UNIT 1: PATTERNS IN THE SKY
ASTRONOMY
HILLGROVE HIGH SCHOOL

First, what is astronomy?

What is astronomy?

The study of celestial objects and the universe

What is science?

Science is the pursuit of knowledge and understanding of the natural following a systematic methodology based on **evidence**.

What is astrology?

A belief in the supposed influences of the stars and planets on human affairs and terrestrial events

M17, 5500 ly away, 100 ly across

Don’t write this down, but appreciate subtleties !

If you expect to see flames in the telescope and aliens flying by….you will be disappointed !

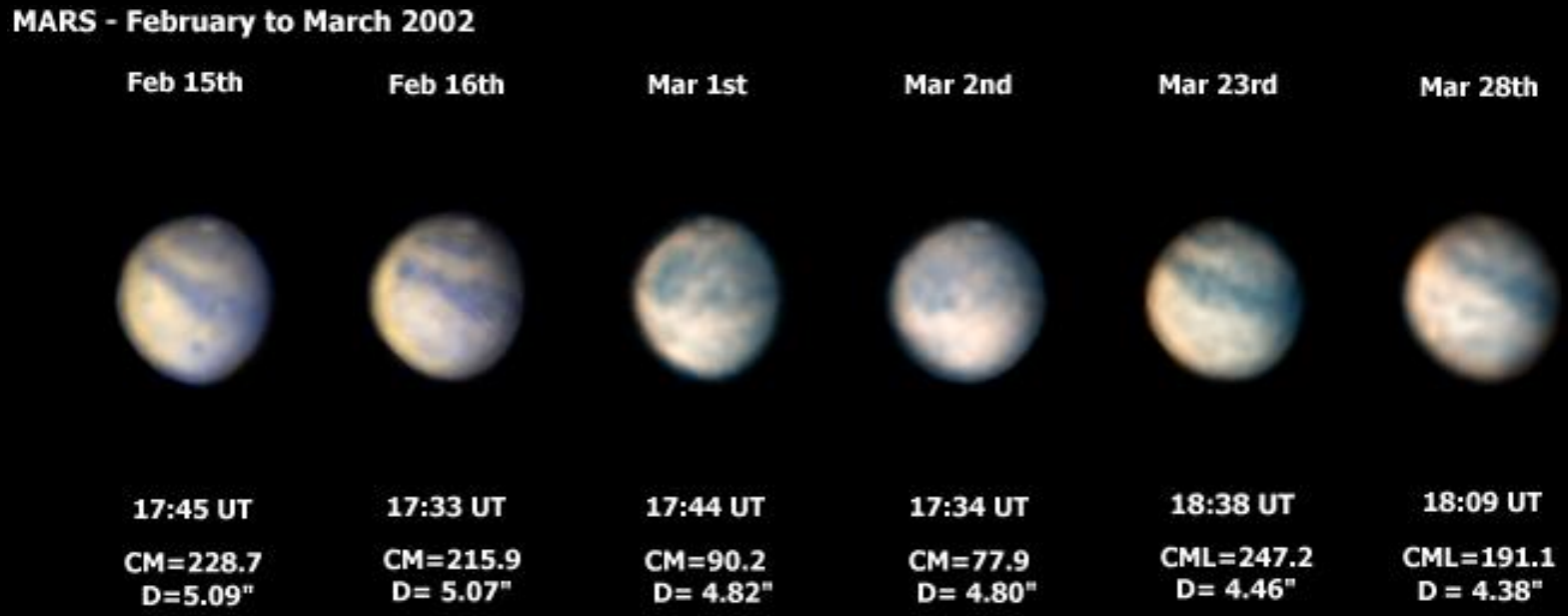
The closest star to us (other than the sun) is approximately 4 years away if you were traveling at the speed of light.

Anticipation of next question: No, we can’t travel at the speed of light.

Even looking through a relatively large telescope, one needs to appreciate subtle features (color, brightness, “fuzzy” galaxies etc.)

M45 © Royal Observatory Edinburgh/Anglo-Australian Observatory
Photograph from UK Schmidt plates by David Malin

This is Mars through a really nice telescope and a CCD camera



How many stars can one see on a clear night ?

Approximately 3000.

What is the closest star to Earth?

The sun…after that, ~ 4 light years away

What is a light year?

the distance traveled by a beam of light in one year (~9.5 x 10^{13} km)

That's about 6 trillion miles, and it would take a satellite ~20,000 years to travel one light year

So, we are not going to another star anytime soon

What about time travel?

Watch more Star Trek

On what horizon do stars rise? Set?

Rise from general east- Set in the general west directions (Around Polaris)—the North Star

COORDINATES: ALTITUDE AND AZIMUTH

Coordinate systems

Coordinates

a set of numbers used to locate something

Terrestrial coordinates

latitude and longitude

Equator

0° latitude

Prime meridian

0° longitude

Angular Measurements

Degree = a circle's divided into 360 degrees

minute of arc = 1/60 of a degree

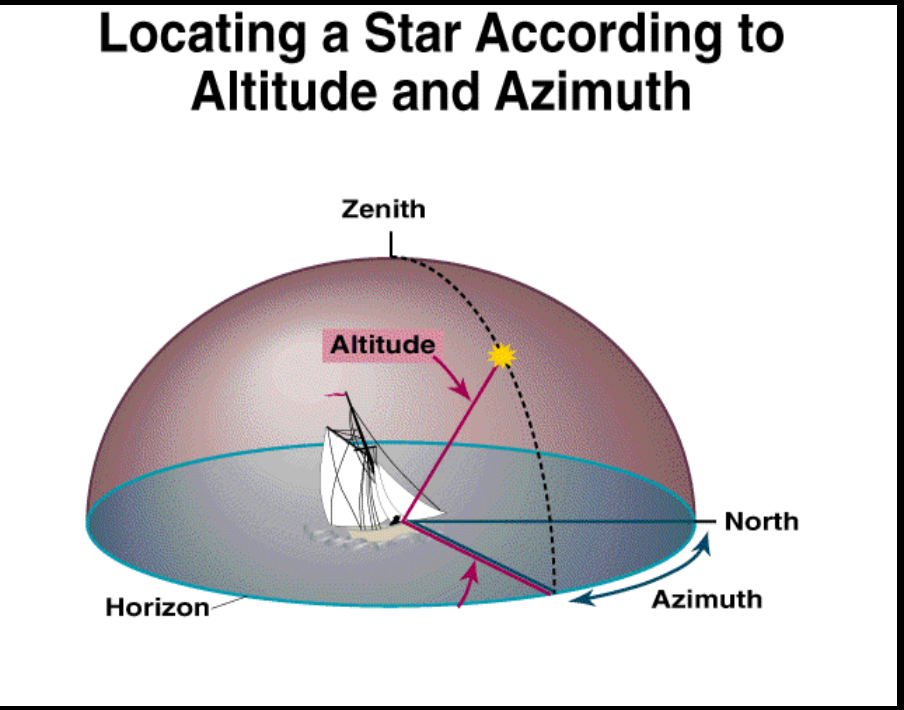
second of arc = 1/60 of a minute (…. Or 1/3600 of a degree)

Hold finger out at arm's length = ~2 degrees

Hold fist out at arm's length = ~10 degrees

Moon and sun are only 0.5 ° (stays constant--if it looks bigger...it's an illusion)

Horizon system



Horizon system
locating a star/planet using altitude (height) and azimuth (around)

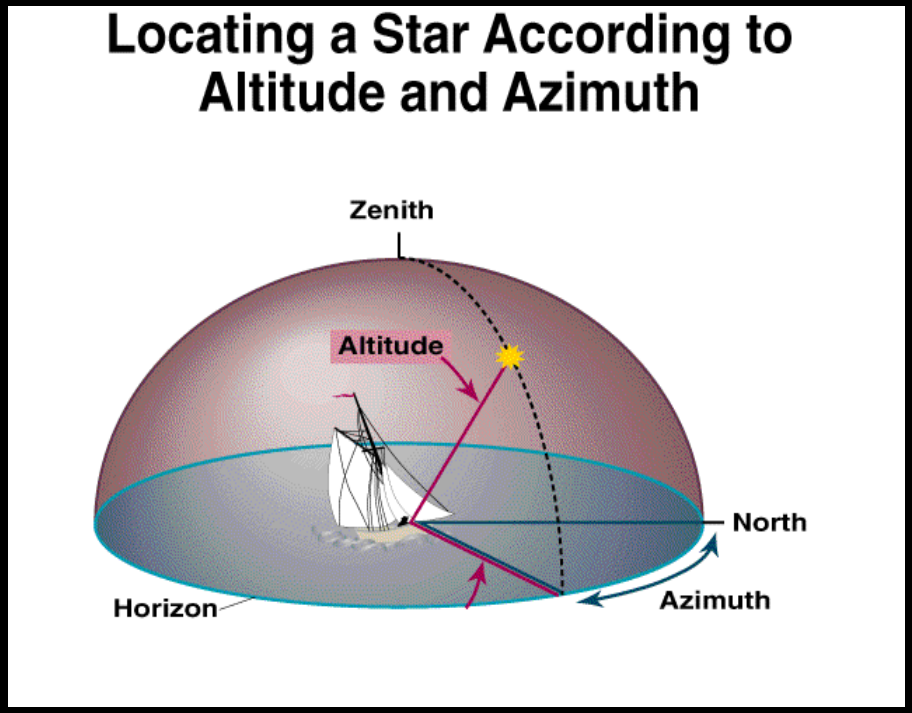
Zenith
the point directly above you in the sky

Horizon
where the ”land” or treeline meets the sky

Altitude
from 0º on horizon to 90º at zenith

Azimuth
from 0º at North and going around 360º

Horizon system



Problems...

- 1. Stars change position over the course of the night because of rotation of Earth—stars rise and set like the sun
- 2. Stars occupy different positions in the sky at different points on the earth (N vs. S hemispheres)

Rotation of the Earth

The Earth spins on its axis and rotates around once every 24 hours. This causes…

1. the Sun to rise and set.

