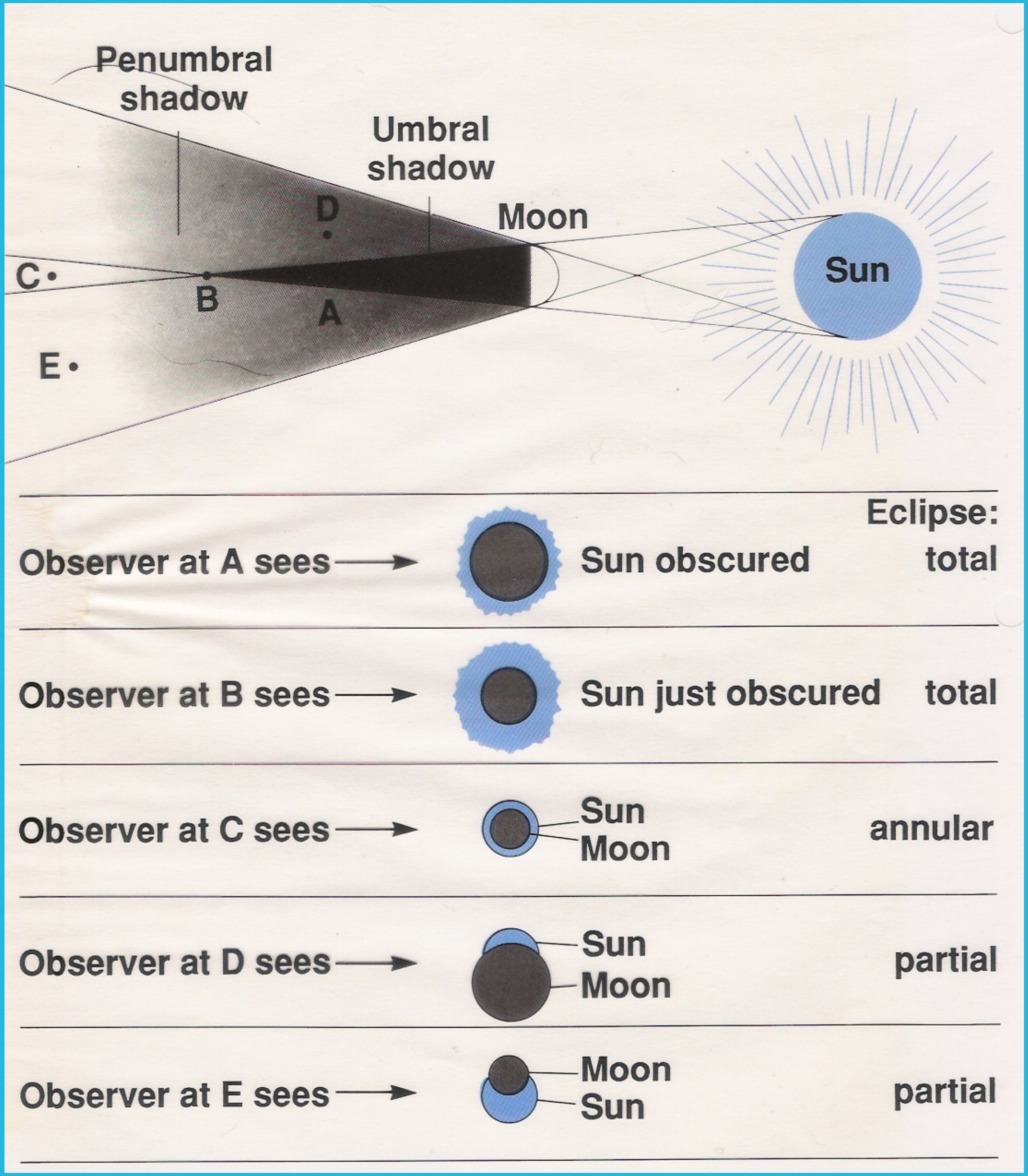
Lunar Eclipses – the shadow of the Earth falls on the Moon. We see a shadow pass over the Moon.

TYPES: Penumbral
Partial
Total

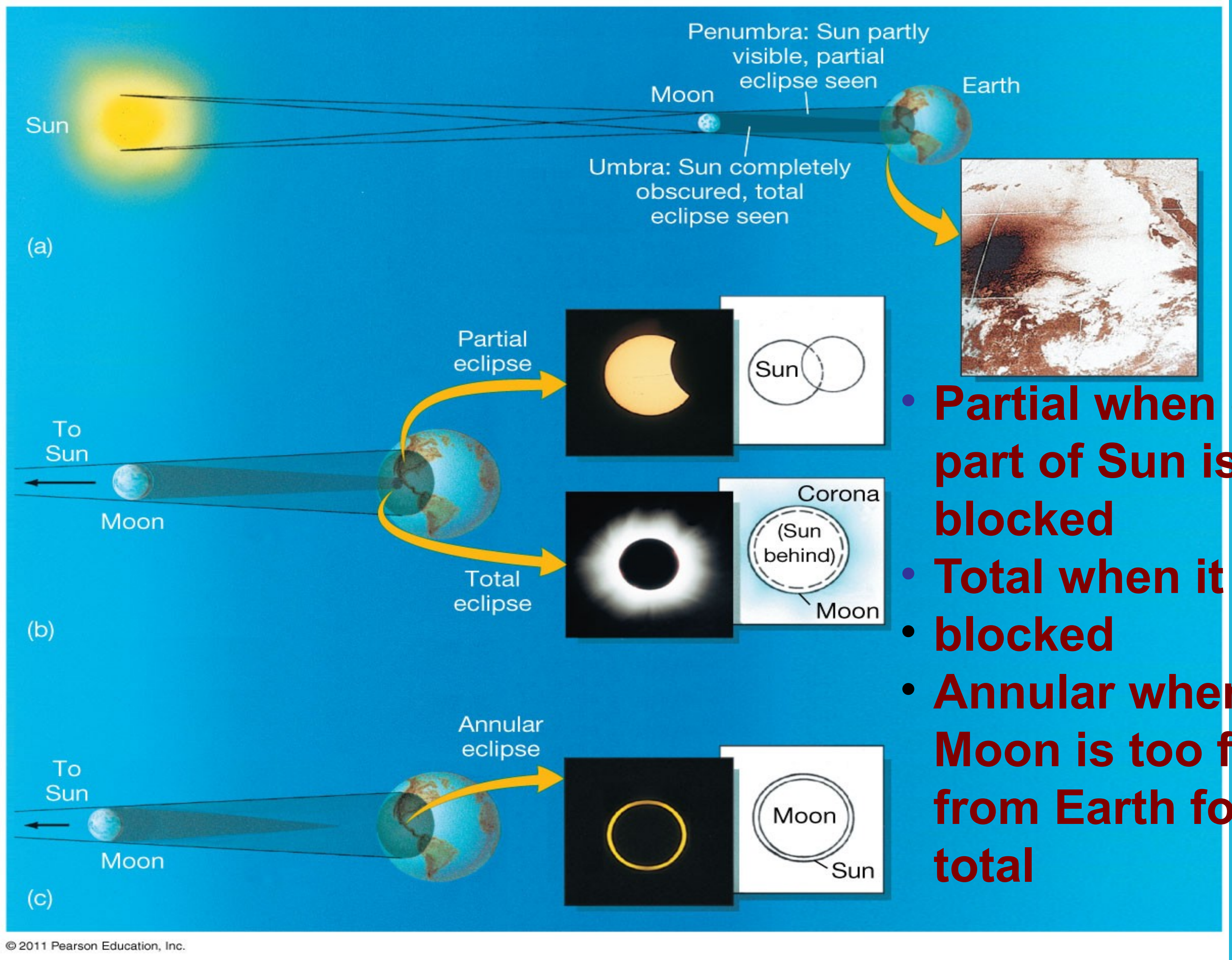
First Simulation: overhead projector used to create a "Sun", while cut-outs represent the Moon.

