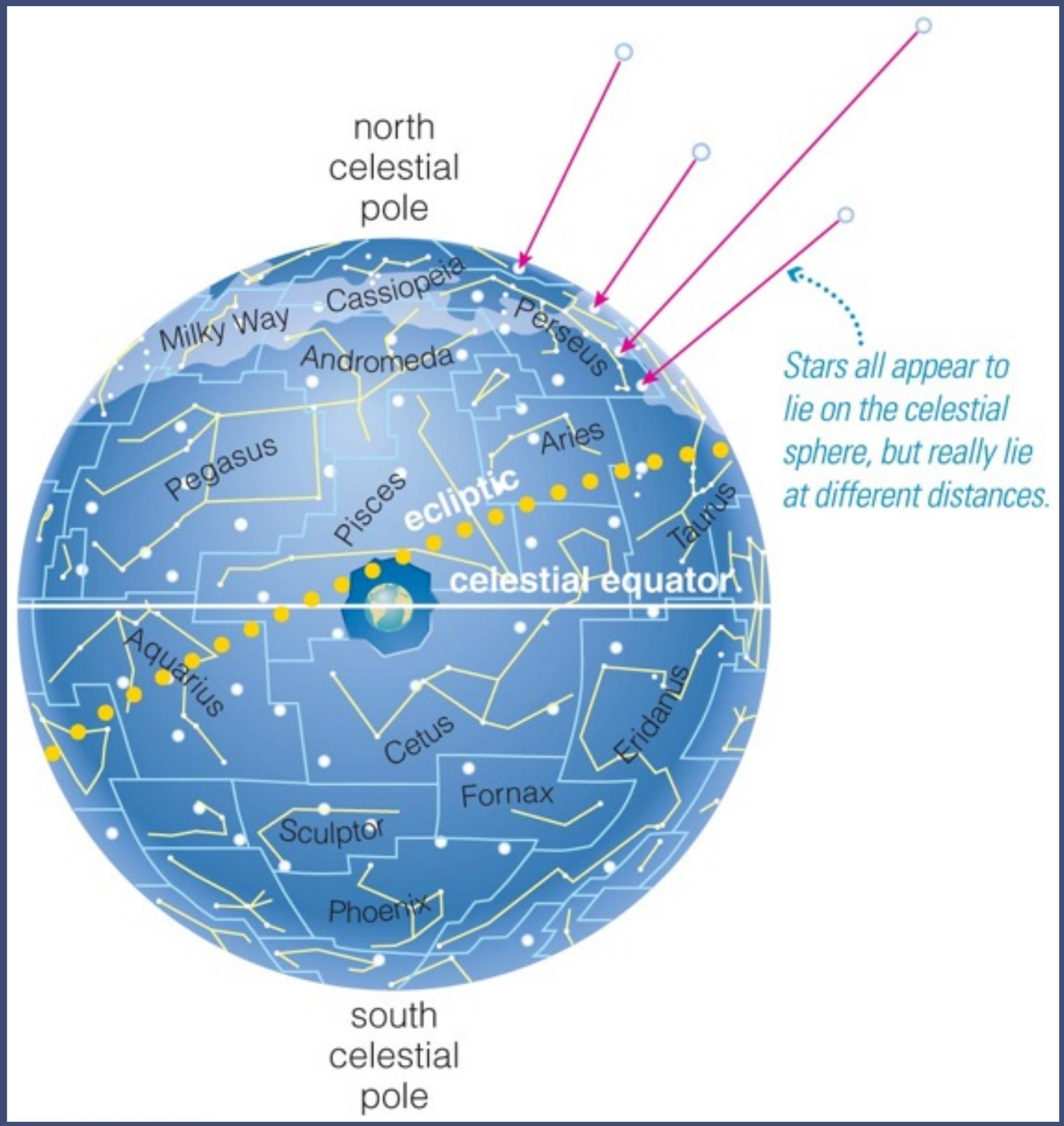
# Astrometry

- Measuring the positions & motions of celestial objects
  - –Positions:
    - Right ascension & declination
    - Constellations

# Celestial Sphere

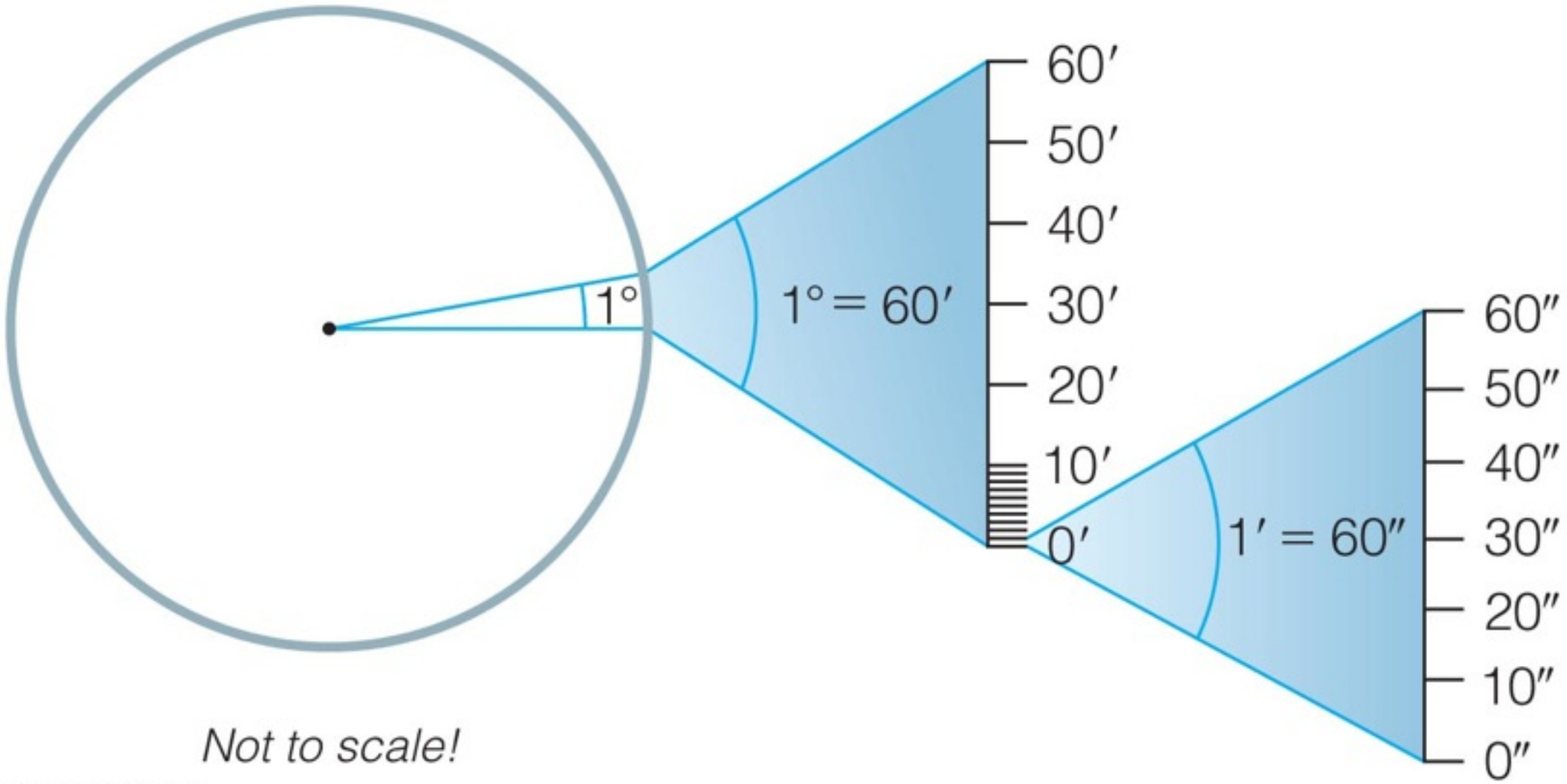
- Ancient astronomers actually believed all celestial objects were rigidly attached to crystal spheres