2. stars to rise and set

THE SEASONS

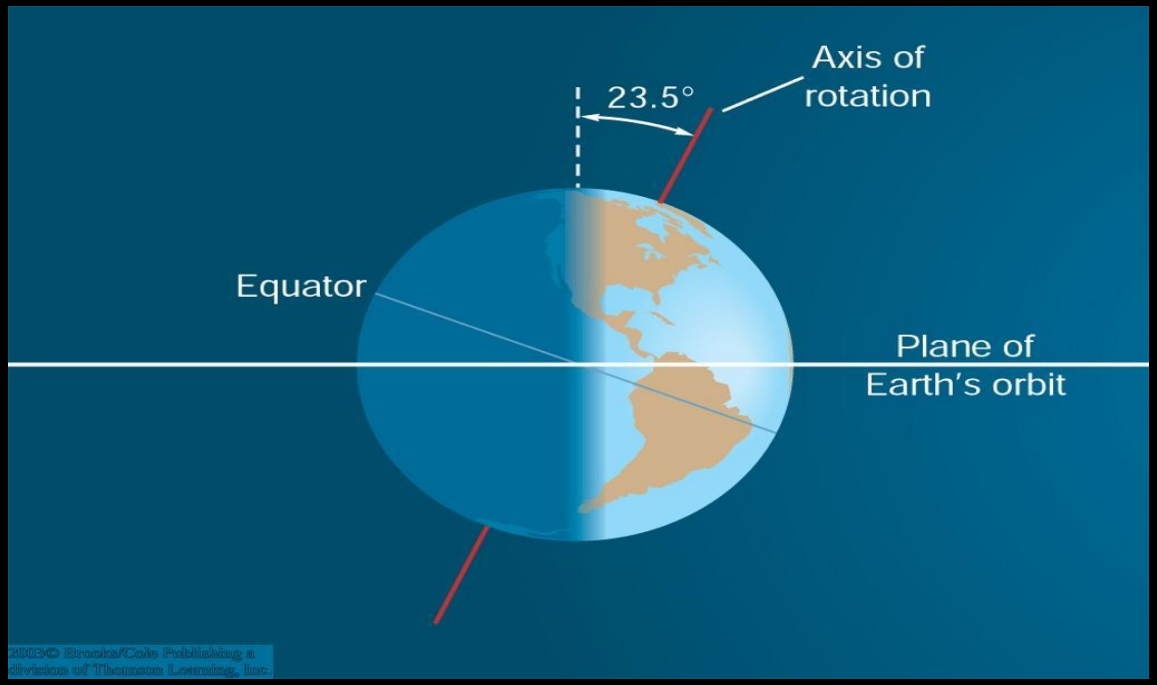
Day vs. Night

Rotation: Turning of a body about an axis through its center

-Example: earth rotates on its axis once a day

Revolution: Motion of a body around a point located outside the body

-Example: earth revolves around the sun once a year.

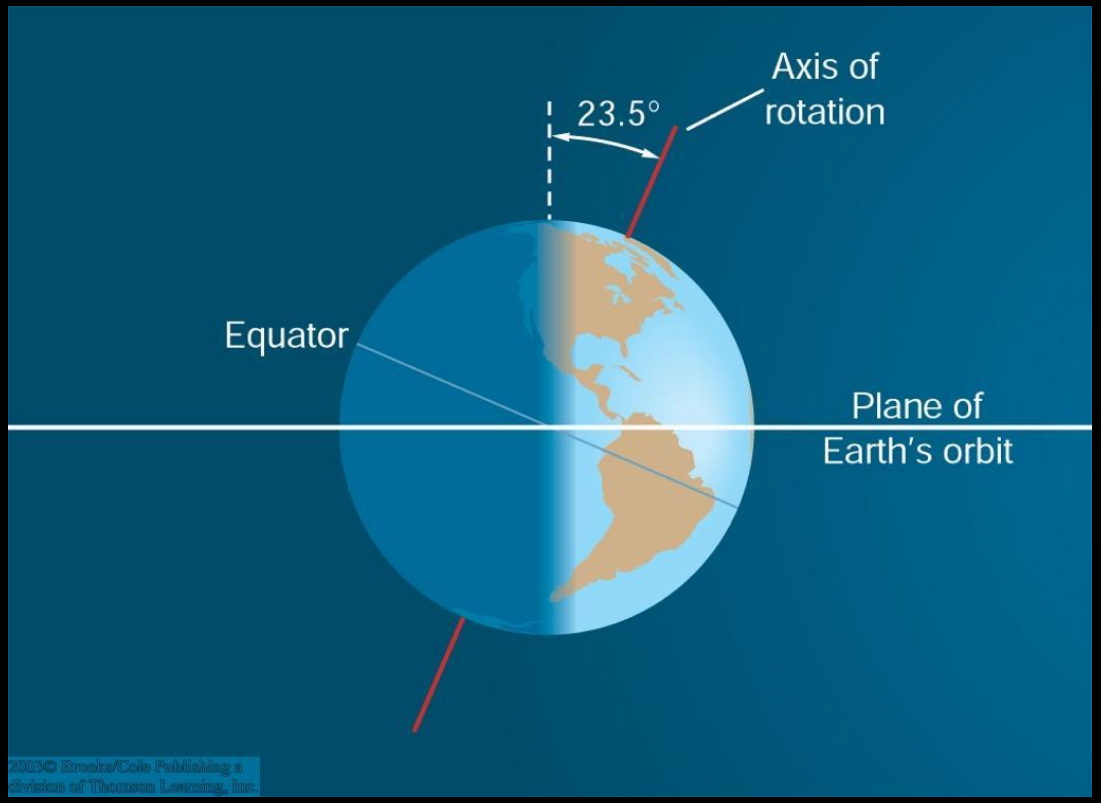


The Earth rotates on its axis, so the sun, moon, and stars will appear to rise and set.

The Seasons

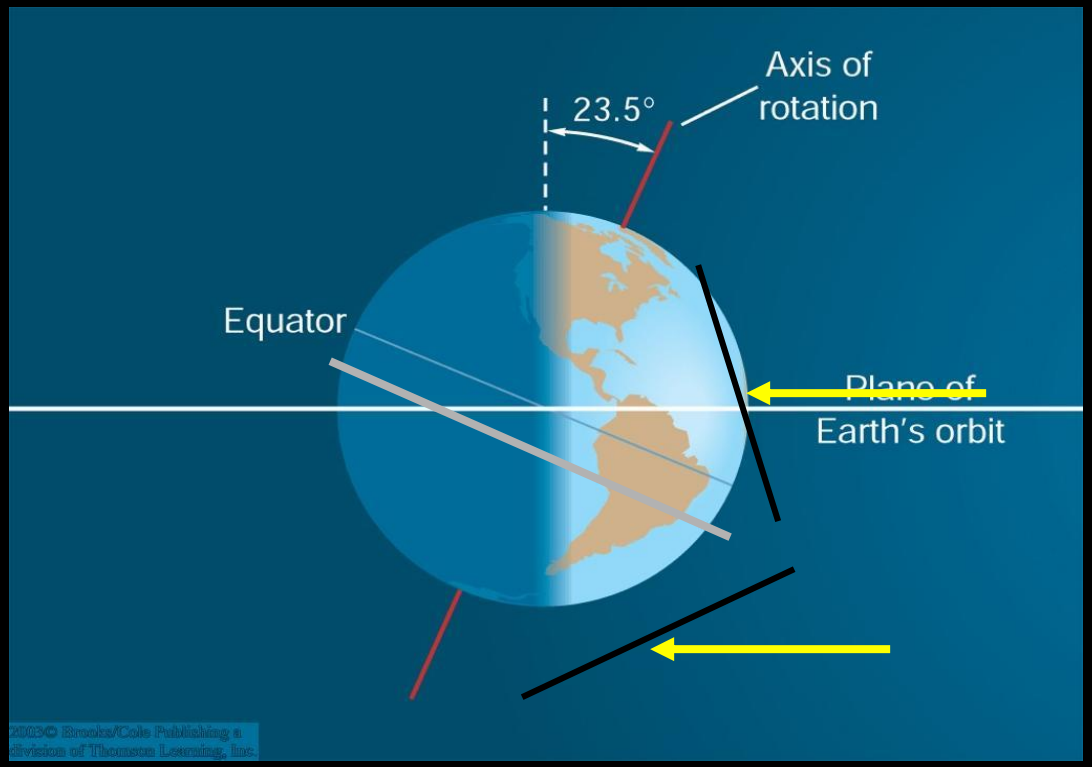
Caused by the fact that:

-Earth's axis of rotation tipped by 23.5° from the perpendicular to its orbit (causes the **seasons**).



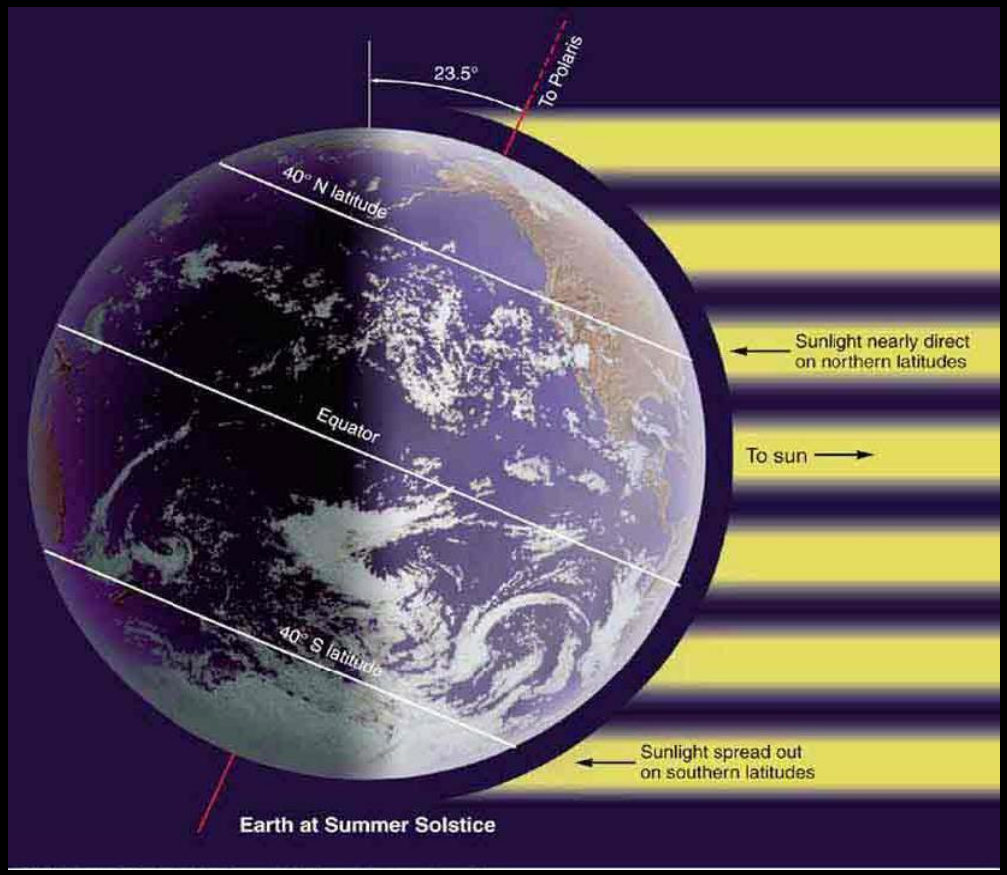
The Seasons

The Seasons are a result of **how direct** the sunlight is that strikes Earth.