Solar eclipses - Moon is between Earth and Sun

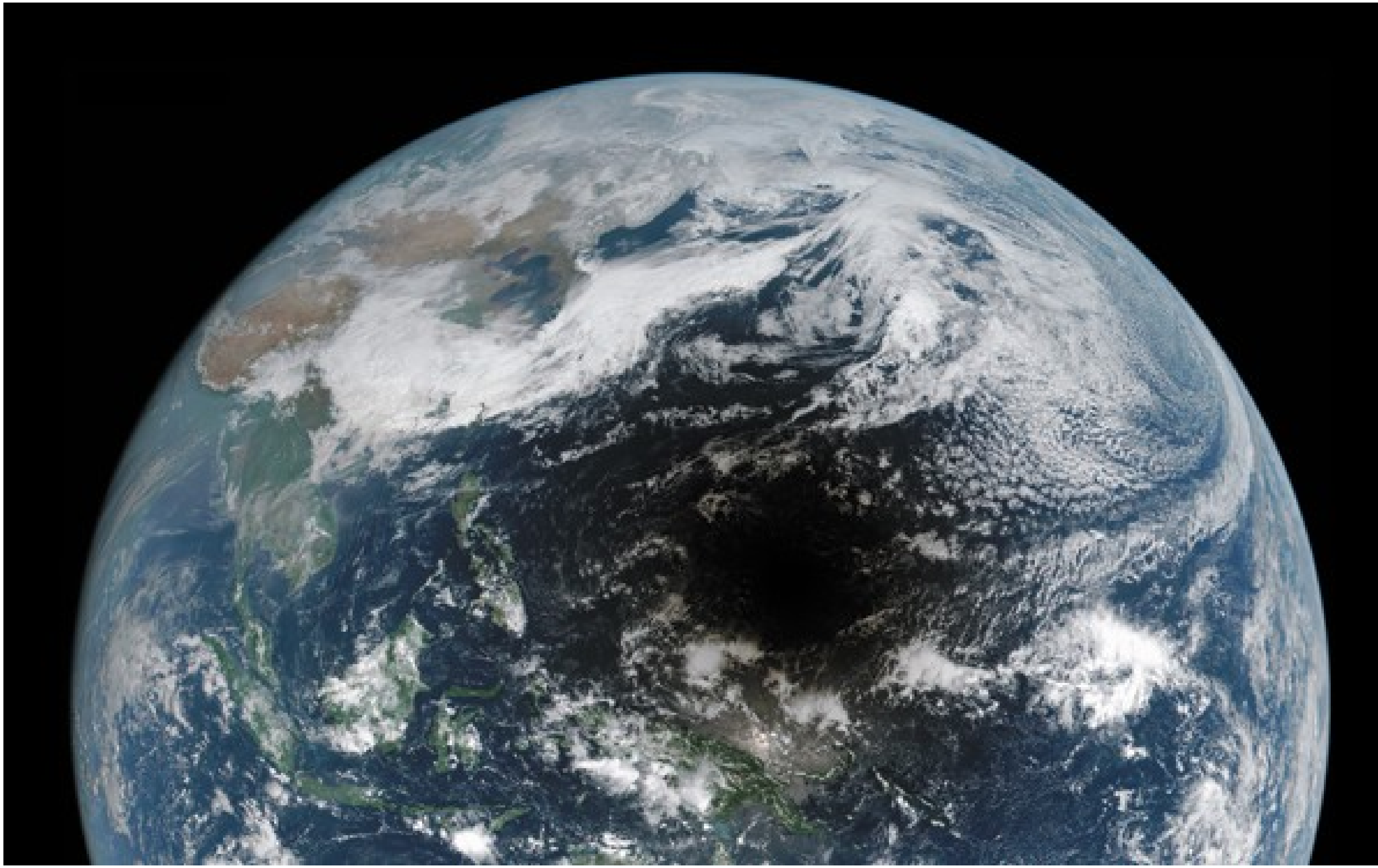
A-E = possible positions of the Earth



Solar eclipses - Moon is between Earth and Sun



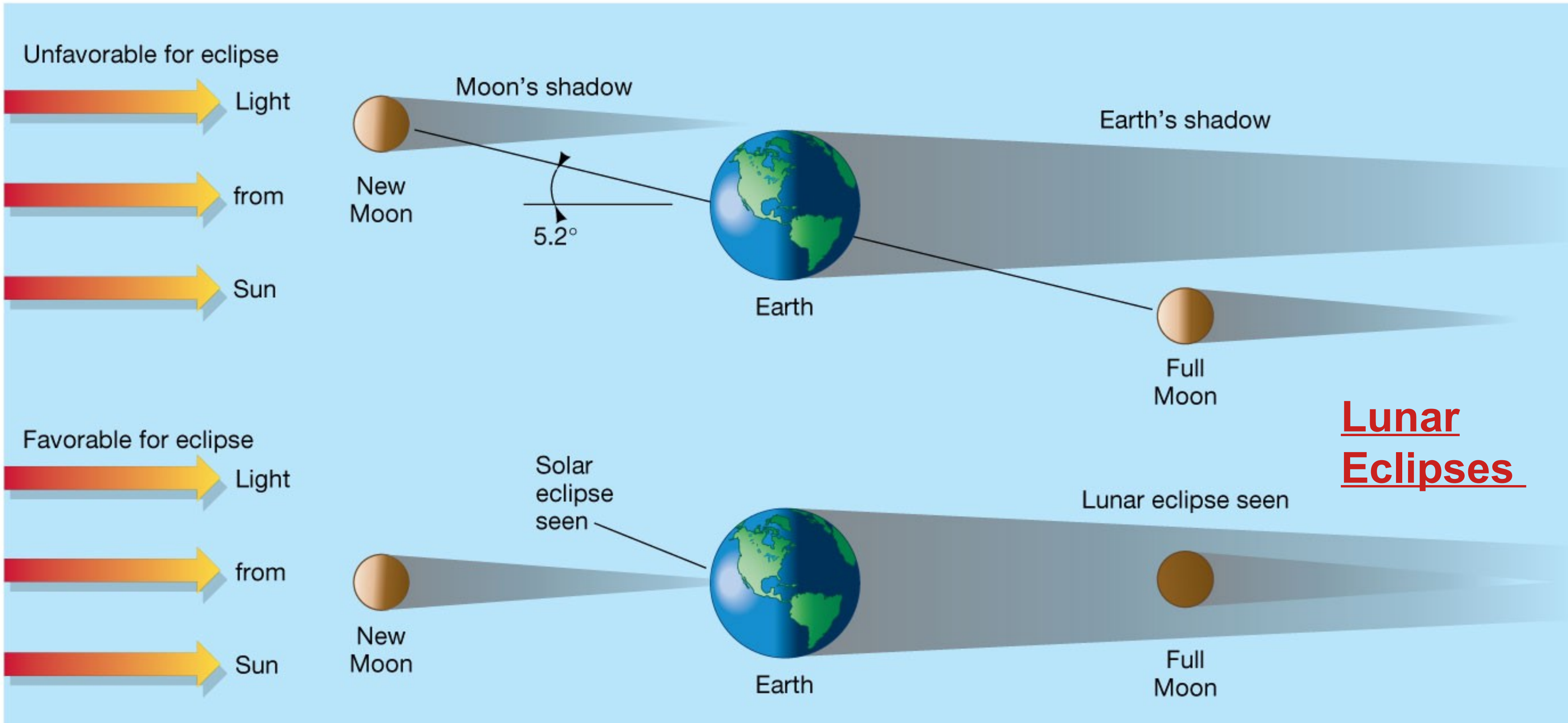
- **Partial when only part of Sun is blocked**
- **Total when it is all**
- **blocked**
- **Annular when Moon is too far from Earth for total**



Satellite photo of Earth during Mar 9, 2016 total solar eclipse (total for Indonesia).

Conditions for an *Eclipse*

Eclipses occur when the Earth, Moon, and Sun fall on (or nearly on) a straight line.*



[Lunar Eclipses](#)

Q: What phase does the Moon have to be in, if any, during a solar eclipse? During a lunar eclipse?

*****syzygy* = alignment of 3 celestial bodies on a line**

VI. Simulating eclipses in the classroom.

<u>YouTube examples</u>

Moon phase demo with styrofoam ball (see 0:55-3:12):

Lunar phase Sim.

Lunar and solar eclipses and phases demonstrated with lightbulb and styrofoam ball (solar 2:55, lunar 4:27):

Eclipse and phase sim.

Solar eclipse from Earth's perspective, showing tilt of Moon's Orbit relative to ecliptic plane (see 0:25-on):

Solar Eclipse Sim. 1 - orbit tilt

A common flaw in these simulations is that the sources of light (light bulbs) are smaller than the objects casting the shadows. No one simulates shadow cones!!

VI. Simulating eclipses in the classroom.