# Celestial Sphere

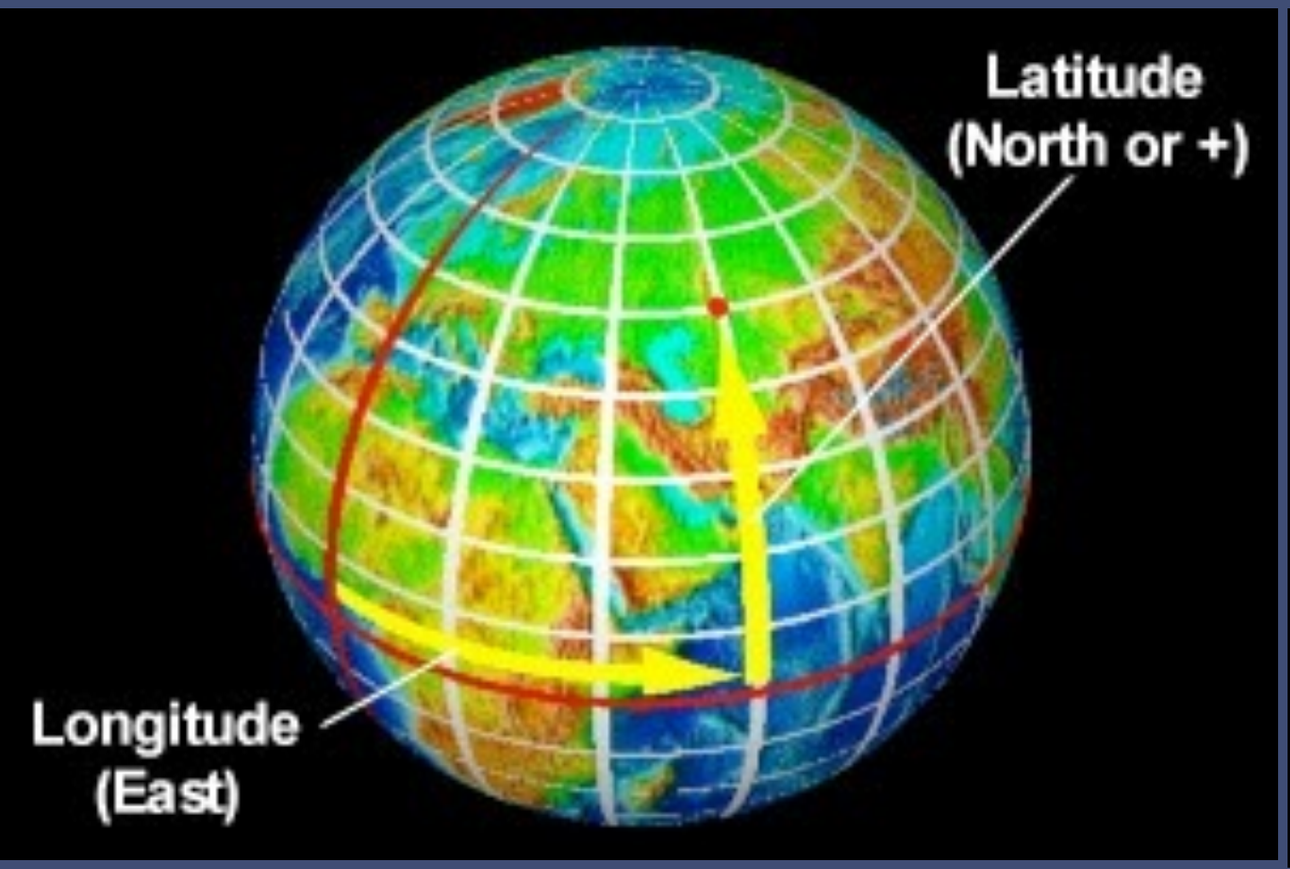


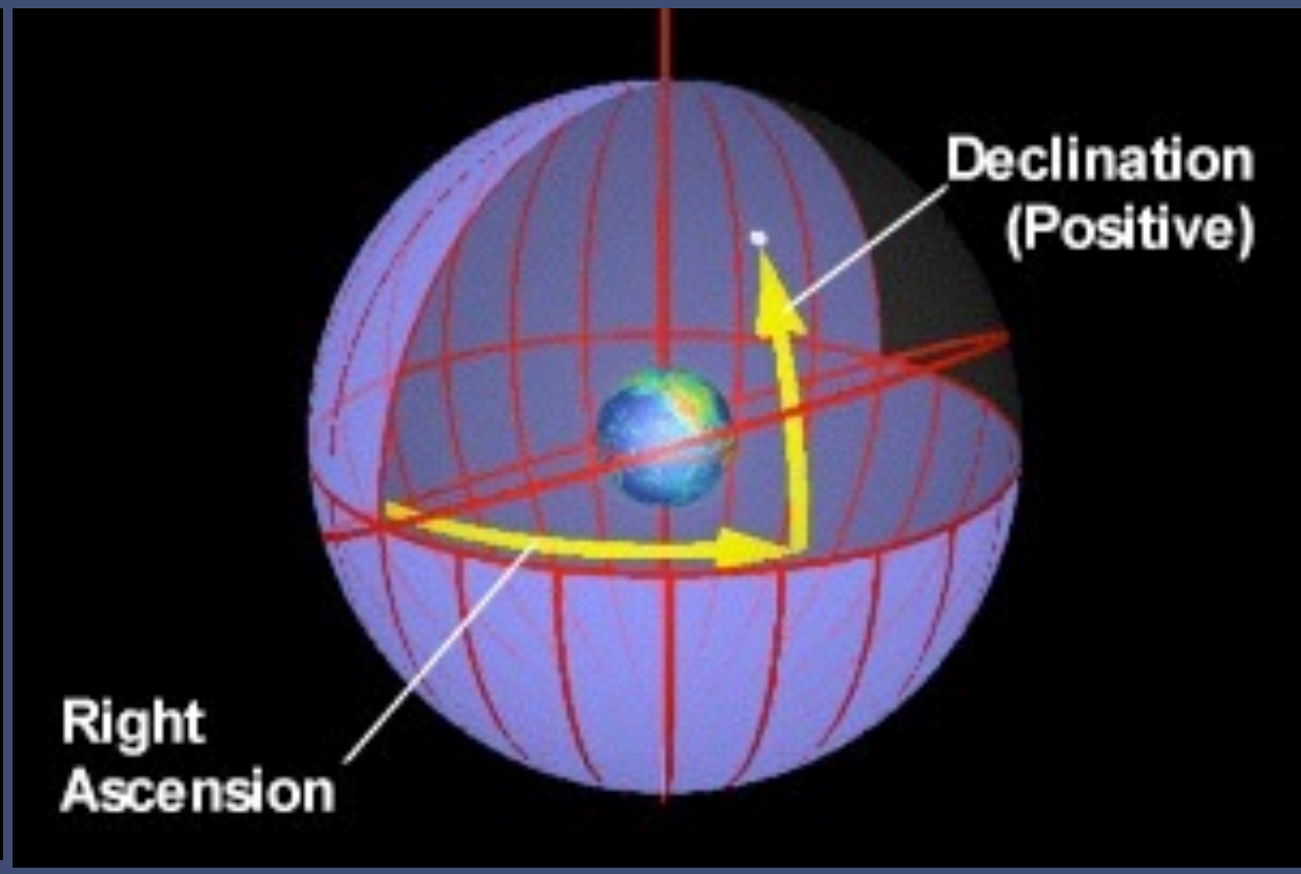
# Angular Measurements

- Full circle = 360º
- 1º = 60′ (arcminutes)
- 1′ = 60″ (arcseconds)



# Equatorial Coordinate System

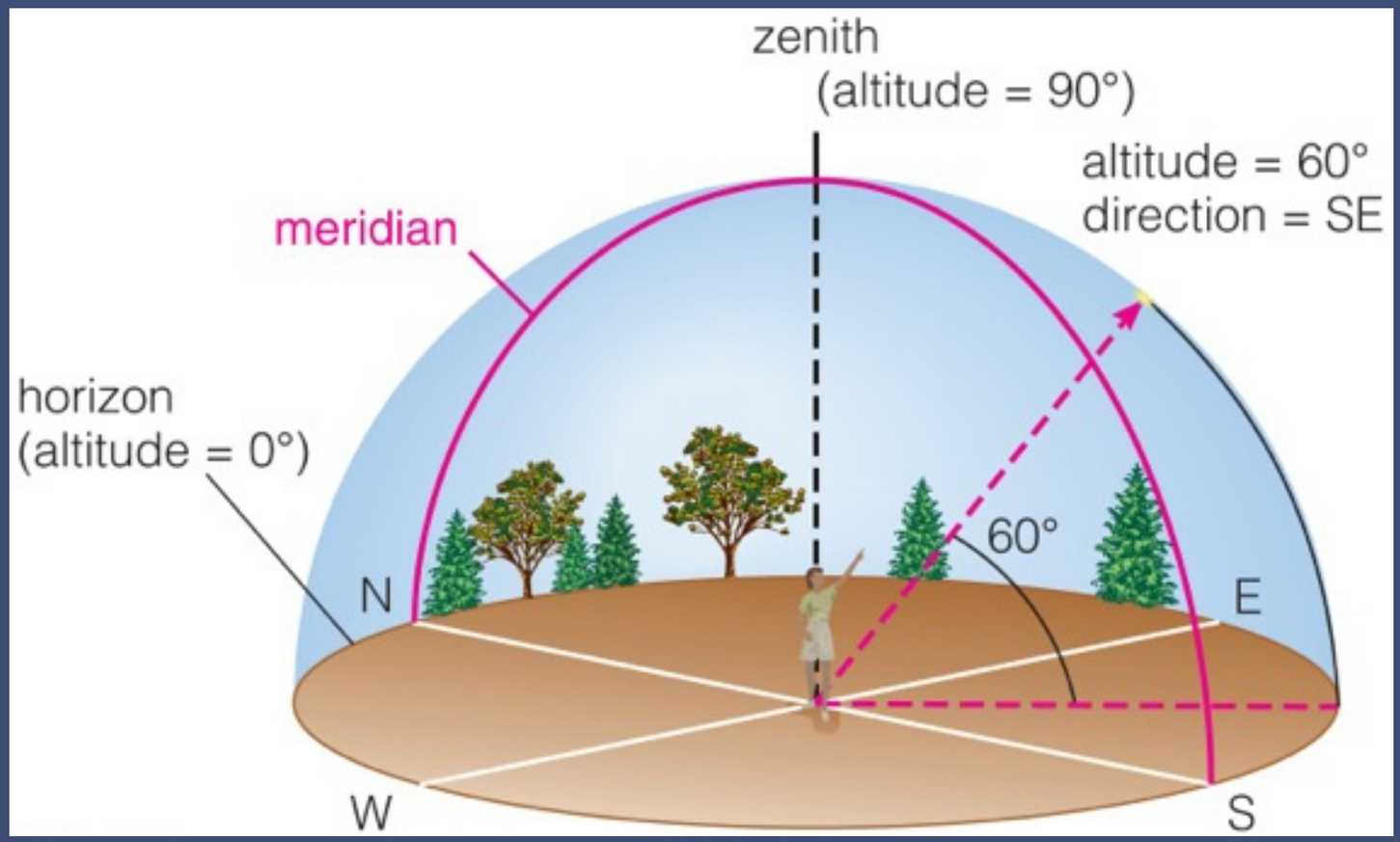



- Earth globe
  - latitude (North/South)
  - longitude (East/West)

- Celestial sphere
  - declination (+/-)
  - right ascension
    - measured in hours (0-24)
    - also called “hour lines”

# Horizon Coordinate System




- Azimuth
  - –angle measured from intersection of celestial meridian and horizon (measured along horizon)
- Altitude (also called Elevation)
  - –measured “up” from horizon toward zenith
- Celestial Meridian
  - –Great circle passing through North & South points of horizon and observer’s zenith