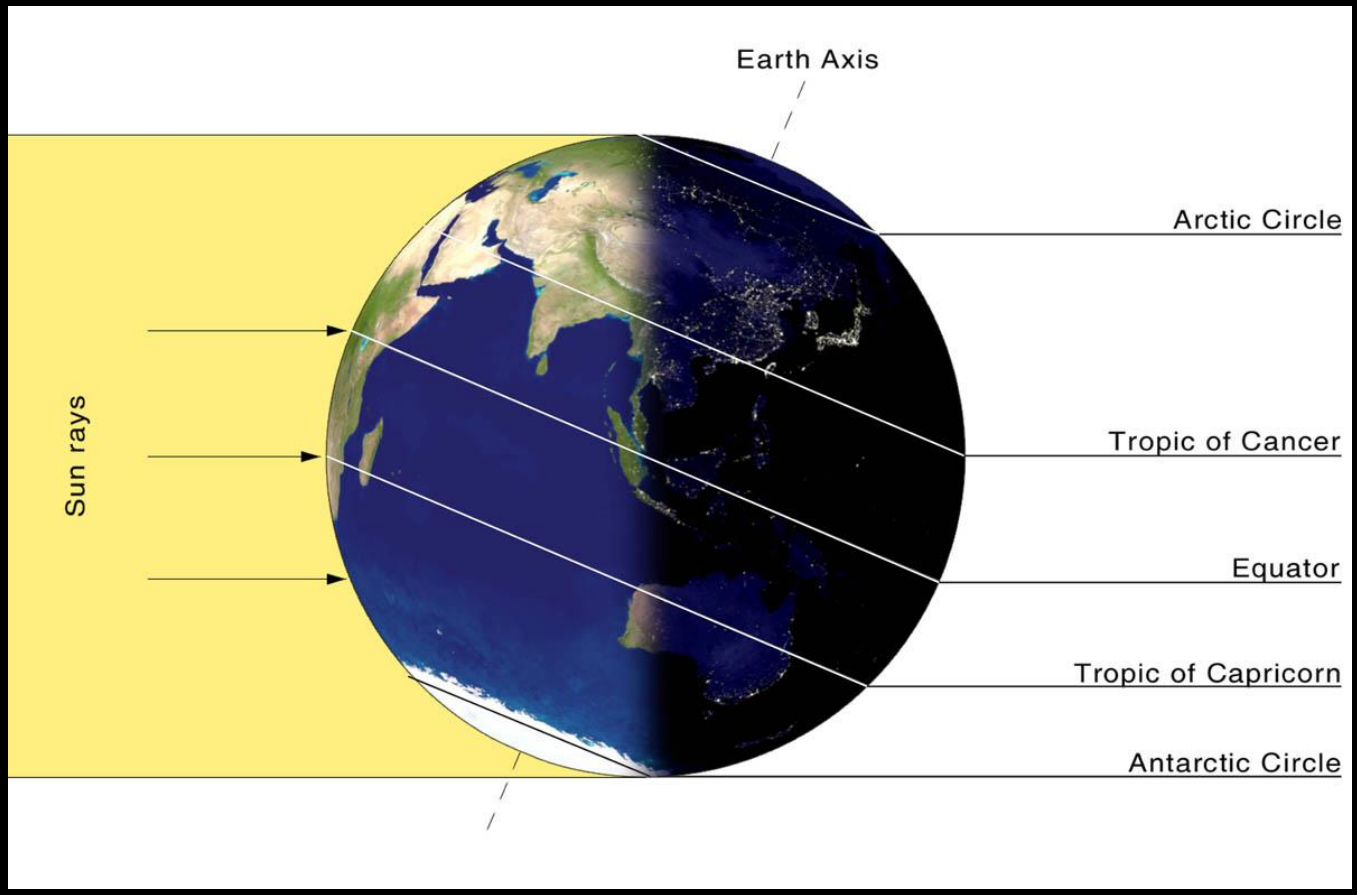
They are **not** related to Earth's distance from the sun. In fact, Earth is slightly closer to the sun in (northern-hemisphere) winter than in summer.

The Seasons



Northern summer = more direct light, sun higher in sky, daytime sunlight is longer

The Seasons



Northern winter = less direct light, sun lower in sky, daytime sunlight is shorter

What is the ecliptic?

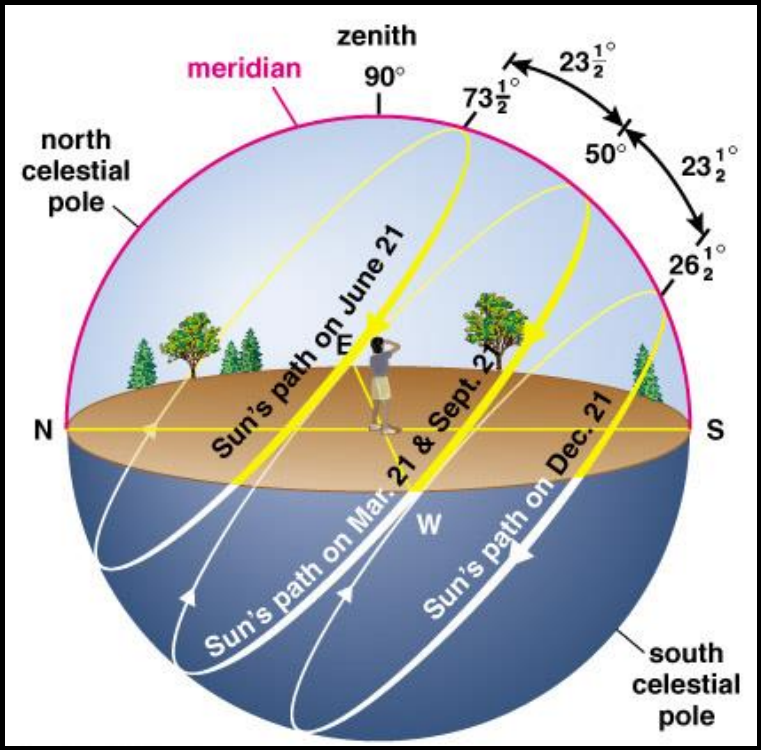
Definition #1

the daily path of the sun in the sky

Definition #2

Path of the sun in its yearly motion around the sky

How the path of the sun changes over the course of the year (this is at 40 degrees latitude)

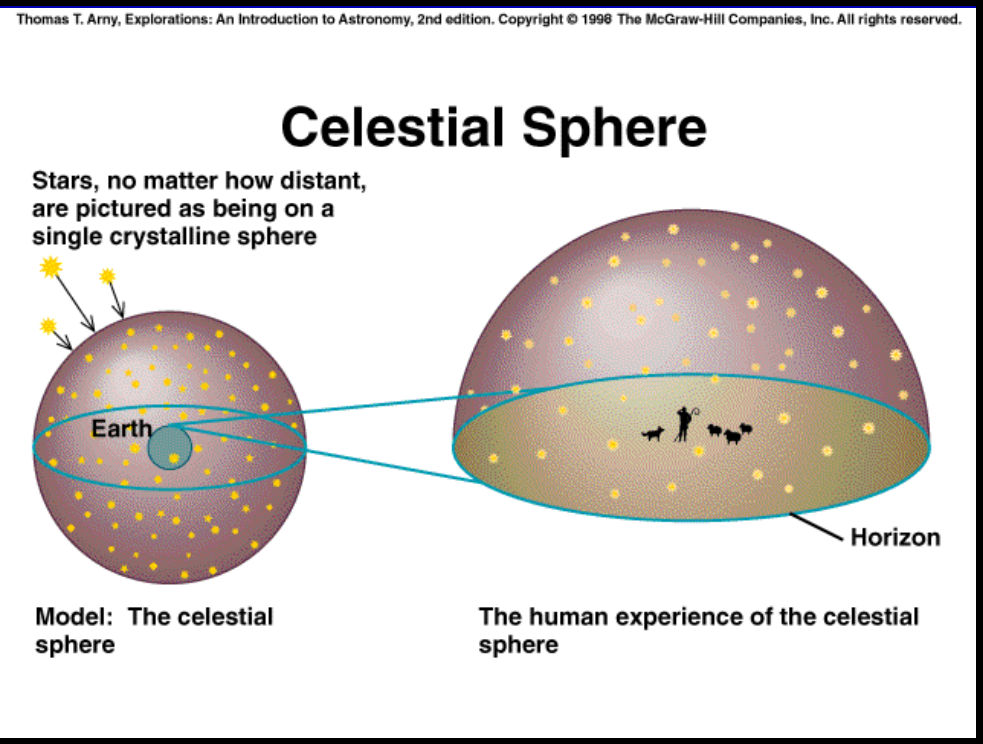


Earth circles (revolves) around the sun in 365.25 days, and the sun appears to circle the sky in the same period.

The sun, traveling 360 degrees around the ecliptic in 365.25 days, travels about 1 degree eastward each day…seasons

COORDINATES:
THE CELESTIAL SPHERE

Celestial Sphere



Celestial Sphere

Imaginary sphere/coordinate system onto which all stars are projected (imaginary sphere of what we see)