<u>1. Phases of the Moon.</u>

a) See lunarapplet.swf
b) Each person can do this independently.
c) Use 3-inch styrofoam sphere.
d) Insert a toothpick about 1/3 of the way.
e) Lights off except an LED lamp
f) Let the sphere be the Moon and your head be the Earth.
g) Make the Moon orbit your head at arm's length by turning around.

<u>2. Compare shadows from a point source of light to an extended circular light (like the Sun).</u>

a) See diagram on board showing shadow cones for point source and for extended source.
b) Form 5 groups, one for each grey screen + stand.
c) Set up screen so that it faces the LED light.
d) One person watches the LED through the screen while the Other moves the spheres between the LED and the screen.
e) Swith roles
f) Repeat with a big circle of light representing the Sun.

VI. Simulating eclipses in the classroom.

3. Make a model of the Earth and Moon to scale using your large and small styrofoam spheres.

a) Work with a partner for best results.

b) Figure out how far your Moon must be from your Earth and space them out that far using a tape measure or ruler.

c) Your sphere dimensions are:

Large sphere diameter = 7.4 cm

Small sphere diameter = 1.9 cm

d) Check $d_{\oplus}/d_{◖}$, the diameter ratio. Is it close to 3.67?

e) Check $D_{◖}/d_{◖}$, the distance:diameter ratio. Is it close to 111?

f) Compare to numbers on next slide.