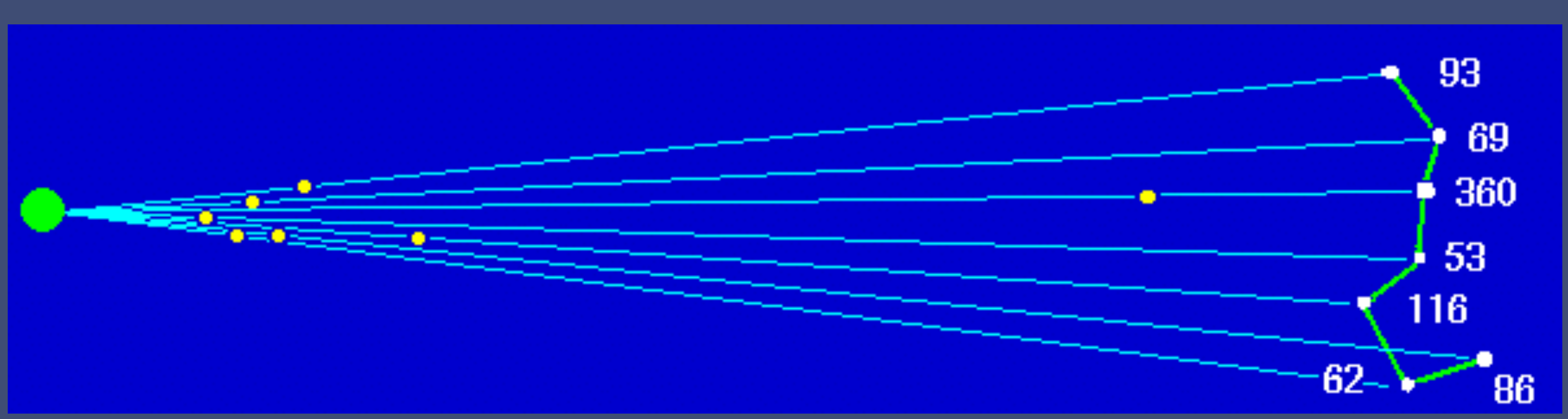
# Constellations



- 88 constellations arranged in a patchwork that covers the entire sky
- Astronomers often refer to stars by what constellation they are in
  - $\alpha$ Cen (1st star in Centaurus), $\beta$ Ori (2nd star in Orion)

# Constellations

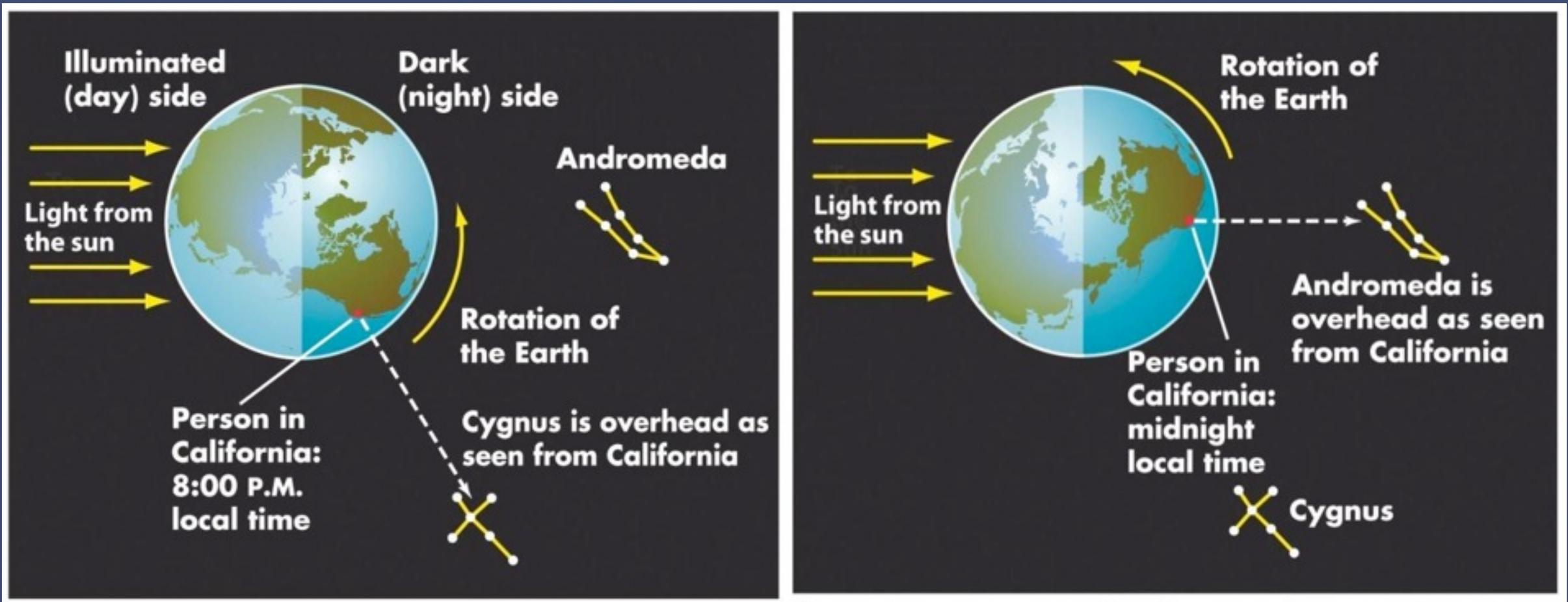
- Although stars in constellations appear close together in the sky, they may, in reality, be quite far apart




distances to stars in Big Dipper (ly)

# Diurnal Motion

- Daily movement of celestial objects (Sun, Moon, stars)
- Rise in the East, set in the West
- Caused by Earth's rotation



# Diurnal Motion

(a) At middle northern latitudes

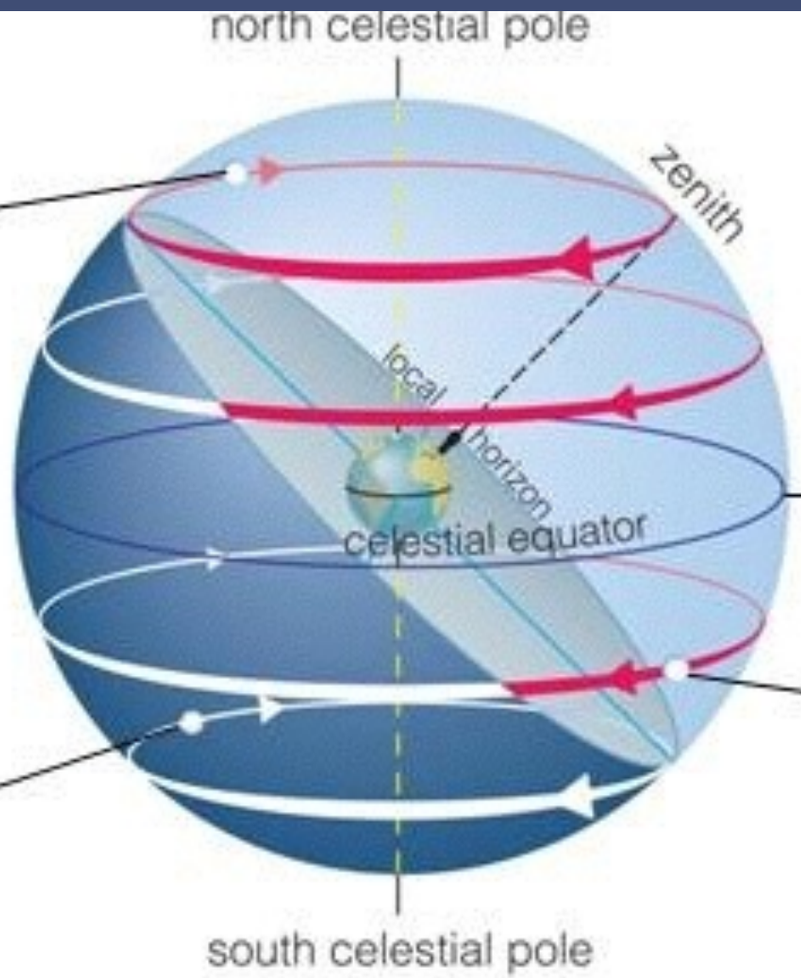
(b) At the north pole

(c) At the equator

- What is significant about the angle that the star streaks make with the horizon?
  - –It is equal to the zenith angle of the North Star

# Diurnal Motion

A circumpolar star never sets.