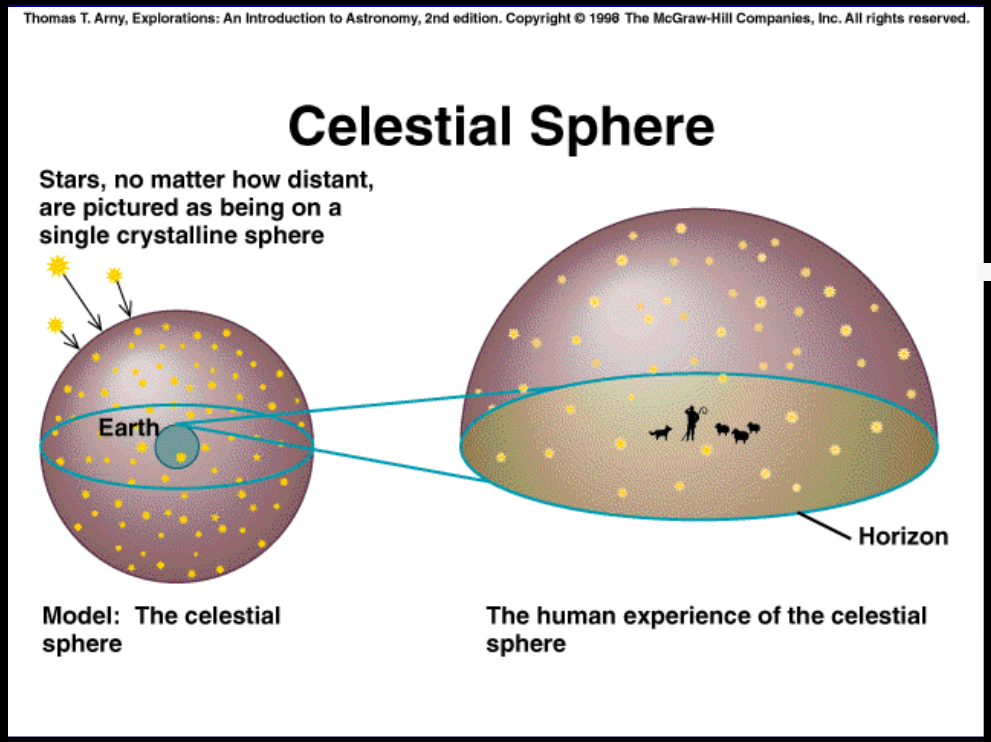
North Celestial Pole

Point on celestial sphere directly above North Pole of earth

Polaris

The North Star because it is practically located on the North Celestial Pole

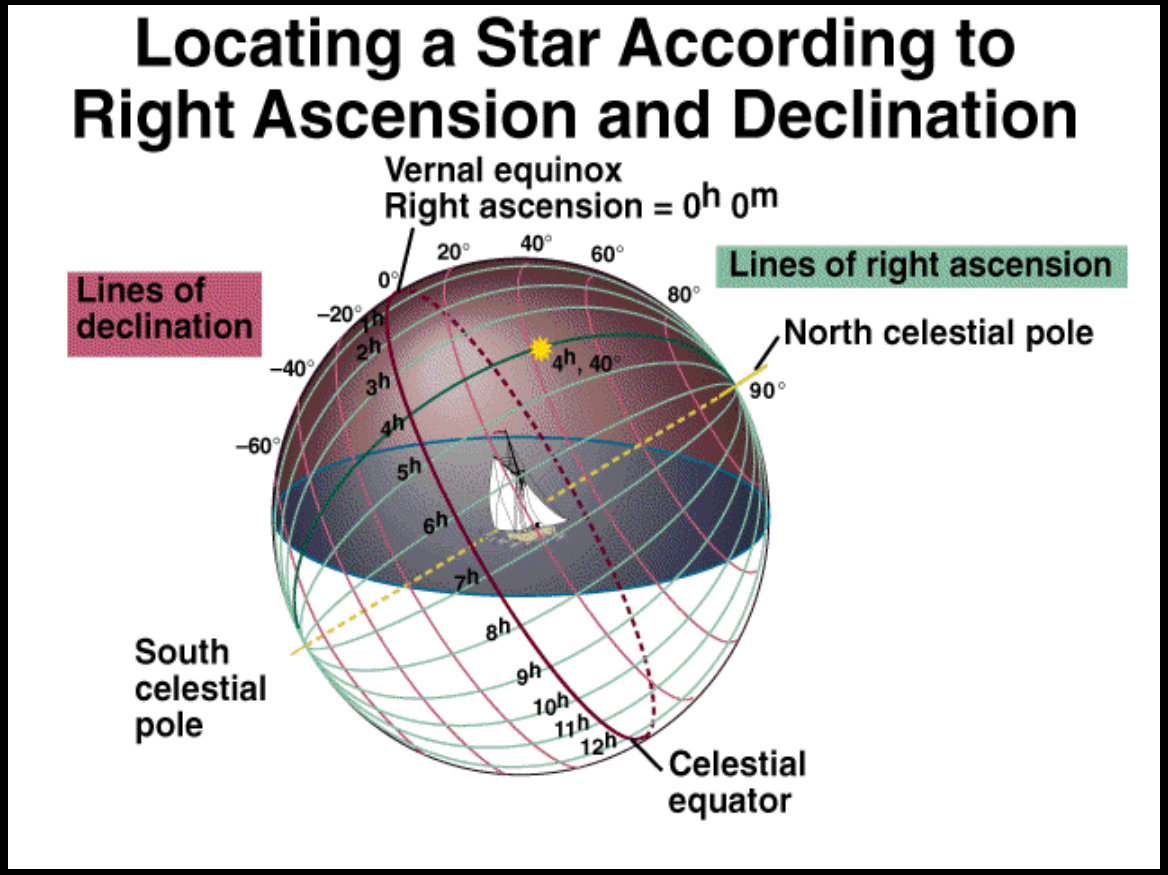
Celestial Sphere



Why use it?

- The Celestial sphere is an easier way to locate stars because they are **fixed** coordinates on this map

Celestial Sphere



Right ascension (RA)

like longitude; RA is an angular measurement around sphere (measured in hours)

Declination (dec)

like latitude; declination is an angular measurement above or below celestial equator

Question #1

1. Right ascension is a coordinate that is similar to

a) Longitude
b) Latitude
c) Declination
d) Time

Question #2

2. Over the course of the year, the Sun's position on the celestial sphere

a) changes because the Earth spins on its axis.

b) remains constant because the Sun never changes position on the celestial sphere.

c) changes because the Earth orbits the Sun.

Question #3

3. At 9:00 p.m. tonight, you locate a star that is at RA= 9 hr and dec = +30 degrees. What will be the celestial sphere coordinates at 10:00 p.m.?

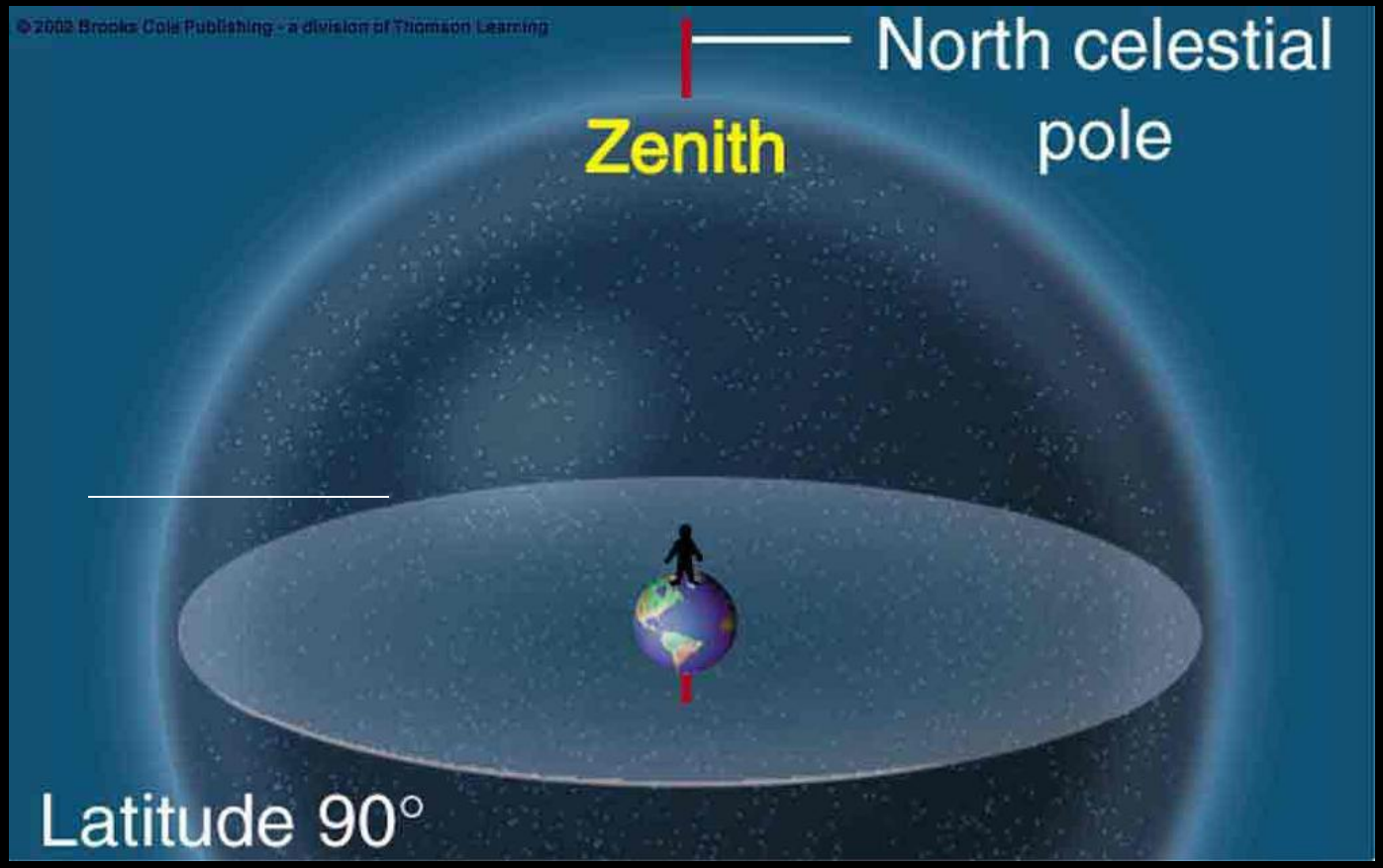
a) RA = 9 hr, dec = +30°
b) RA = 9 hr, dec = +40°
c) RA = 10 hr, dec = +30°
d) RA = 10 hr, dec = 40°

Question #4

4. If you were standing at +23.5 degrees latitude, when would the Sun be directly overhead at the zenith at noon?

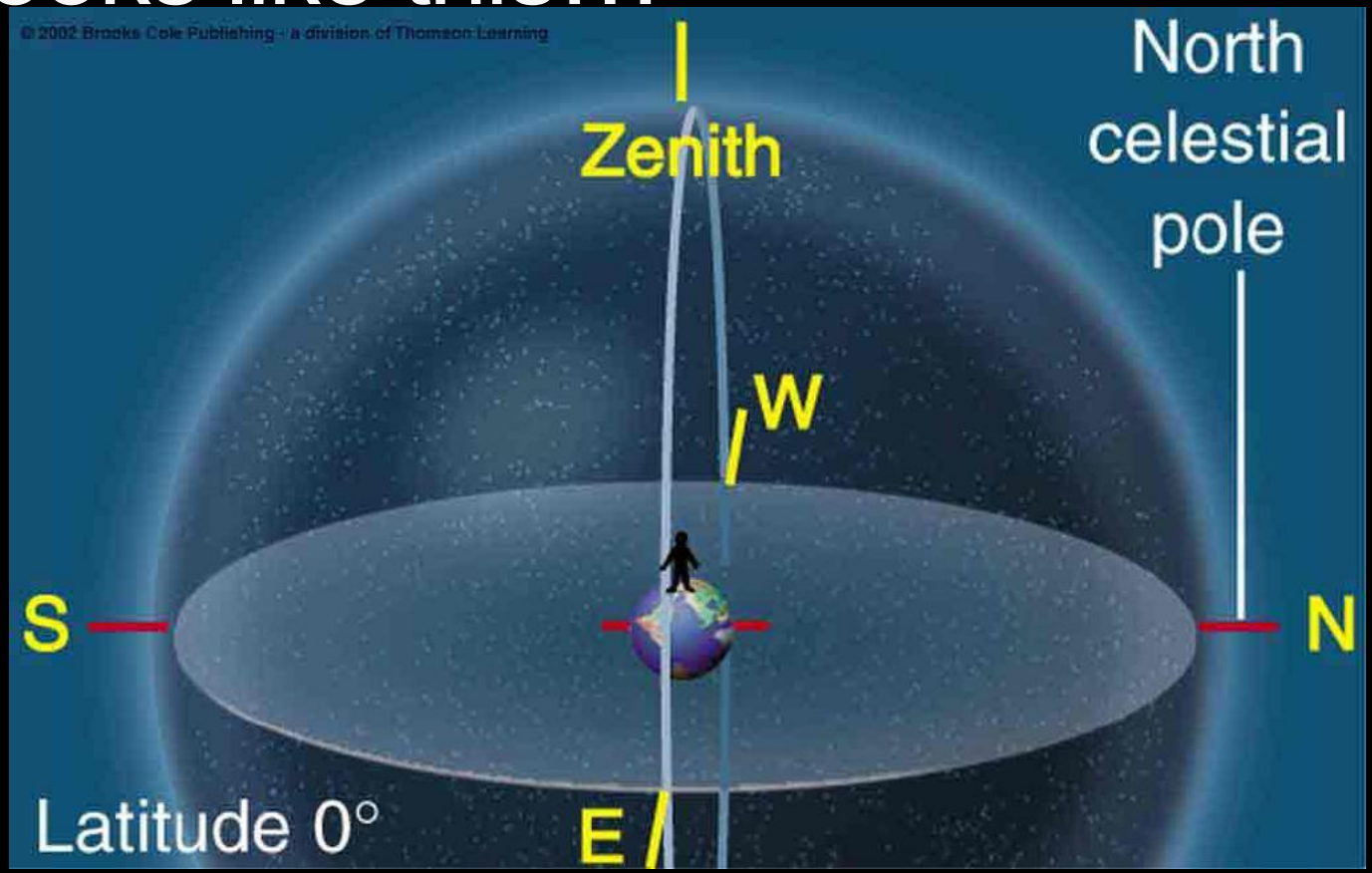
a) March 21
b) June 21
c) Sept. 21
d) Dec. 21