VI. Simulating eclipses in the classroom.

Actual sizes

Moon (◖)	diameter	3480 km	2160 mi
Earth (⊕)	diameter	12,740 km	7920 mi
Sun (☉)	diameter	1,390,000 km	865,000 mi

→ We find $d_{☉}/d_{⊕}$ = 109, and $d_{⊕}/d_{◖}$=3.67

Actual average distances

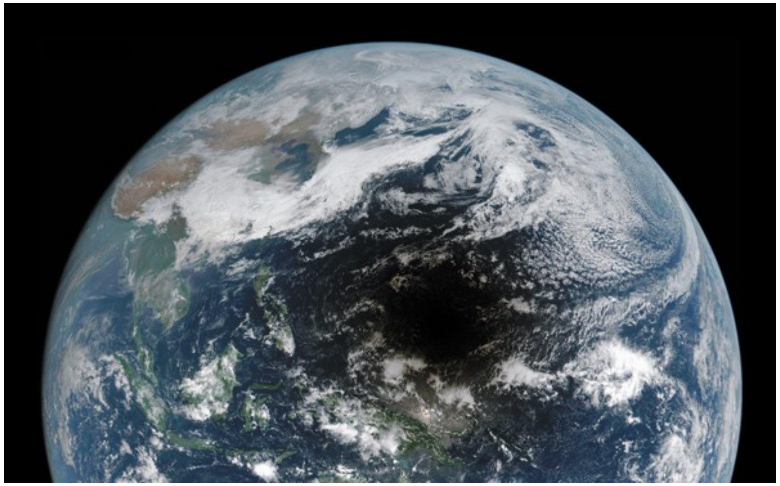
$D_{◖}$ (Earth to Moon)	384,000 km	239,000 mi
$D_{☉}$(Earth to Sun)	149,600,000 km	93,000,000 mi

→ We find $D_{☉}/D_{◖}$ = 389, $D_{☉}/d_{☉}$=108, $D_{◖}/d_{◖}$= 111

You rarely see a picture where these ratios are Correct!! Try drawing the Earth Moon system to scale!

VI. Simulating eclipses in the classroom.

<u>4. Reproduce a TSE on a screen and then a sheet of paper.</u>
a) Work in 5 groups.
b) Use the 3-inch sphere for the Earth.
c) Make your screen face the big circle of light (Sun).
d) Person 1 puts eye right up close to the back of the screen.
e) Person 2 moves sphere so that person 1 sees it just barely covering the Sun. That means the apex of the umbra is on the screen!
f) Measure the screen-to-sphere distance (D_sphere).
g) Check that D_sphere/d_sphere = D_sun/d_sun. Ratios will vary from group to group.



VI. Simulating eclipses in the classroom.

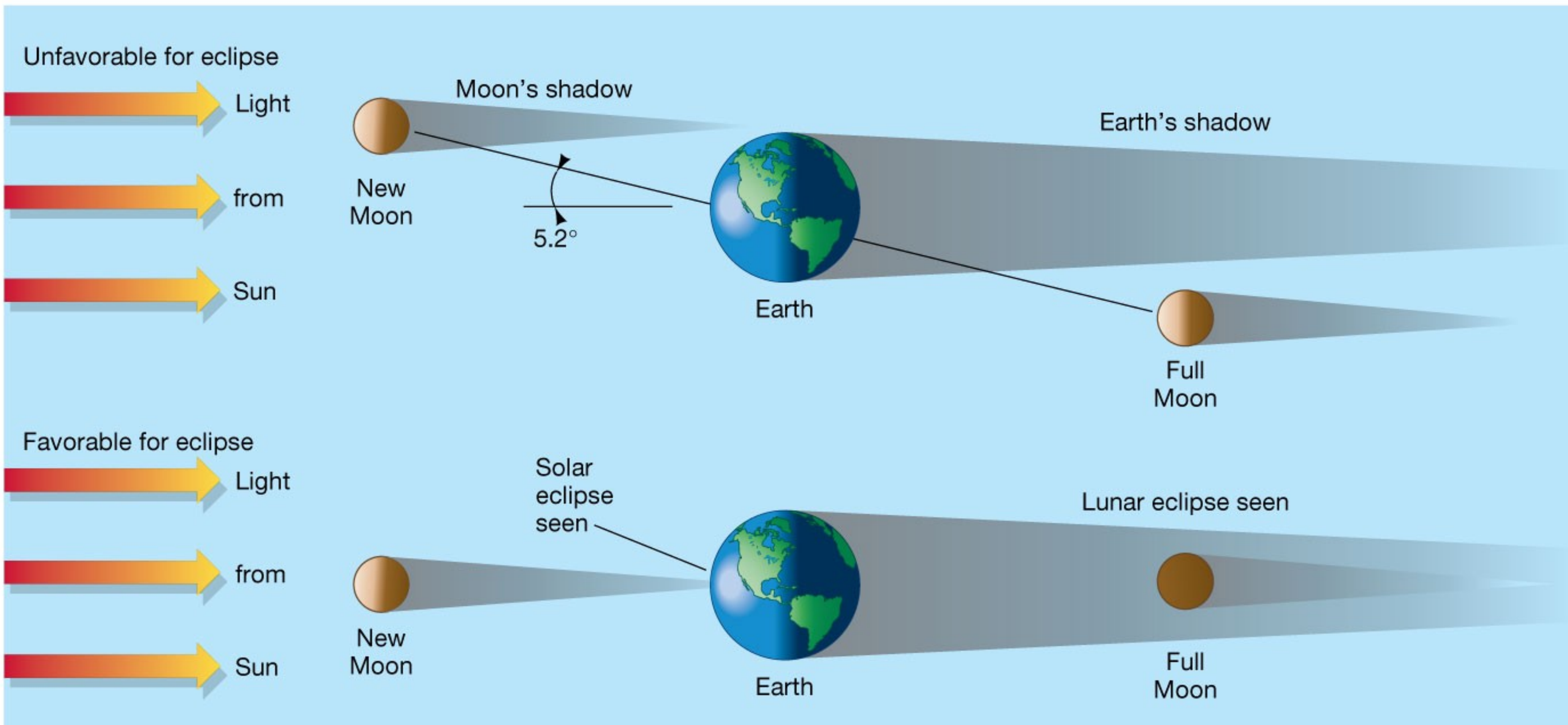
5. Reproduce a TSE on the Earth using the 3-inch sphere as the Earth and the 0.75-inch sphere as the Moon.