Celestial Equator

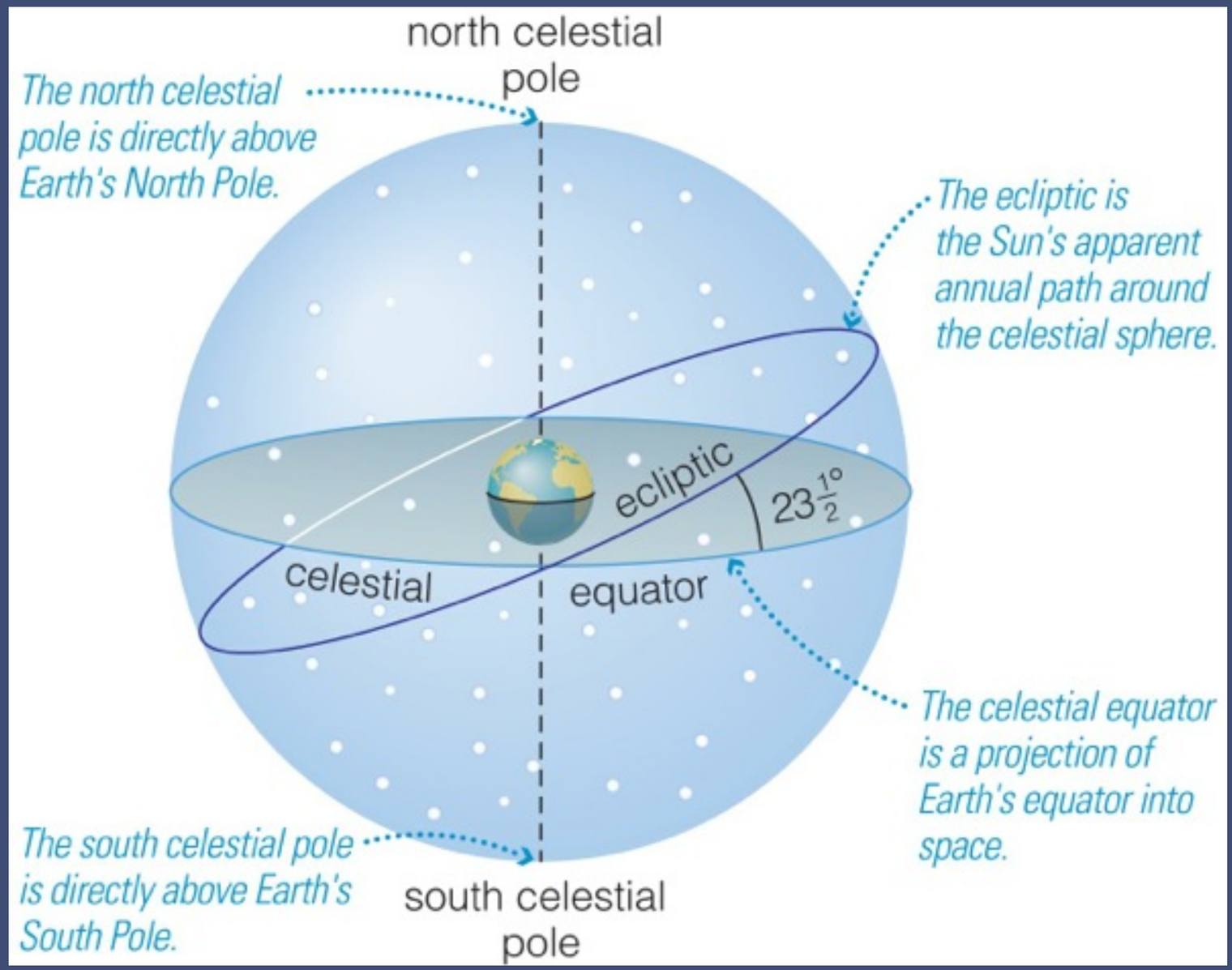
Your Horizon

A star below your horizon never rises.

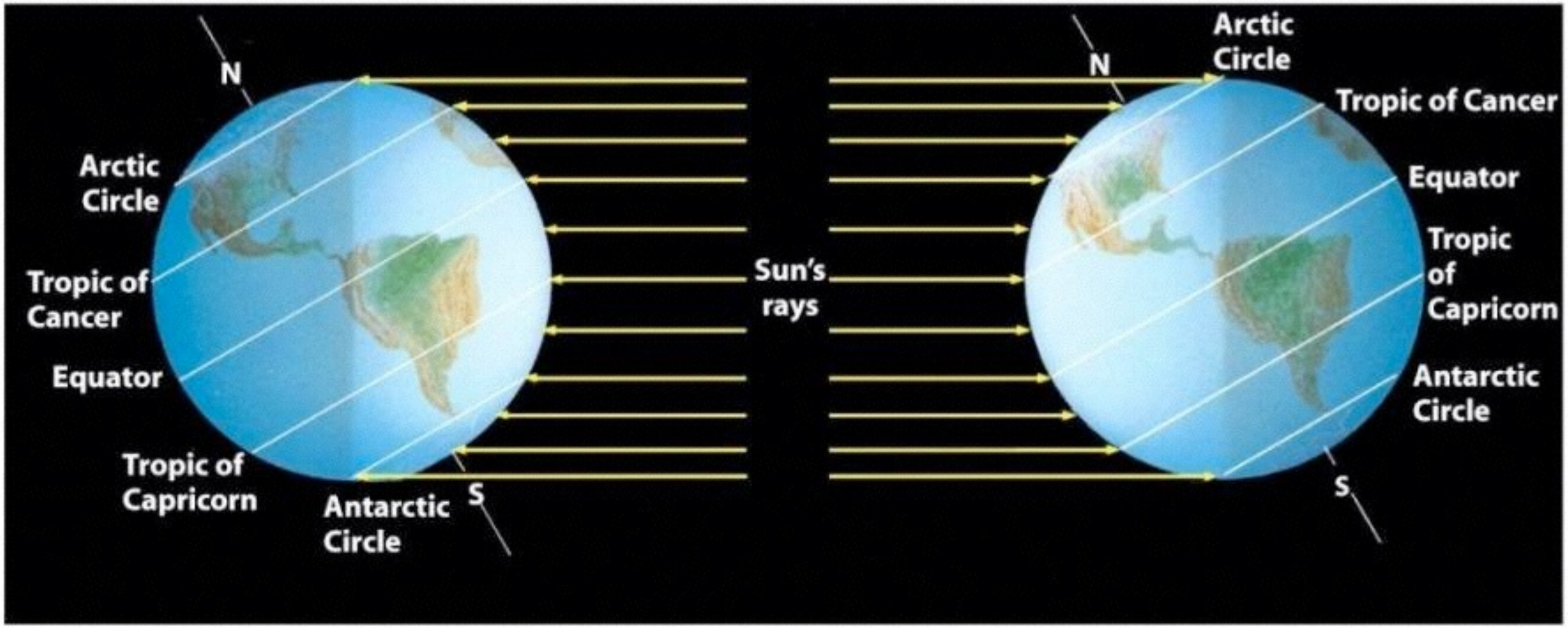
# Ecliptic

- Sun's apparent path on the celestial sphere
- Why is this related to seasons?

vernal equinox – Mar 21
autumnal equinox – Sep 22
summer solstice – Jun 21
winter solstice – Dec 21