If you are standing at the North Pole, your view of the celestial sphere looks like this…



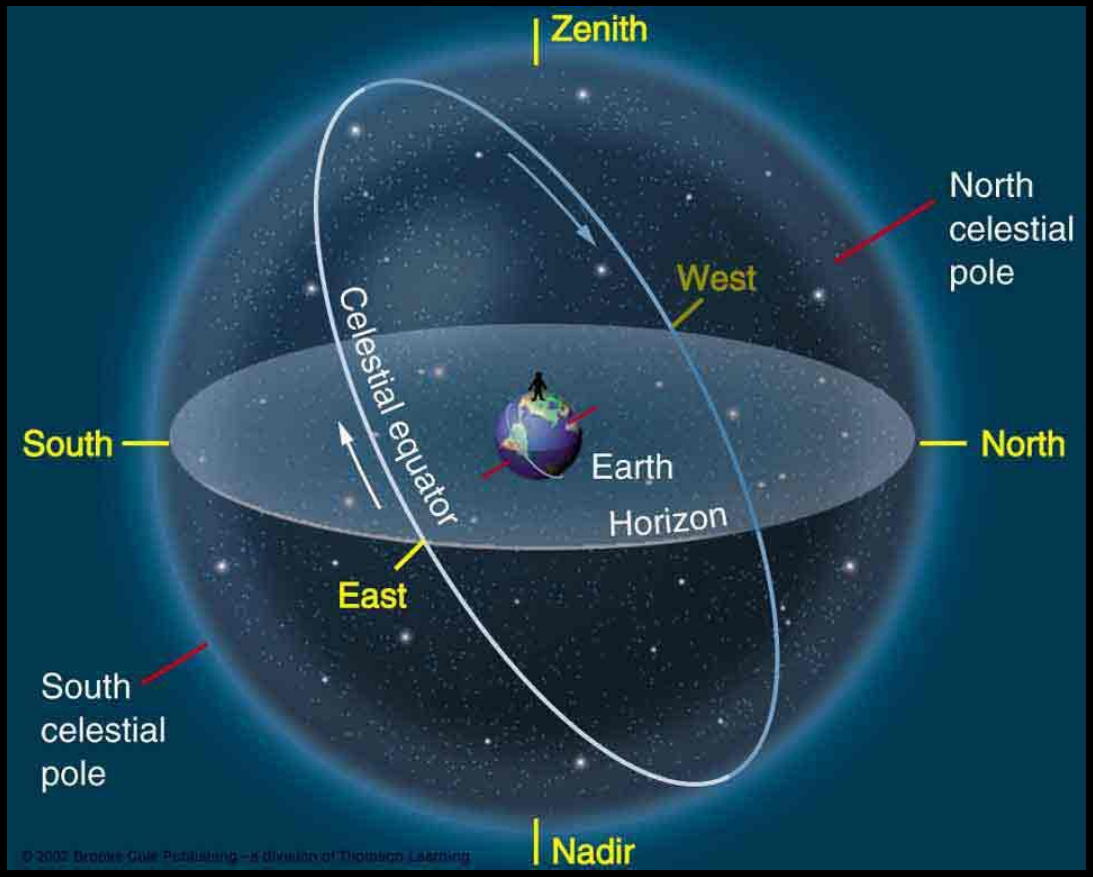
Diurnal Circles (daily “star trails”) from North Pole; Polaris at 90 degrees altitude

If you are standing at the equator, your view of the celestial sphere looks like this…

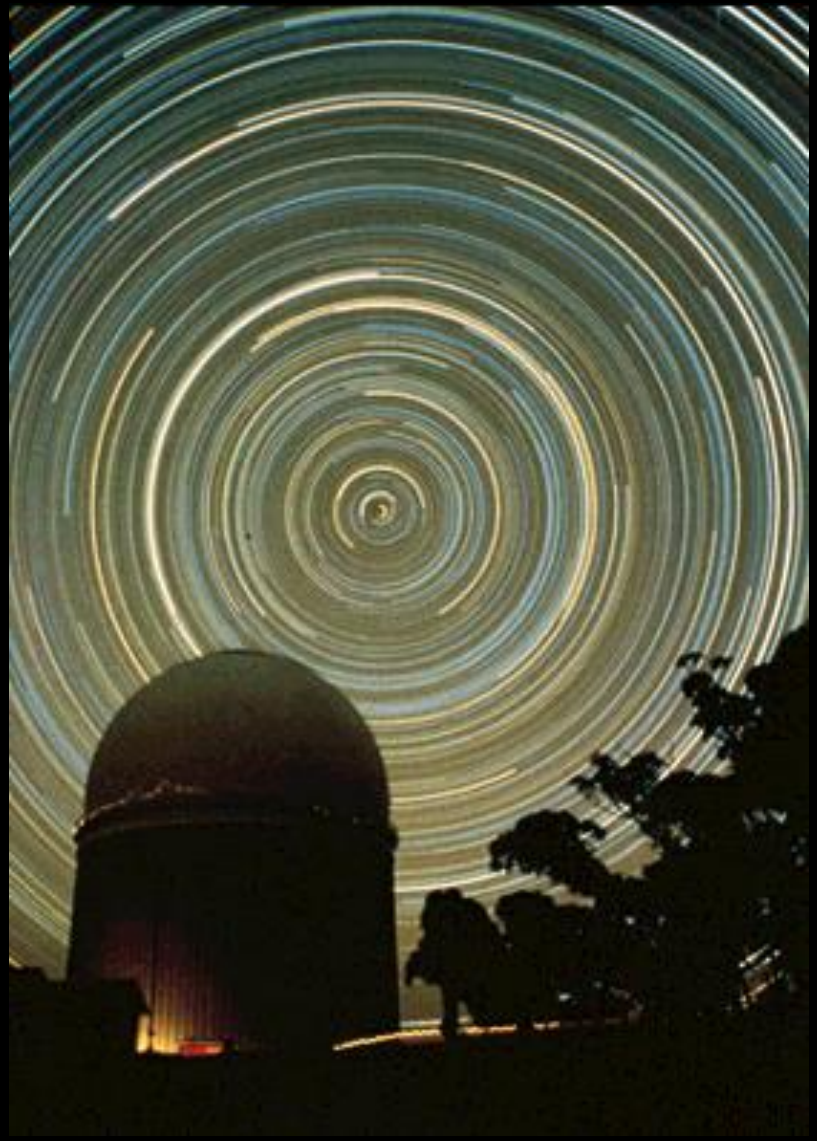


Diurnal Circles from Equator; Polaris at 0 degrees altitude

If you are standing in Atlanta, your view of the celestial sphere looks like this…



Diurnal Circles from mid-latitude



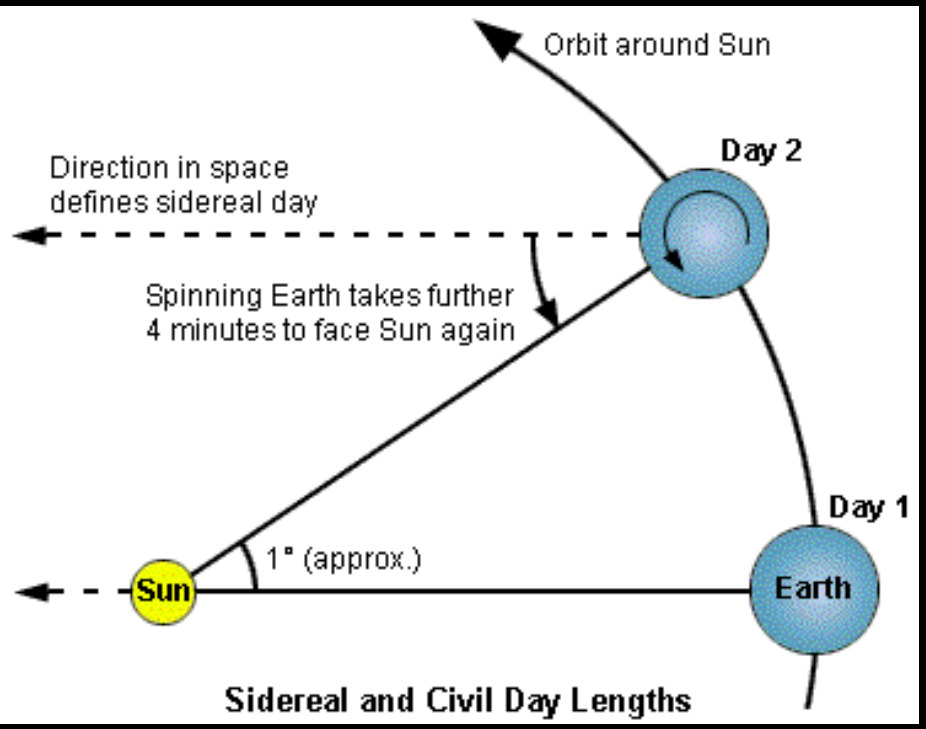
Circumpolar stars

group of stars that do not set below horizon (they go around Polaris)

Latitude and Polaris

The angle of Polaris above your horizon is the same as your latitude in degrees.