6. Reproduce a TLE using the 3-inch sphere as the Earth 0.75-inch sphere as the Moon.

VII. How are eclipses predicted?

Conditions for an *Eclipse*

Eclipses occur when the Earth, Moon, and Sun fall on (or nearly on) a straight line.



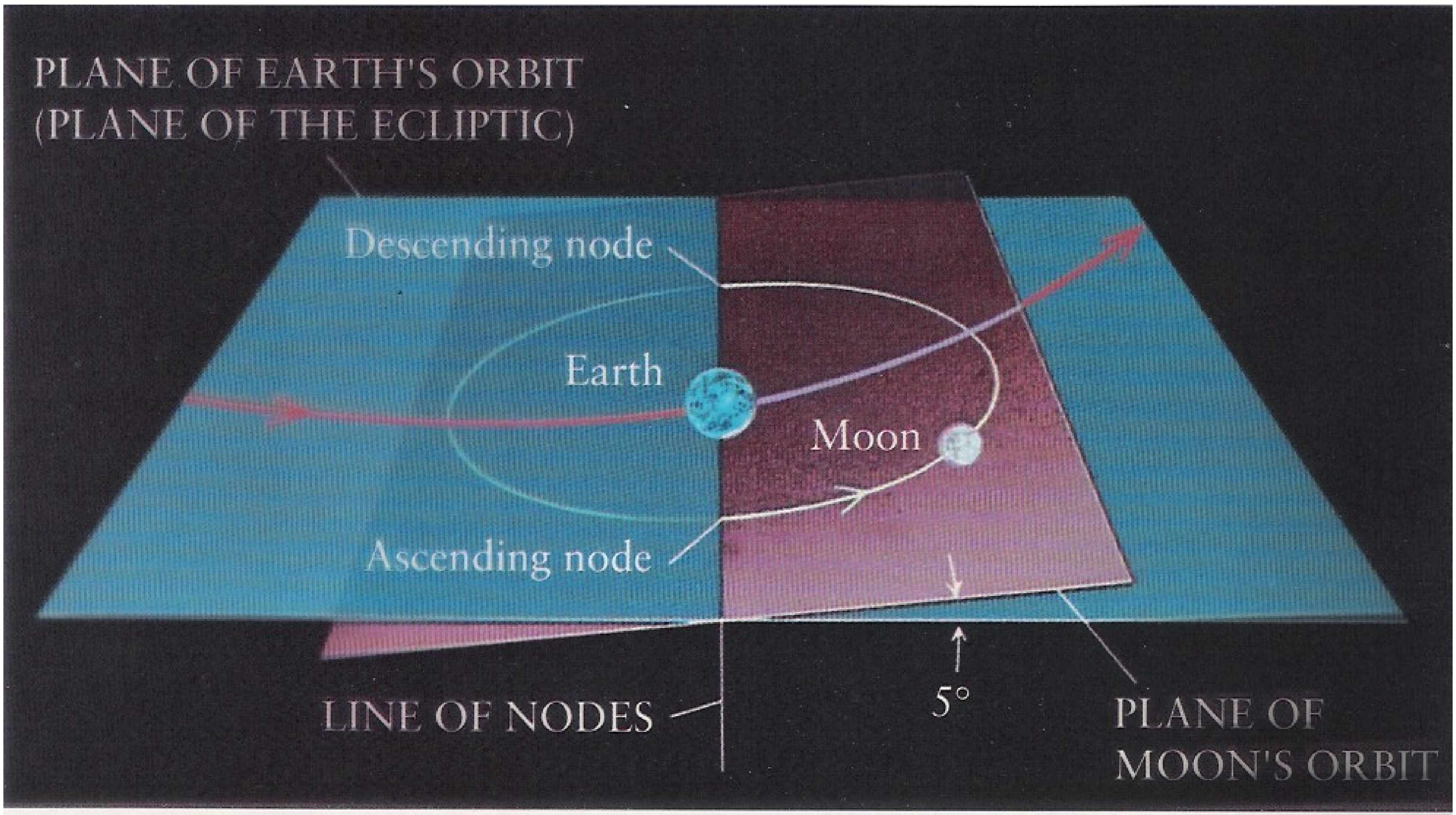
(a)