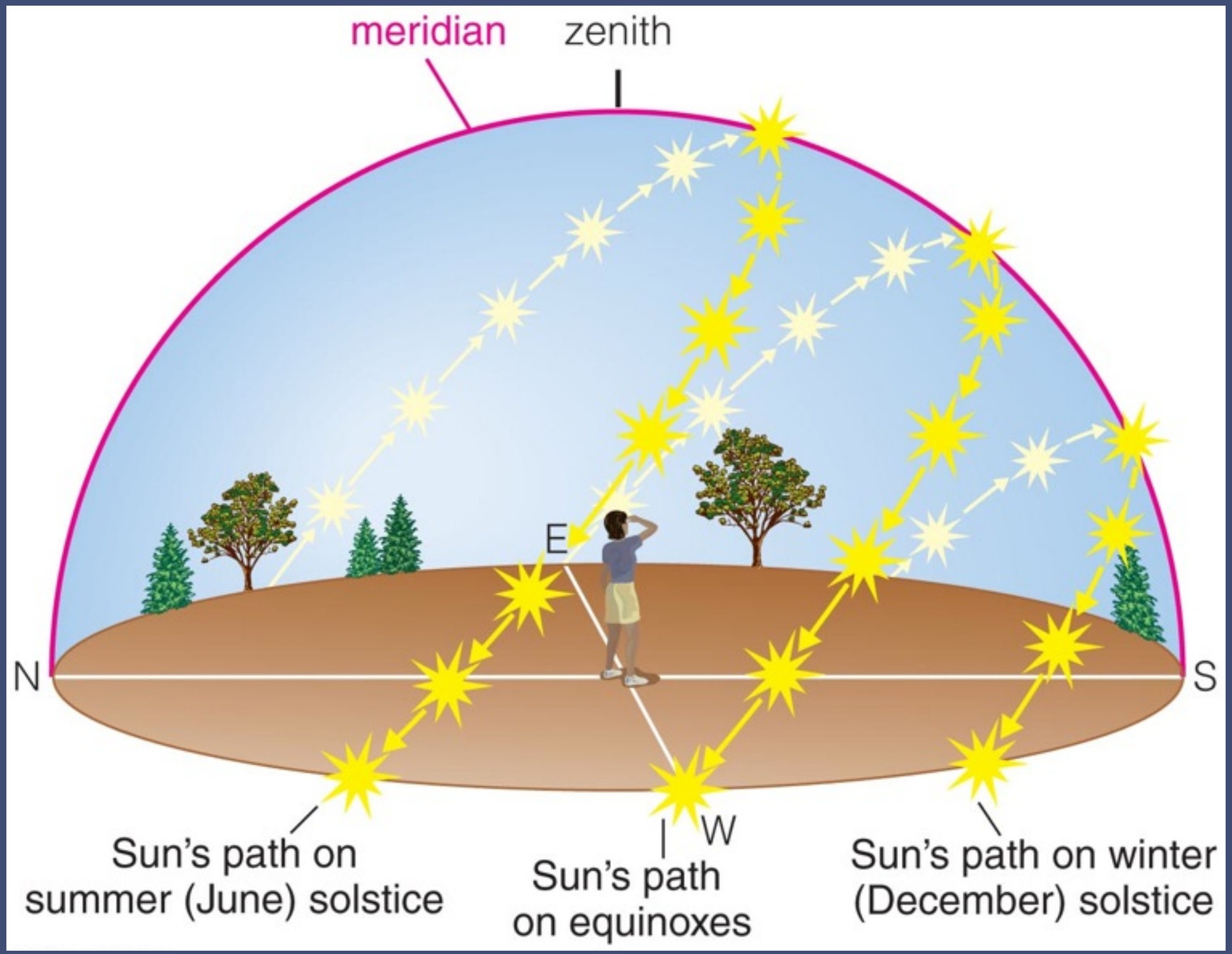
# Seasons
# A Geocentric Point of View



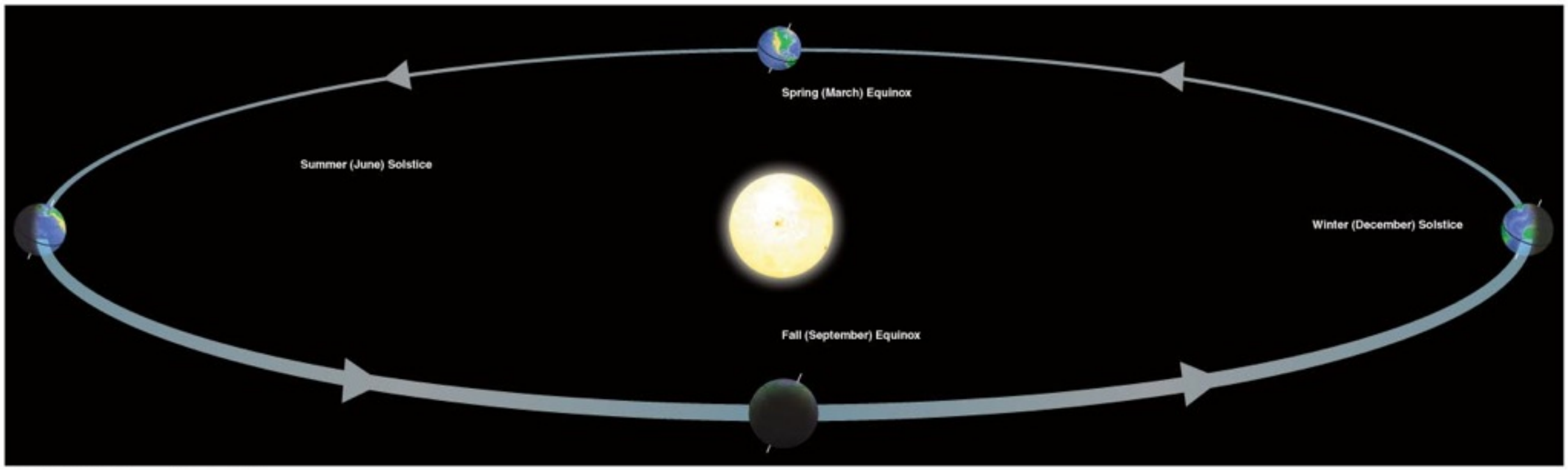

(a) Earth at winter solstice

(b) Earth at summer solstice

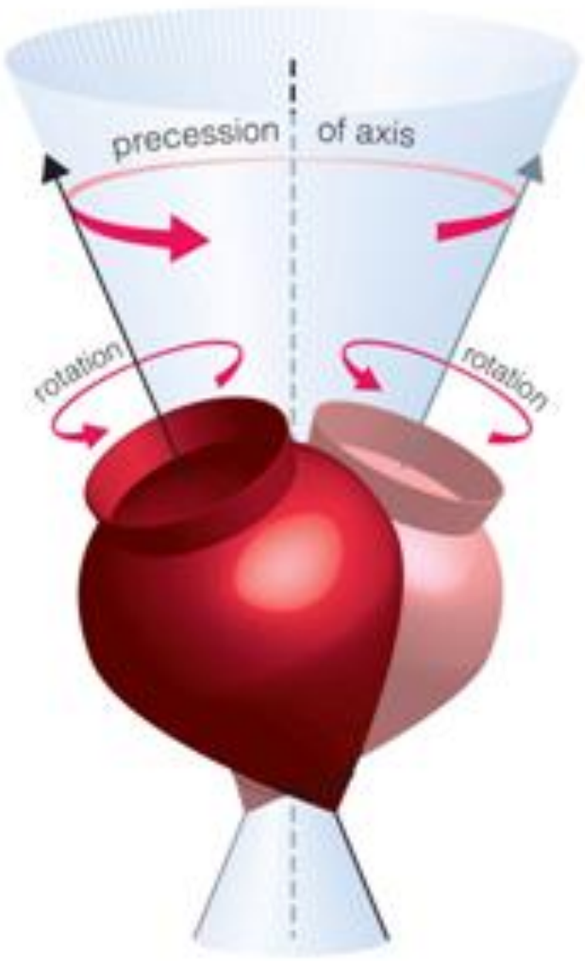
# Seasons
# A Geocentric Point of View



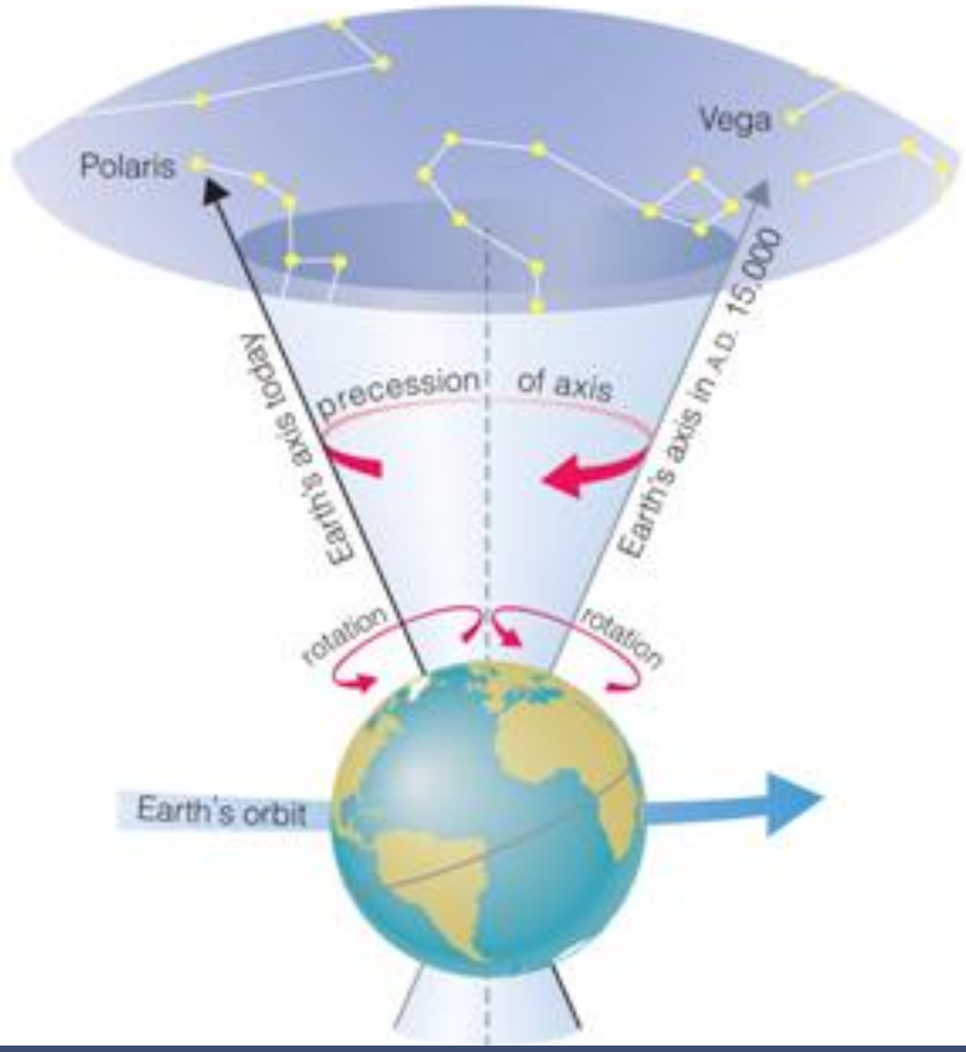
# Seasons
# A Heliocentric Point of View