Sidereal Day vs. Solar Day



Sidereal Day

The time it takes a star to line back up with Earth

23 hours, 56 minutes, 4 seconds (~4 minutes shorter than a 24 hr day)

Therefore stars rise

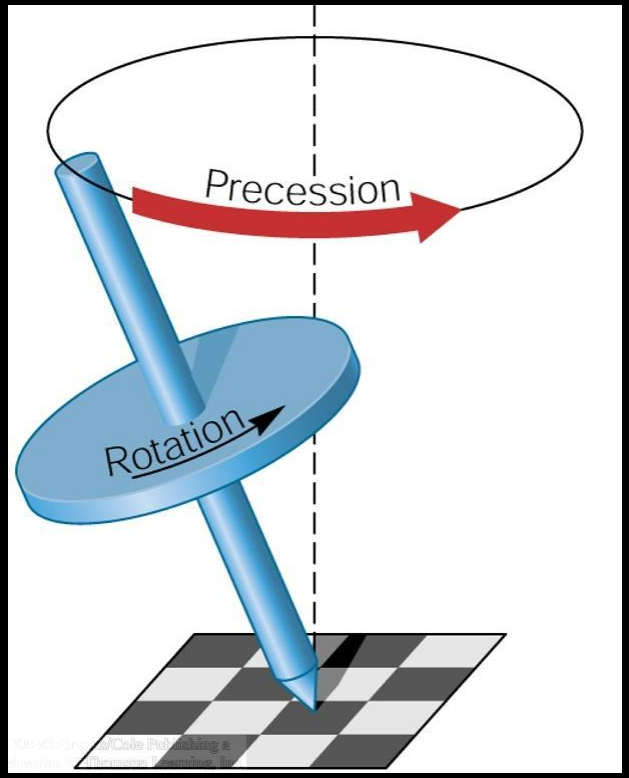
~ 4 minutes earlier each night

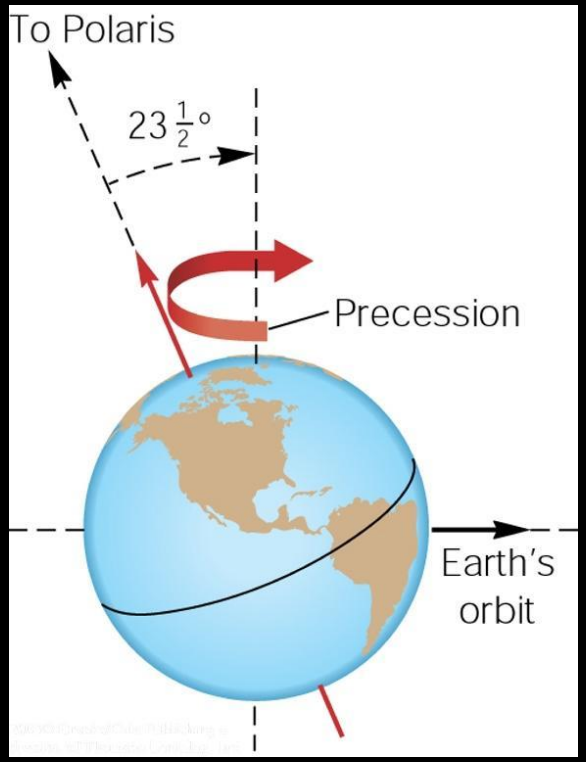
Mean Solar Day

=24 hrs (avg. time for Sun to return to same position)

Precession

At left, gravity is pulling on a slanted top.
Wobbling around the vertical.





The Sun's gravity is doing the same to Earth.

The resulting "wobbling" of Earth's axis of rotation around the vertical w.r.t. the Ecliptic takes about 26,000 years and is called **precession**.

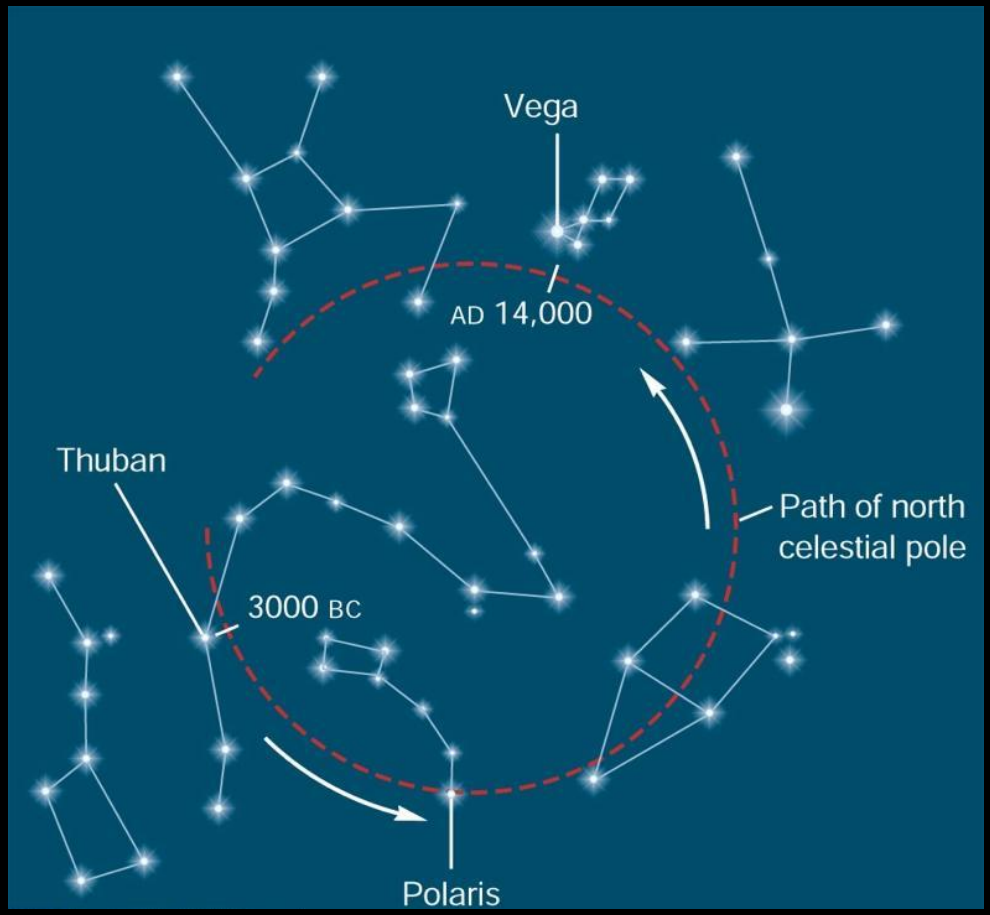
Precession

As a result of precession, the celestial north pole follows a circular pattern on the sky, once every 26,000 years.

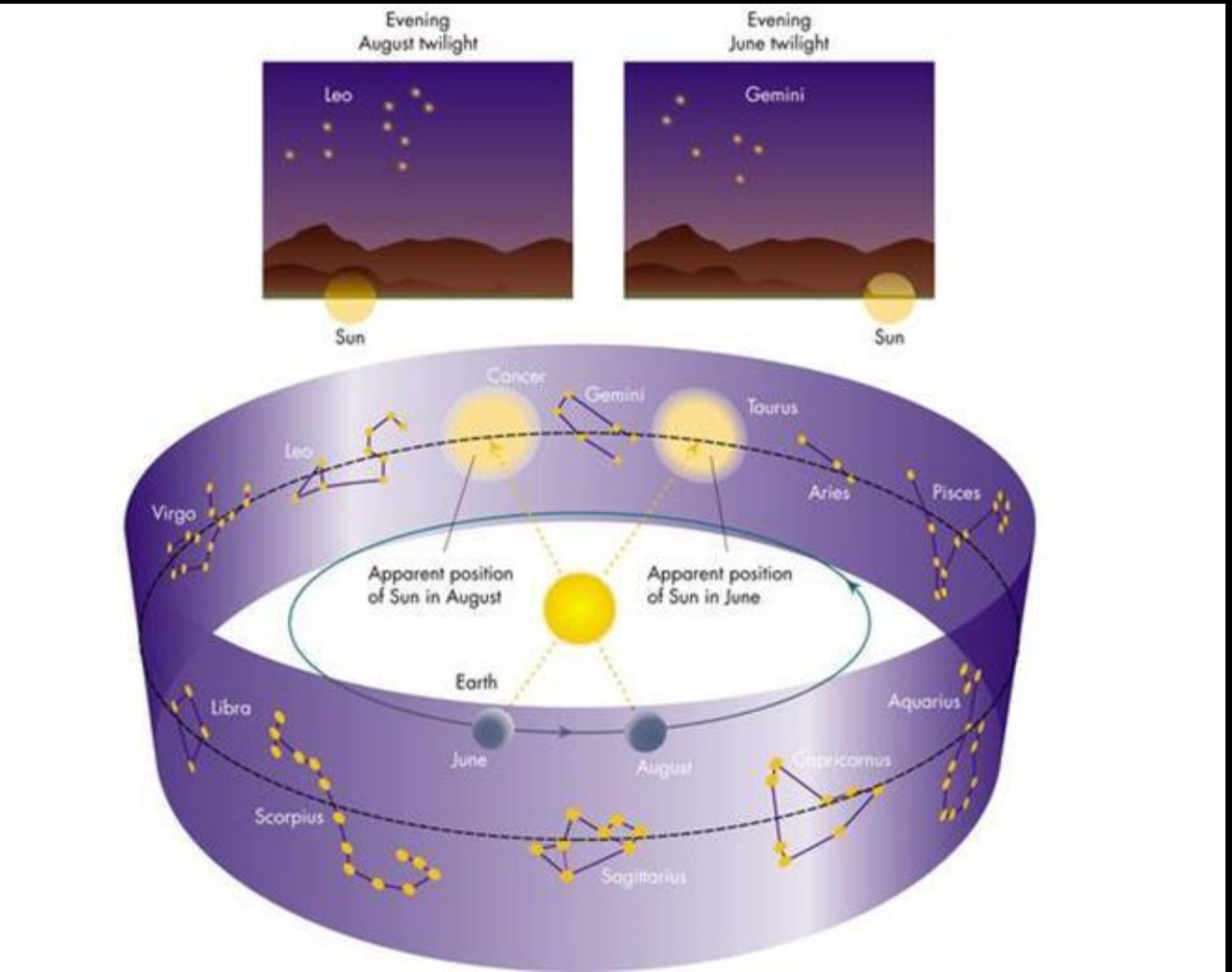
It will be closest to Polaris ~ A.D. 2100.

There is nothing peculiar about Polaris at all (neither particularly bright nor nearby etc.)

~ 12,000 years from now, it will be close to Vega in the constellation Lyra.