Note: *syzygy* = alignment of 3 celestial bodies on a line

Conditions for an eclipse

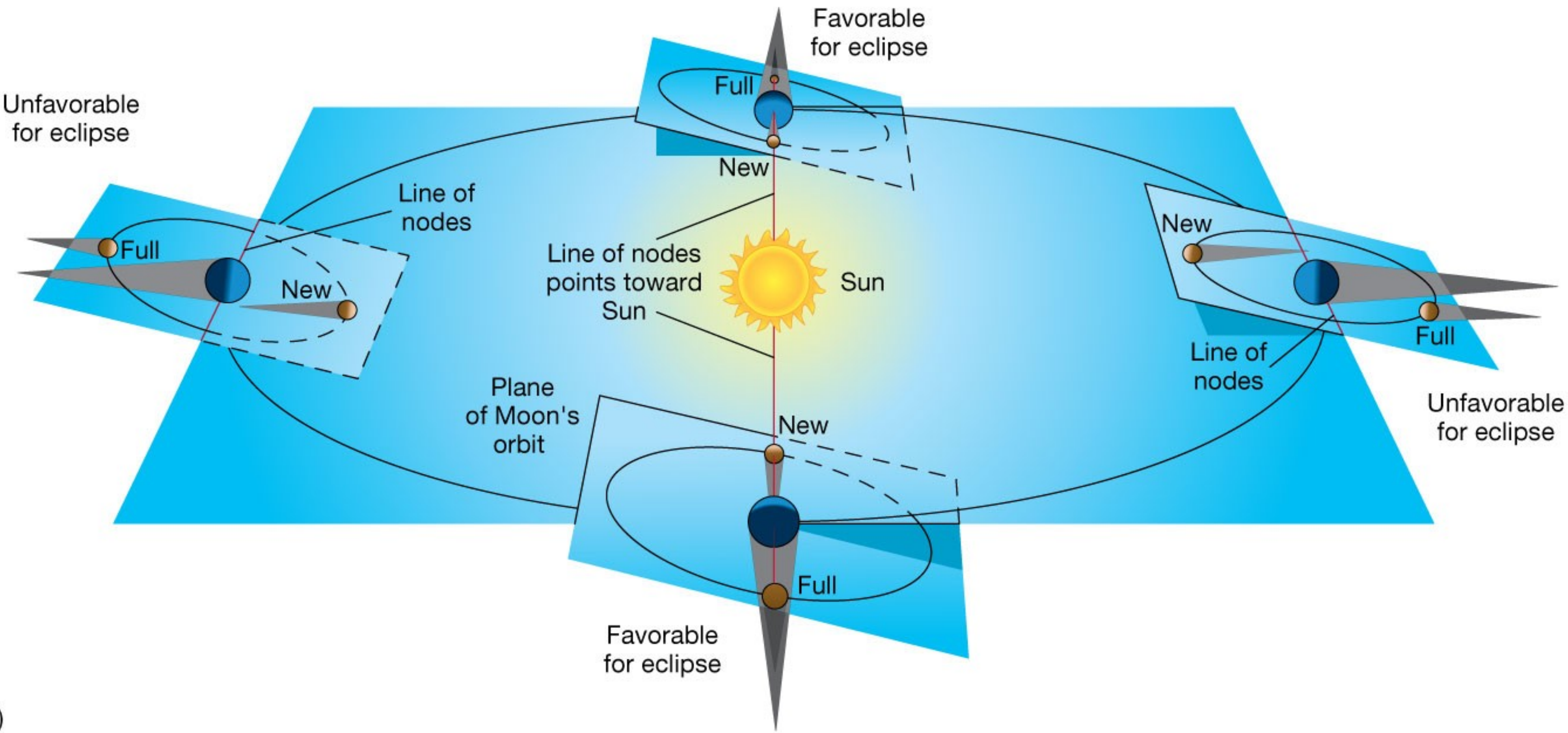
Moon's orbit intersects ecliptic plane at a *line of nodes*.

The line of nodes connects two points: an ascending node and a descending node.



Conditions for an *Eclipse*

Eclipses don’t occur every month because Earth’s and Moon’s orbits are not in the same plane



(b)

Predicting Eclipses

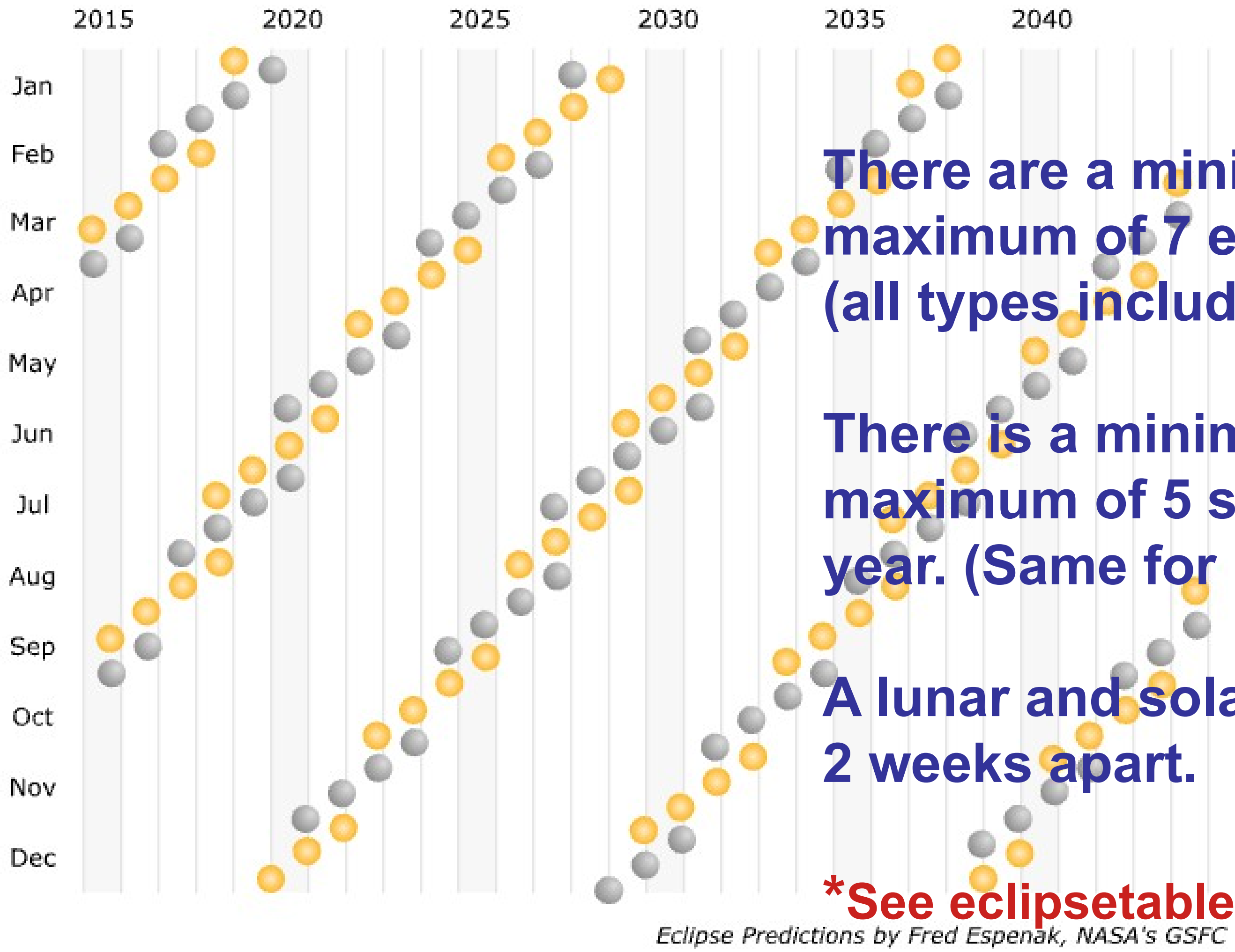
Eclipses happen during eclipse seasons which are ...
34.5 days in duration (on average)
5.7 months apart
(2x5.7=11.4 months in a Draconic year)

Every 18 yrs 11.33 days an eclipse will happen with the Moon in the same phase, node, and part of its orbit with respect to its perigee. This period of time is a *saros*.