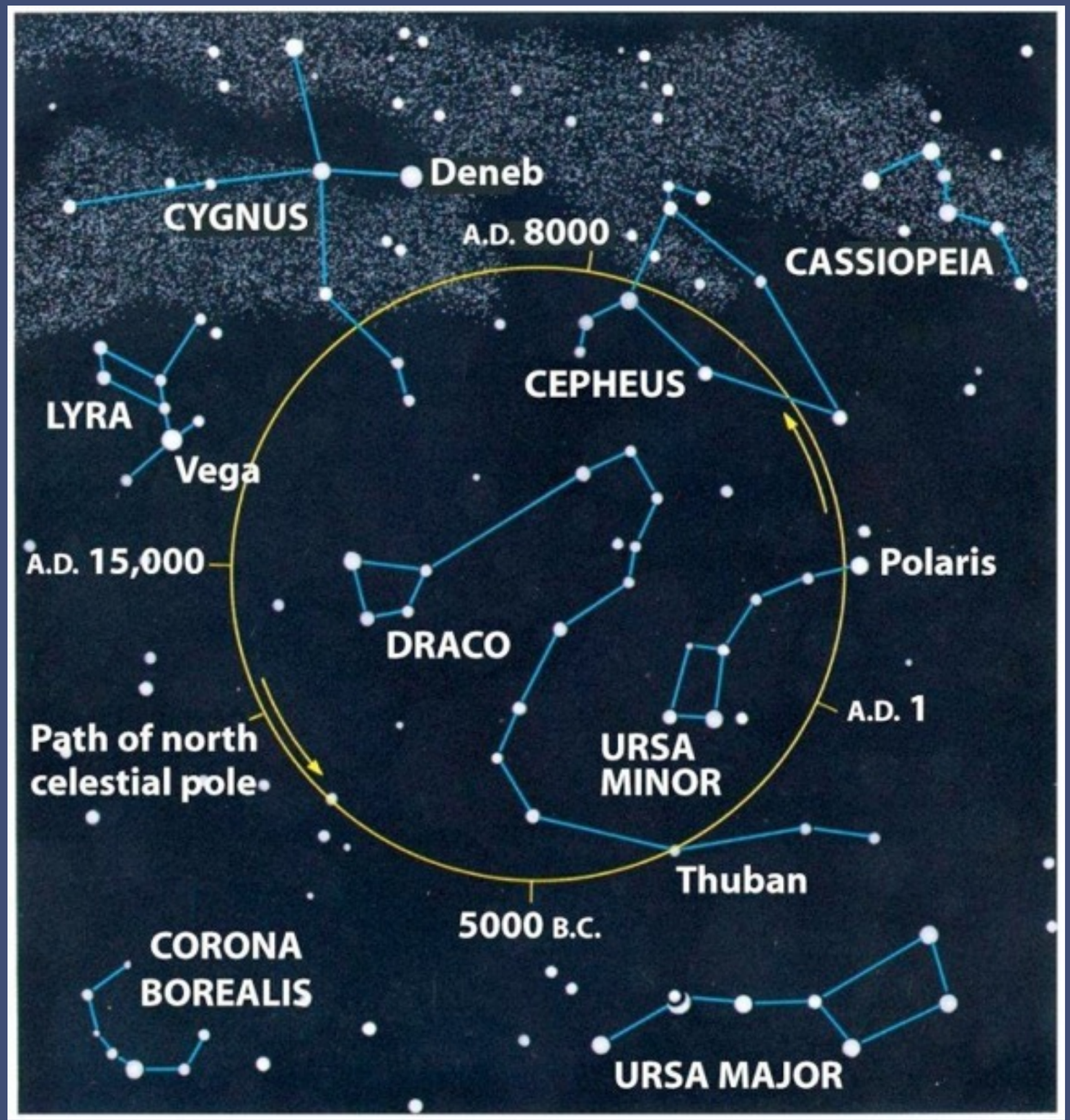
# Earth’s Precession



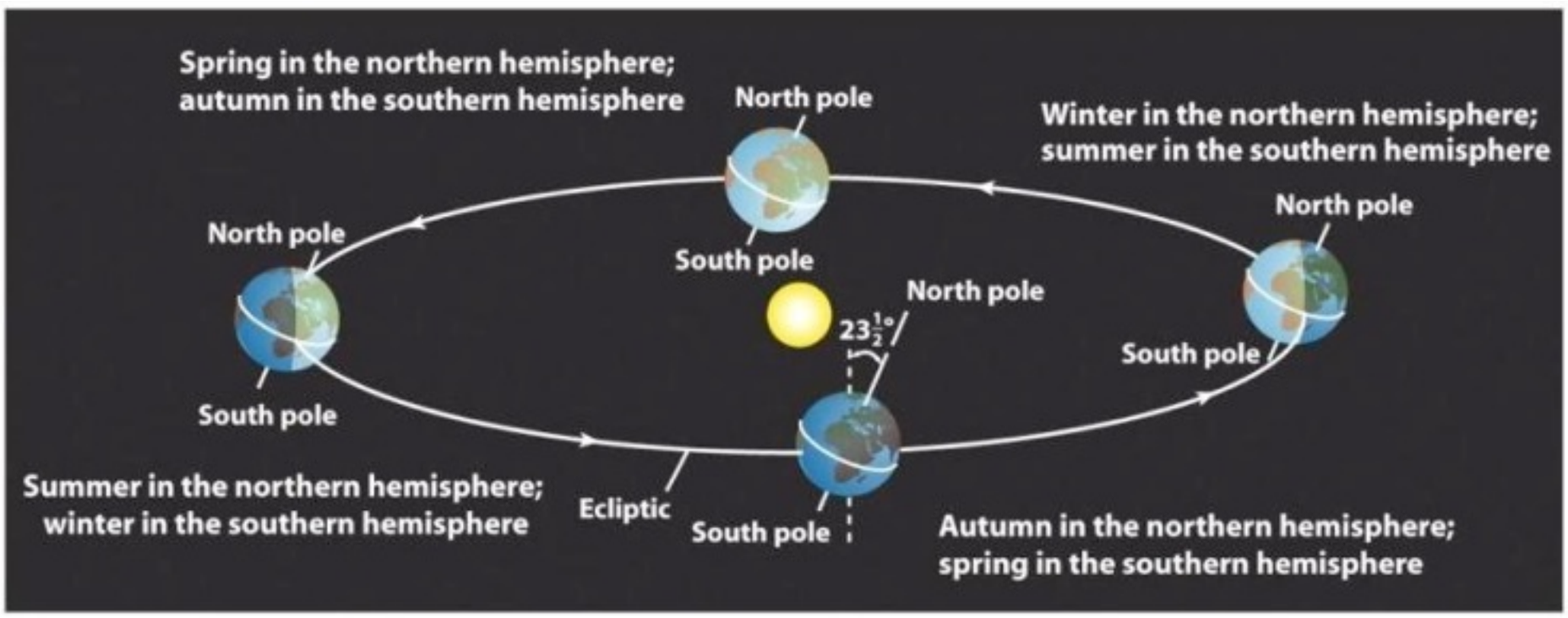

Earth's axis precesses like the axis of a spinning top



# Earth's Precession



# Earth's Precession





- In 13,000 years a winter constellation like Orion will be a summer constellation
- In about 12,000 years the zodiac will be 6 months out of sync
- Precession is accounted for in western calendars so that the start of spring will always be around Mar 21

# Moon Phases

- New Moon
  - –start of lunar cycle
  - –face of Moon is dark
- Waxing crescent
  - –waxing means “growing bigger”
  - –crescent means “horn shaped”
- First quarter
  - –western half of Moon’s face is illuminated

# Moon Phases

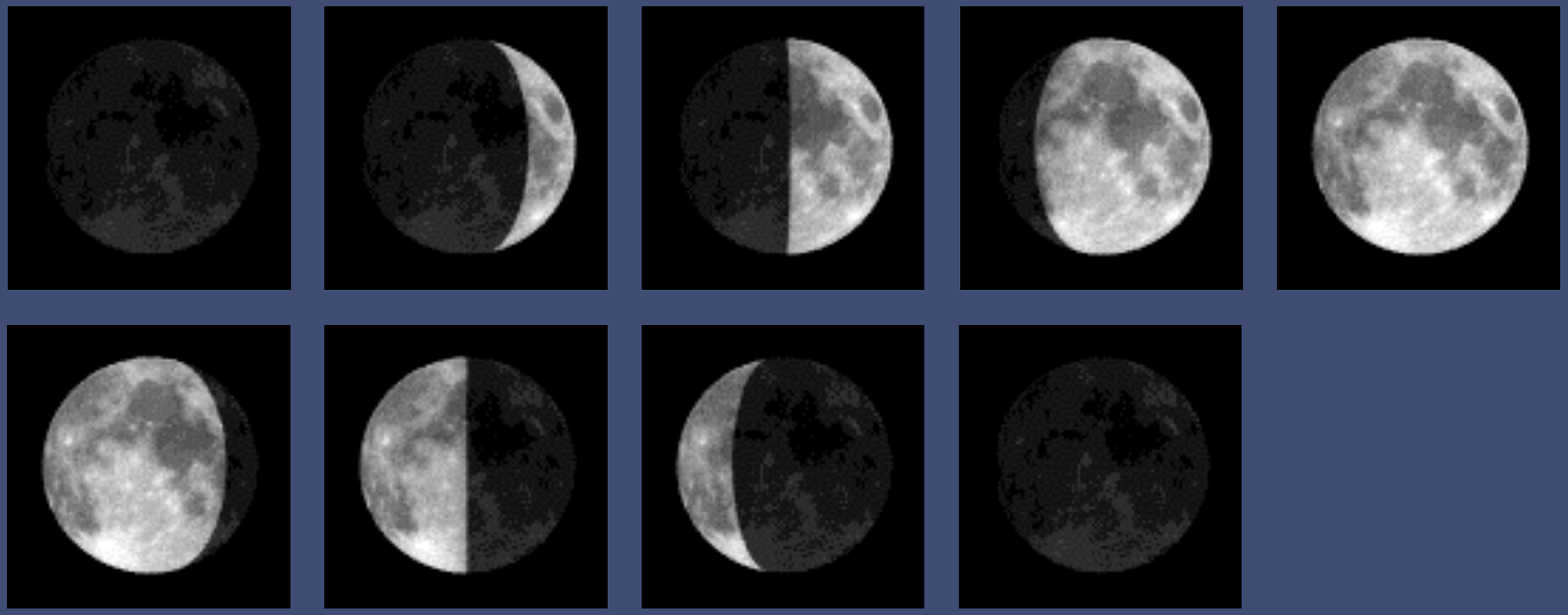
- Waxing gibbous
  - –gibbous means “swollen”
  - –Moon is getting closer to full
- Full Moon
  - –entire face of Moon is lit up
- Waning gibbous
  - –waning means “getting smaller”

# Moon Phases

- Third Quarter
  - –eastern half of Moon's face is illuminated
- Waning crescent
  - –Moon is growing smaller each night, approaching New Moon
- New Moon
  - –start of a new lunar cycle

# Face of the Moon

# Face of the Moon



- Surface features don’t change with phases
  - We always see the same side (or hemisphere) of the Moon
  - Why? What does this tell us?
  - Synchronous rotation