The positions of the stars change over the course of the year because the Earth orbits the Sun…

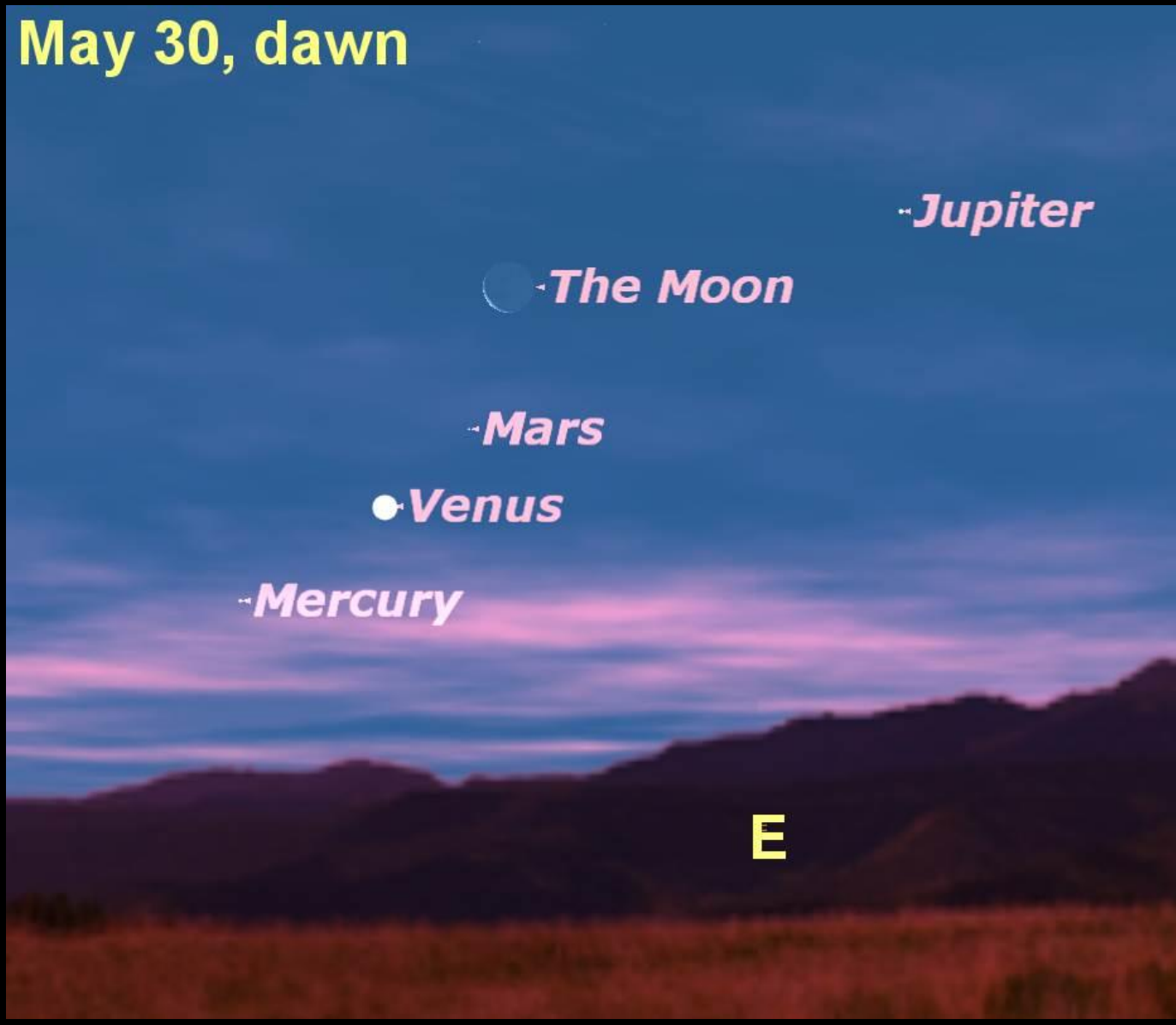


Off-season constellations are "up" during the daytime

Notice that between June and August, the Sun is directly "in" Gemini

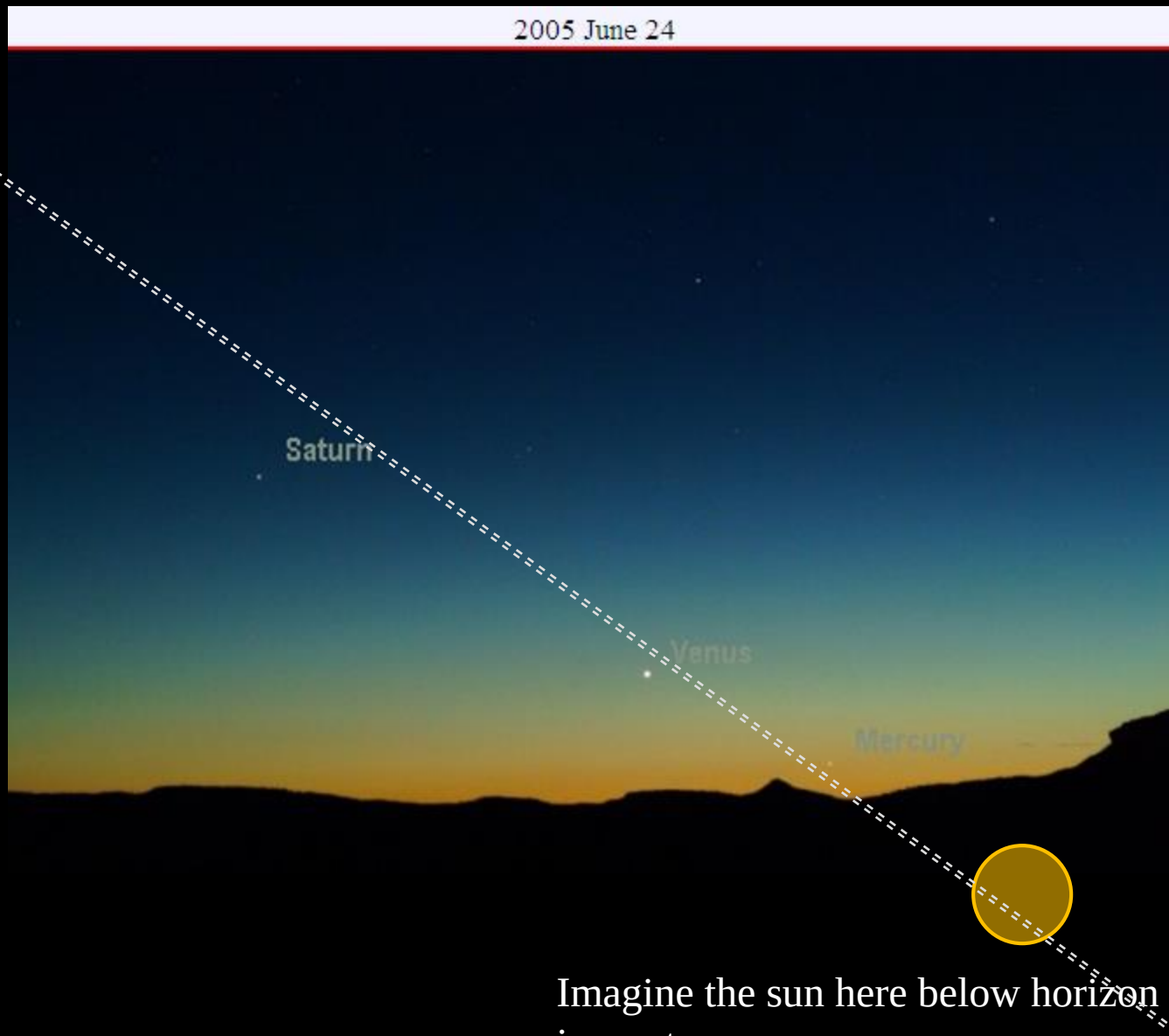
Notice that June to August, Sagittarius is prime viewing during summer nights

POSITIONING OF THE PLANETS IN THE SKY



Where are planets located in the sky?

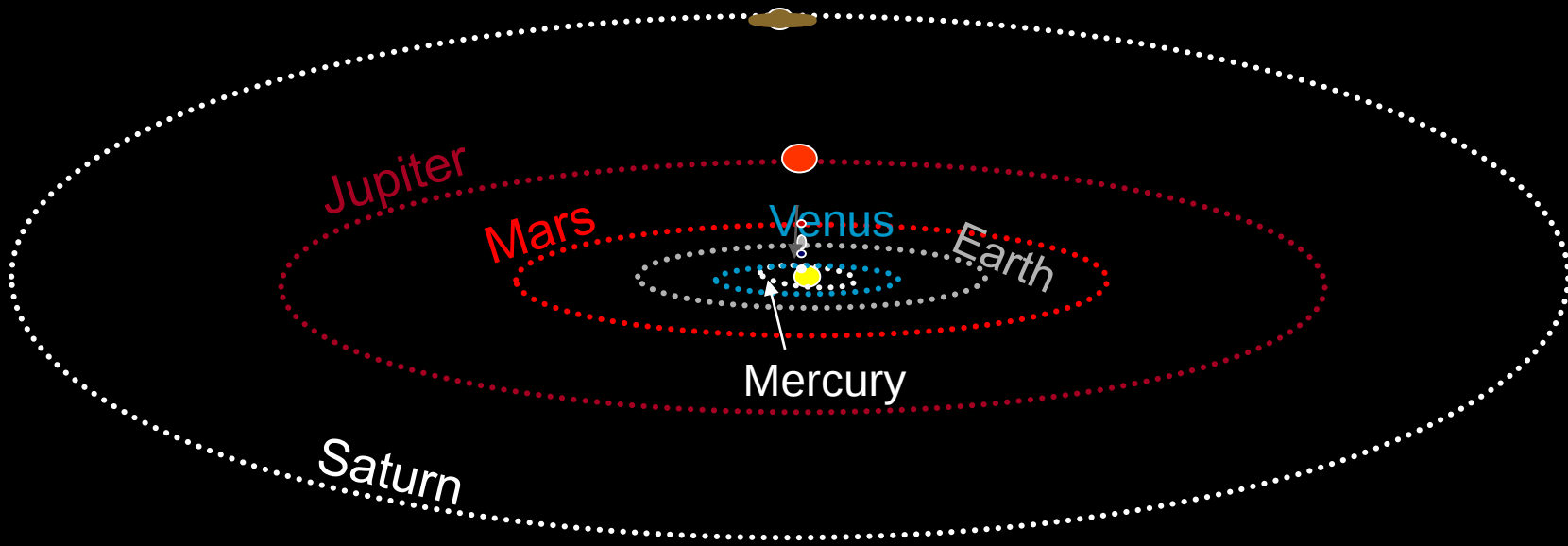
Notice that the planets lie along the **ecliptic** because the solar system is in the same plane (a flat disc)



Imagine the sun here below horizon in west

The Motion of the Planets

The planets are orbiting the sun almost exactly in the plane of the Ecliptic.