Every 3 saros cycles (54 yrs 34 days), an eclipse will repeat on about the same place(s) on Earth. This is an *exeligmos* :)

Predicting Eclipses

Eclipse Seasons*.



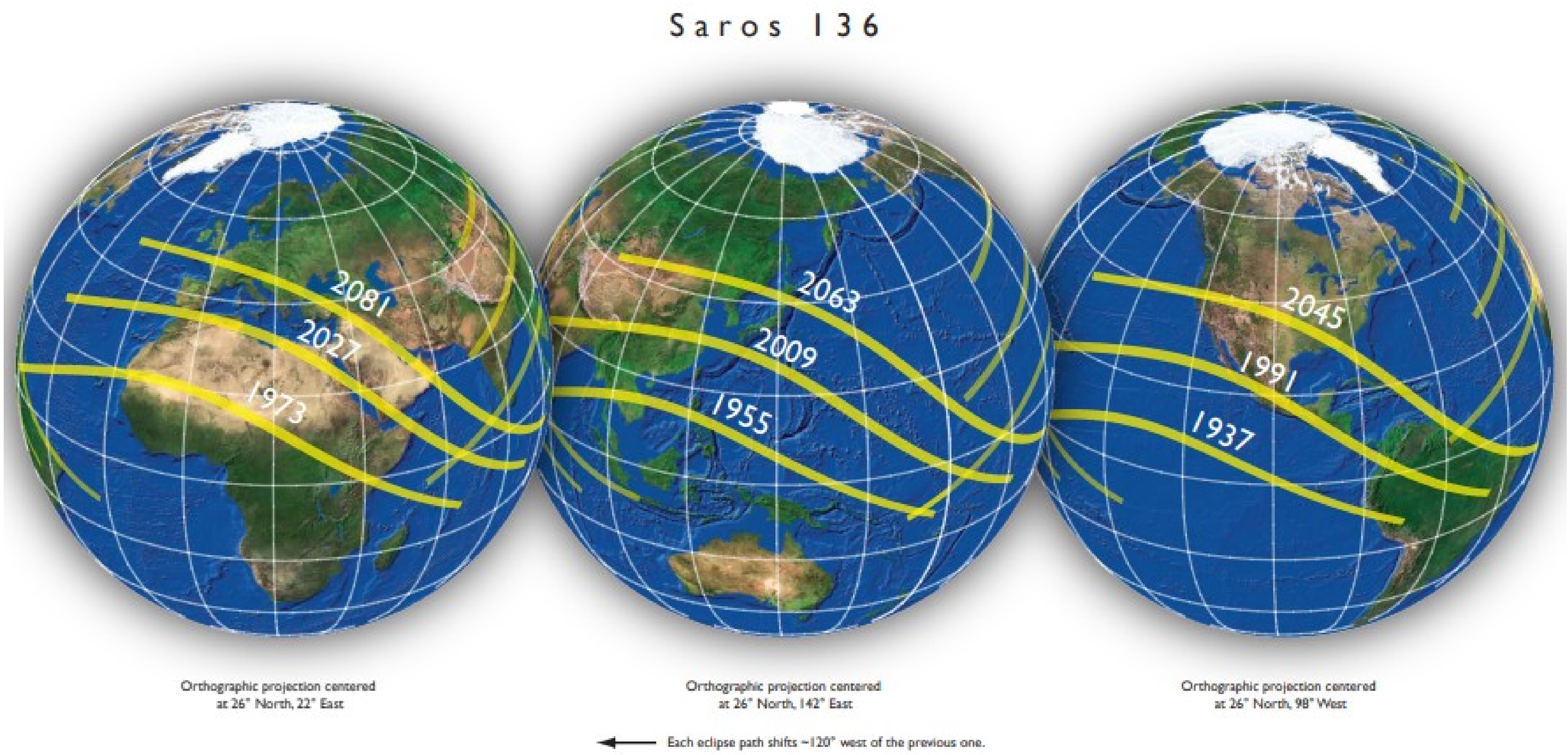
There are a minimum of 4, and a maximum of 7 eclipses per year (all types included).

There is a minimum of 2, and a maximum of 5 solar eclipses per year. (Same for lunar.)

A lunar and solar eclipse are often 2 weeks apart.

***See eclipsetable.swf**

Predicting Eclipses

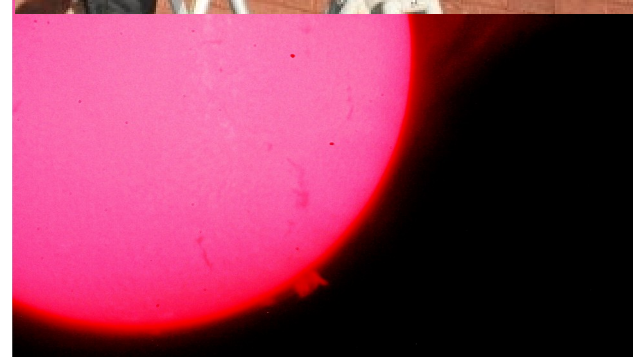


Saros 136 will produce 71 eclipses over 1262 yrs (8part,6annul,6hyb,44tot,7part)

Observing a Solar Eclipse

Telescope with continuum solar filter.