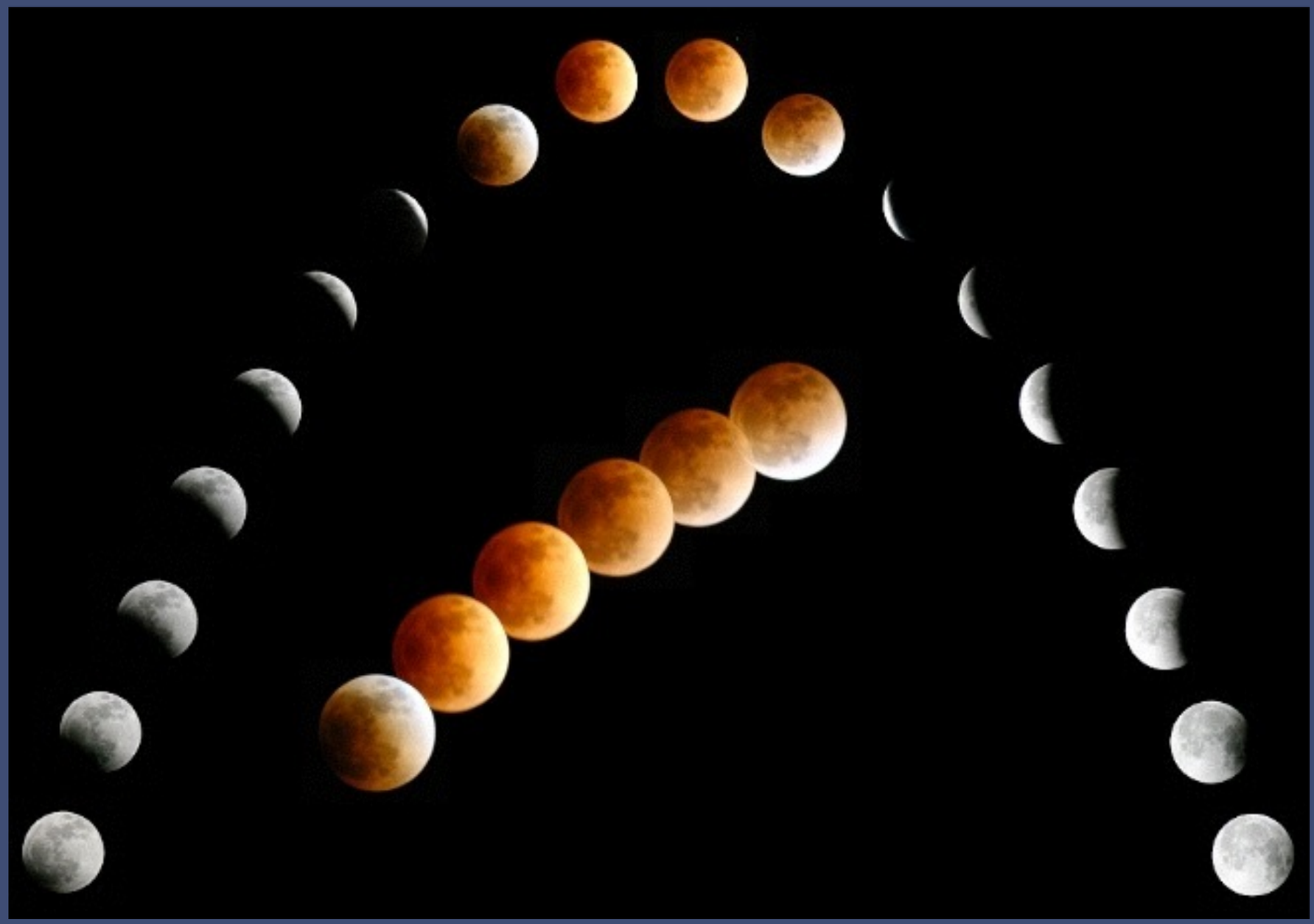
# Eclipses

- Lunar eclipse

8 November 2003

# Eclipses

- Lunar eclipse



4 May 2004, Greece

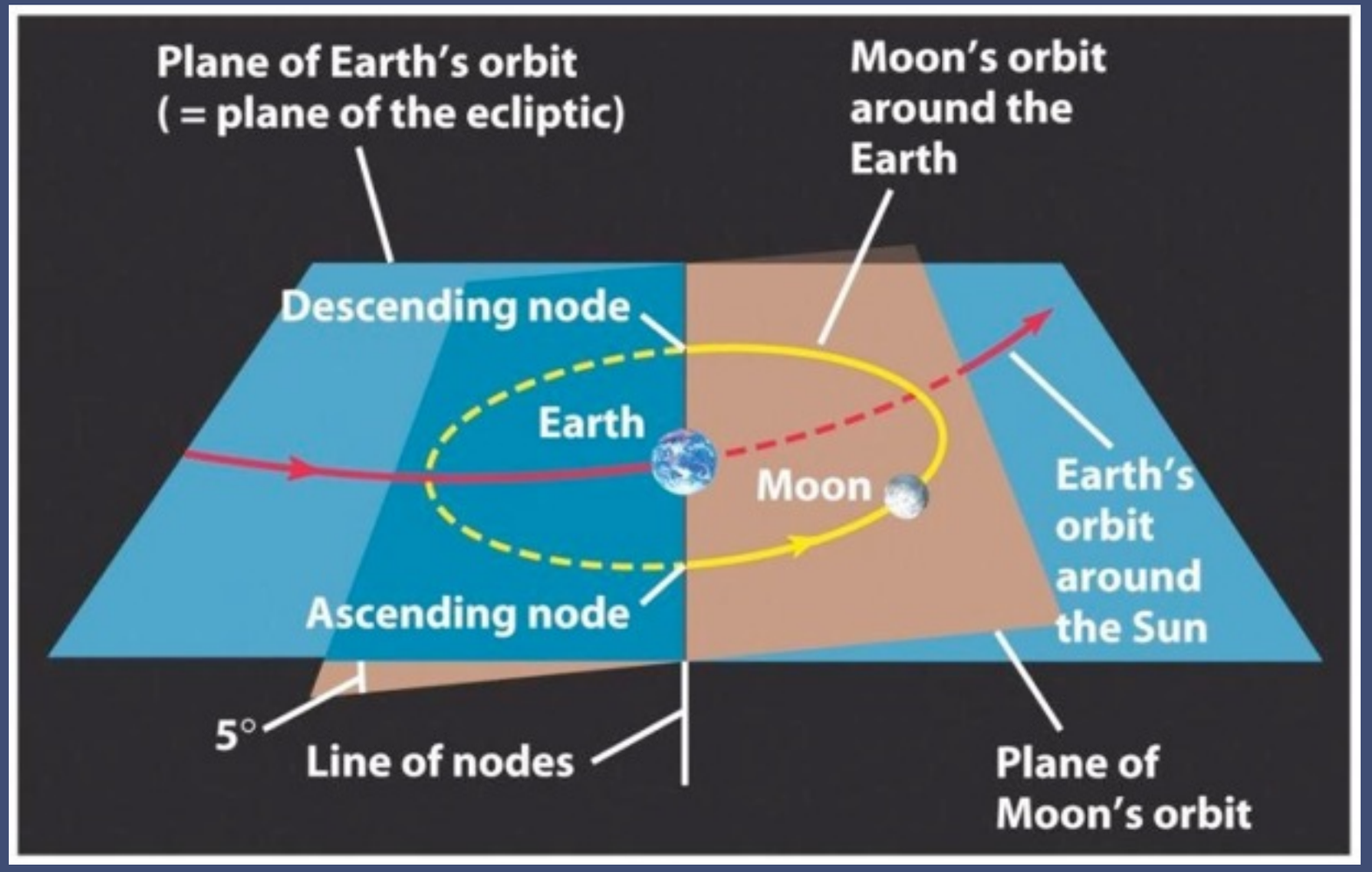
# Eclipses

- Solar eclipse

29 Mar 2006, Turkey

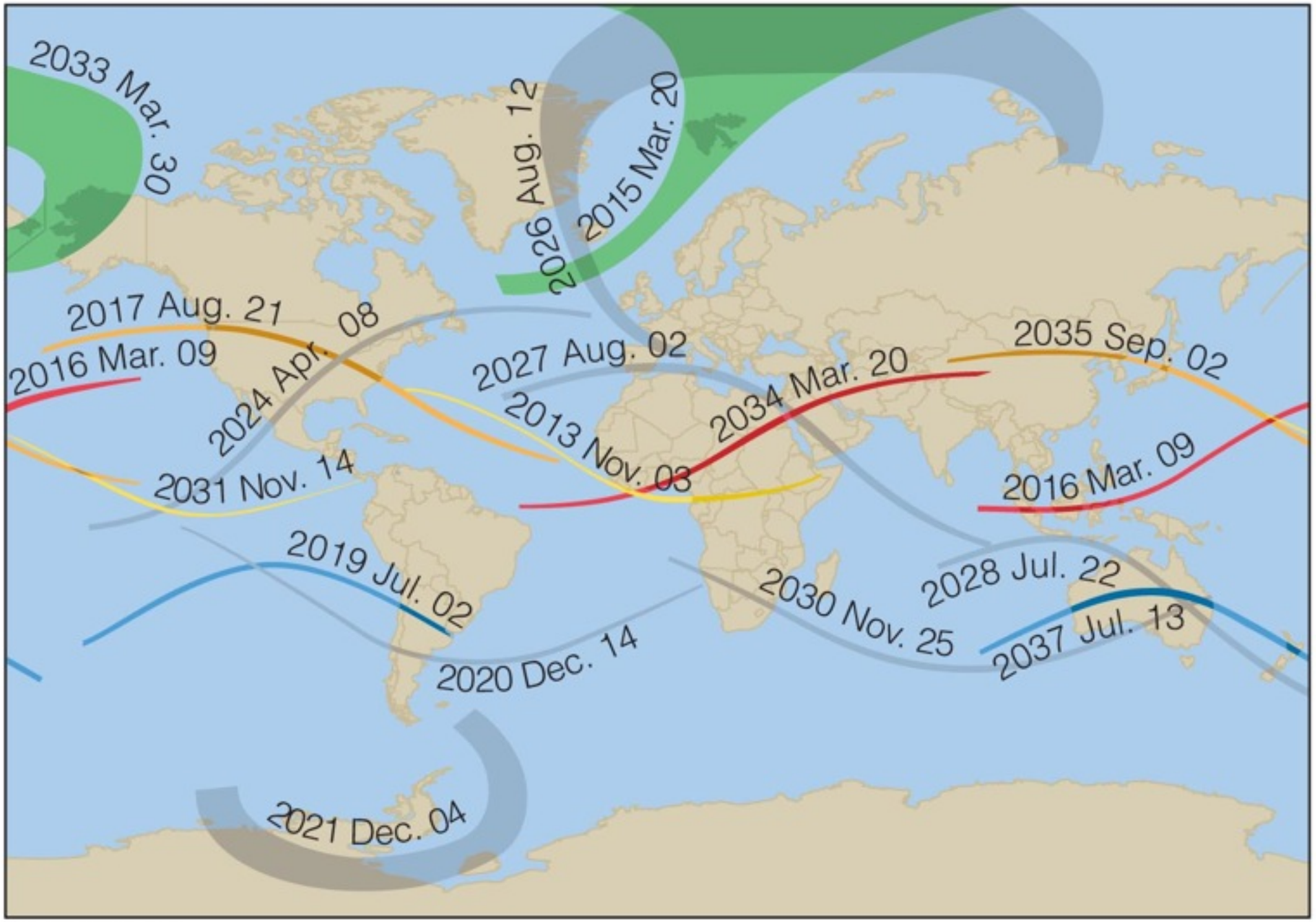
# Eclipses

- Can only occur when:
  1) There is a full or new Moon
  2) The Moon is crossing the ecliptic (hence the name eclipse)



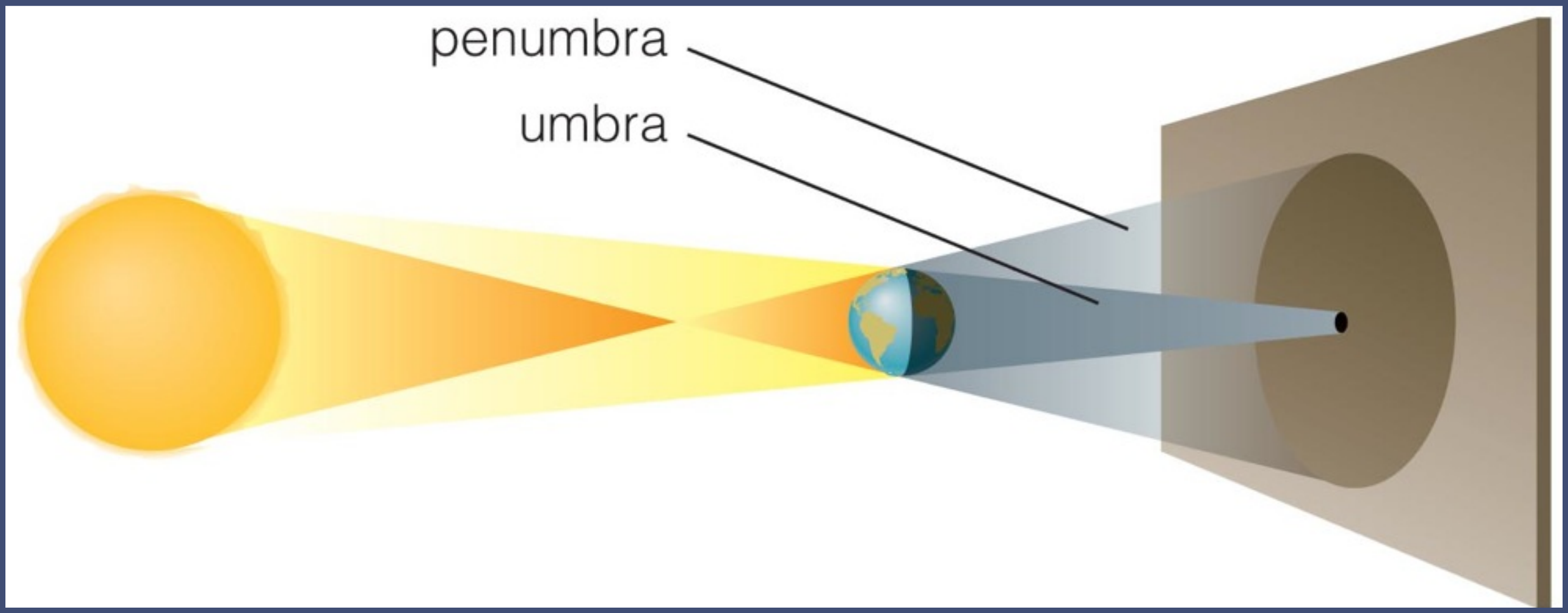
# Predicting Eclipses

- Eclipses recur with the 18-year, 11 1/3-day **saros cycle**, but type (e.g., partial, total) and location may vary.

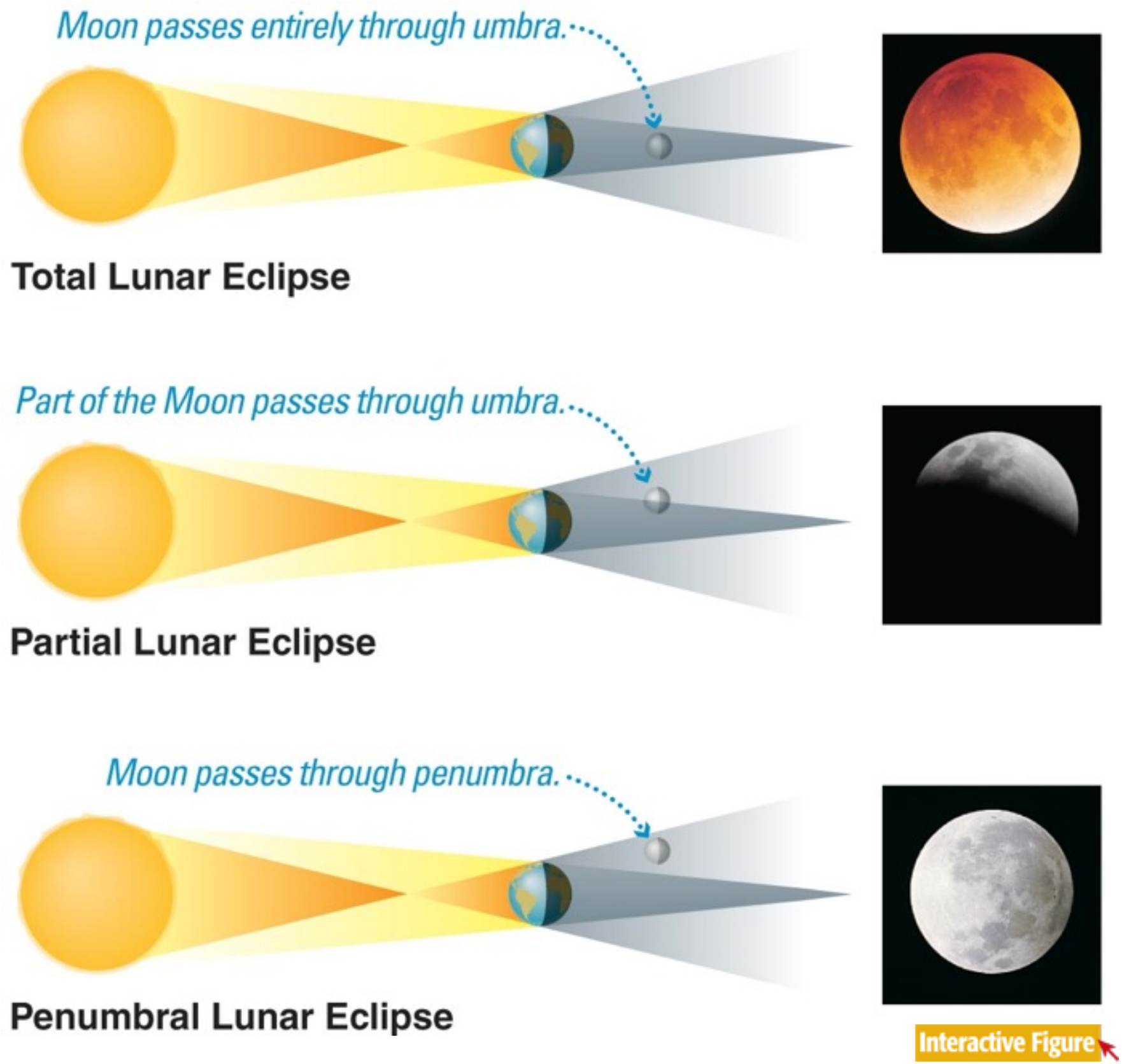


# Partial Eclipses

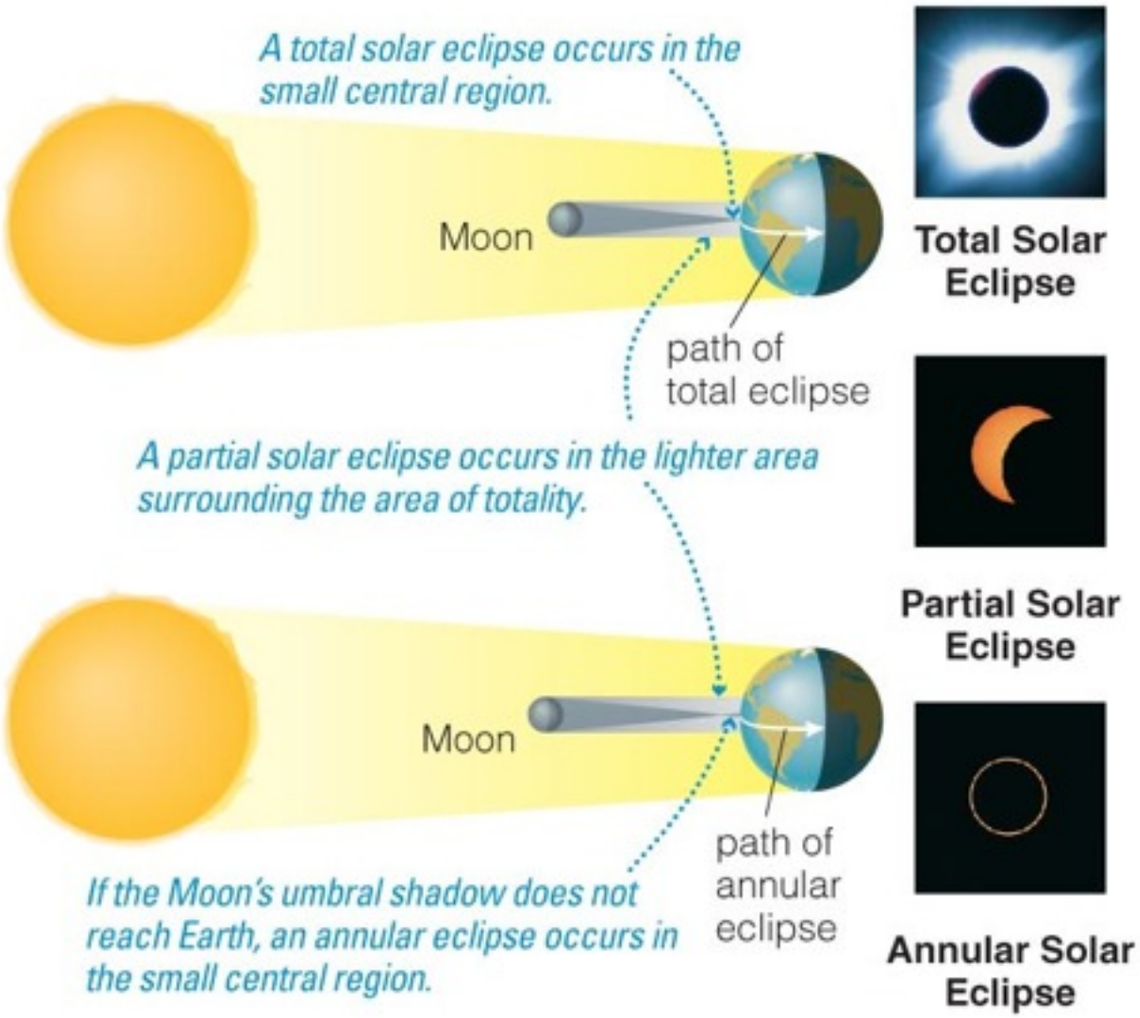
- Lunar eclipse



# Lunar Eclipse



# Solar Eclipse




**a** The three types of solar eclipse. The diagrams show the Moon's shadow falling on Earth; note the dark central umbra surrounded by the much lighter penumbra.

**b** This photo from Earth orbit shows the Moon's shadow (umbra) on Earth during a total solar elipse. Notice that only a small region of Earth experiences totality at any one time.

Interactive Figure

# Annular Eclipse

# Sidereal month vs. Synodic month