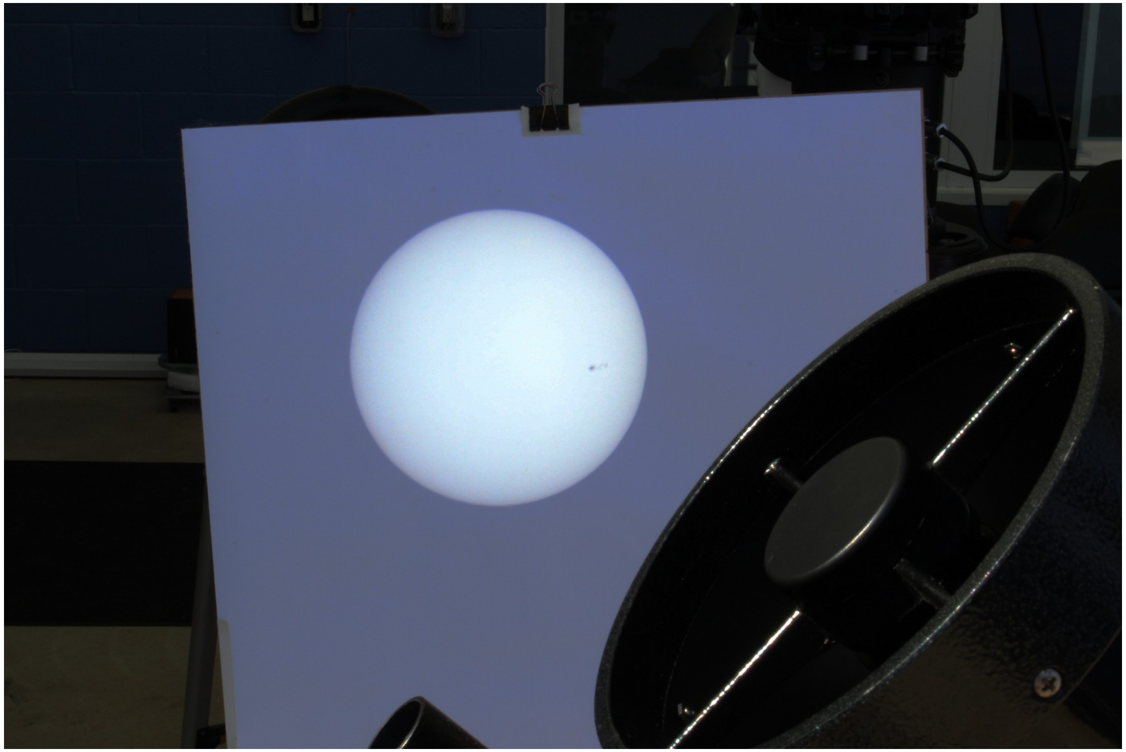
Telescope with narrow band solar filter.



Telescope projected onto screen

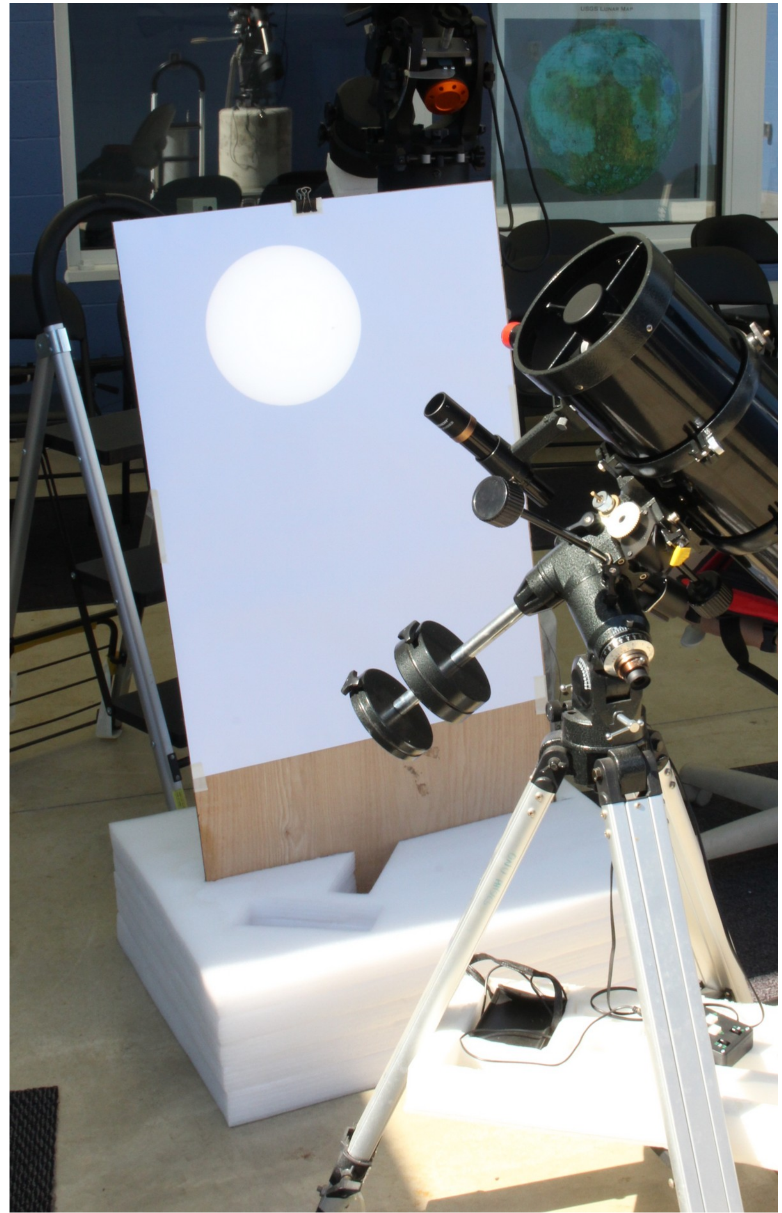
Observing a Solar Eclipse

Telescope projected onto screen



Observing a Solar Eclipse

Telescope projected onto screen



Observing a Solar Eclipse

Telescope projected onto “sun funnel”.