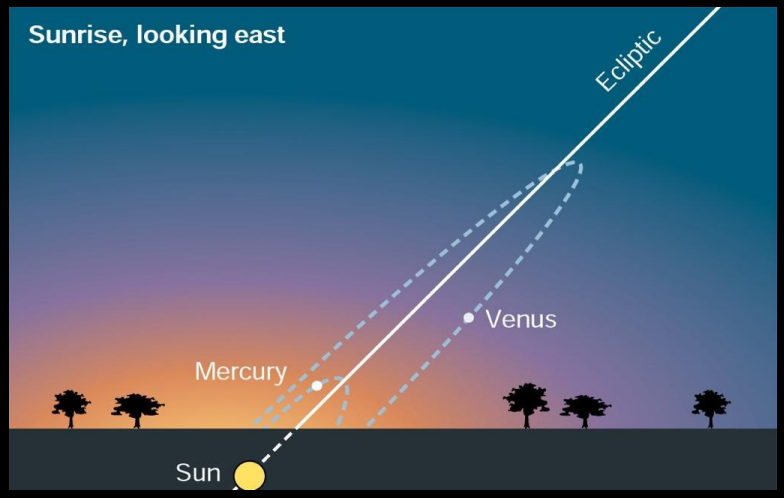
The Moon is orbiting Earth in almost the same plane (Ecliptic).

Motion of the Planets

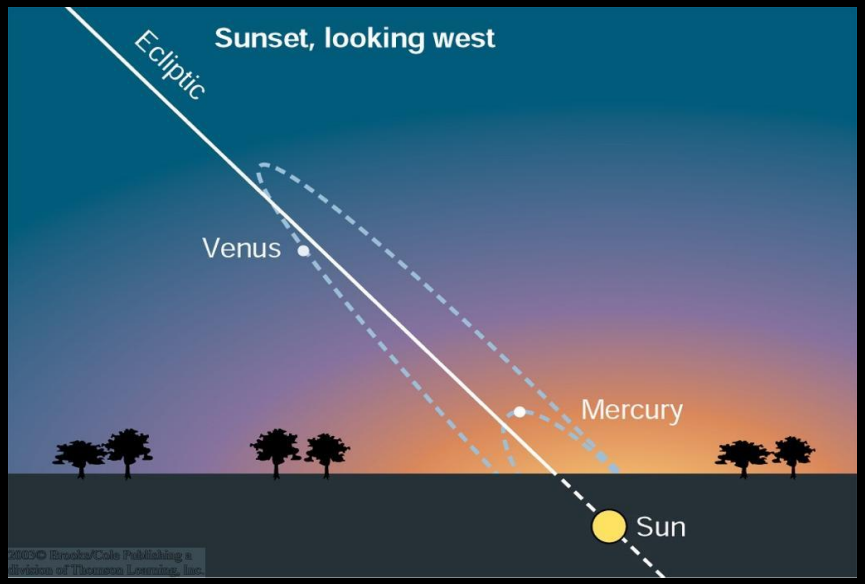
The Sun, Moon and planets can always be found in a Zodiac Constellation on the ecliptic.

Planets "wander" across the celestial sphere and through the stars in two ways:

1. Direct Motion - normal eastward movement of planets
2. Retrograde Motion - occasional westward movement of planets

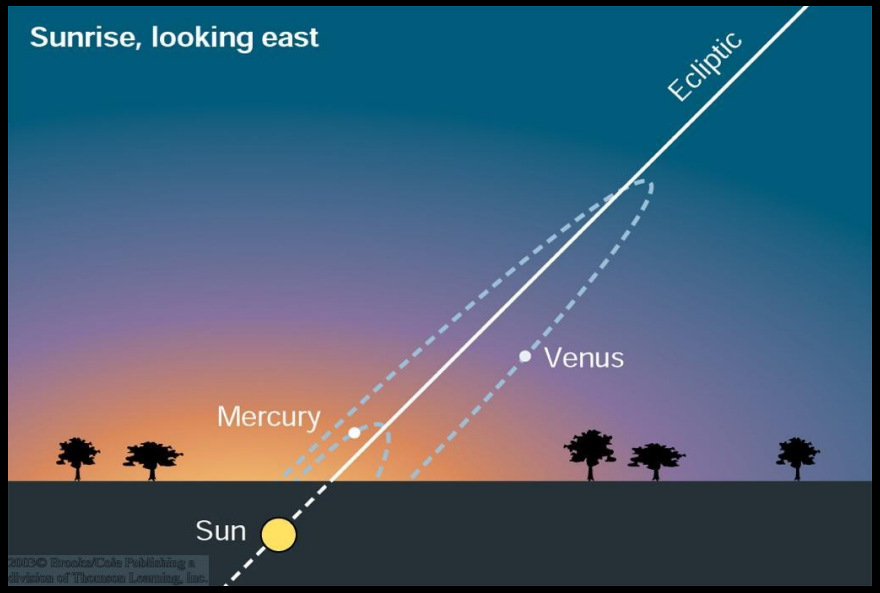


The Motion of the Planets



Mercury appears at most ~28° from the sun.

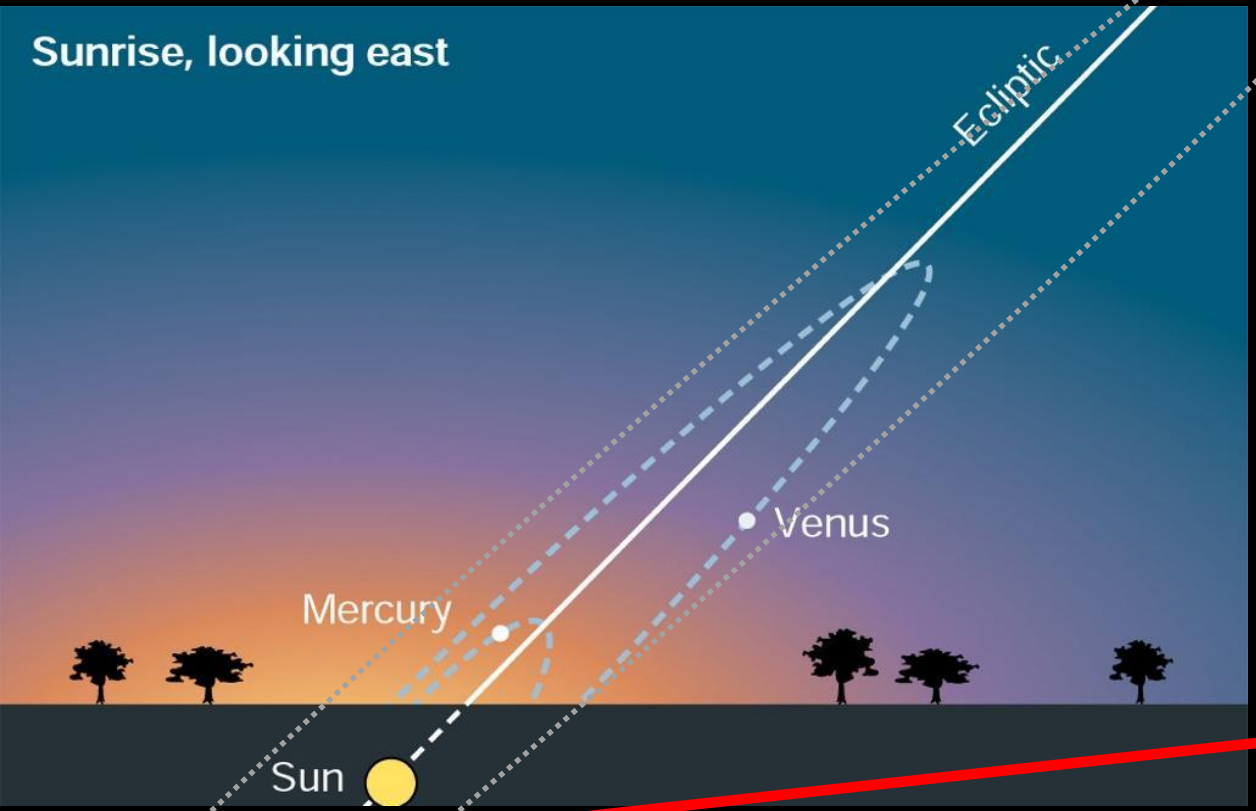
It can occasionally be seen shortly after sunset in the west or before sunrise in the east.



Venus appears at most ~46° from the sun.

It can occasionally be seen for at most a few hours after sunset in the west or before sunrise in the east.

Planets that are NOT visible



Planets may not be visible at night because of where they might be in their orbits.

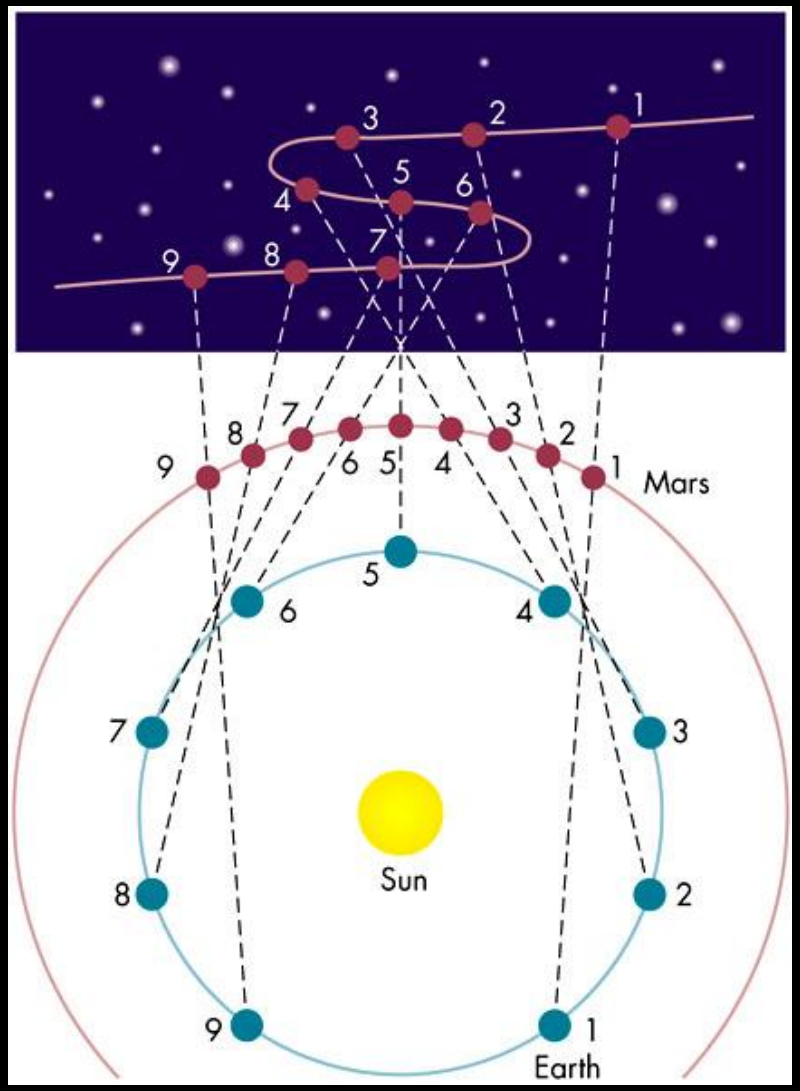
What if Jupiter were here?

Retrograde Motion

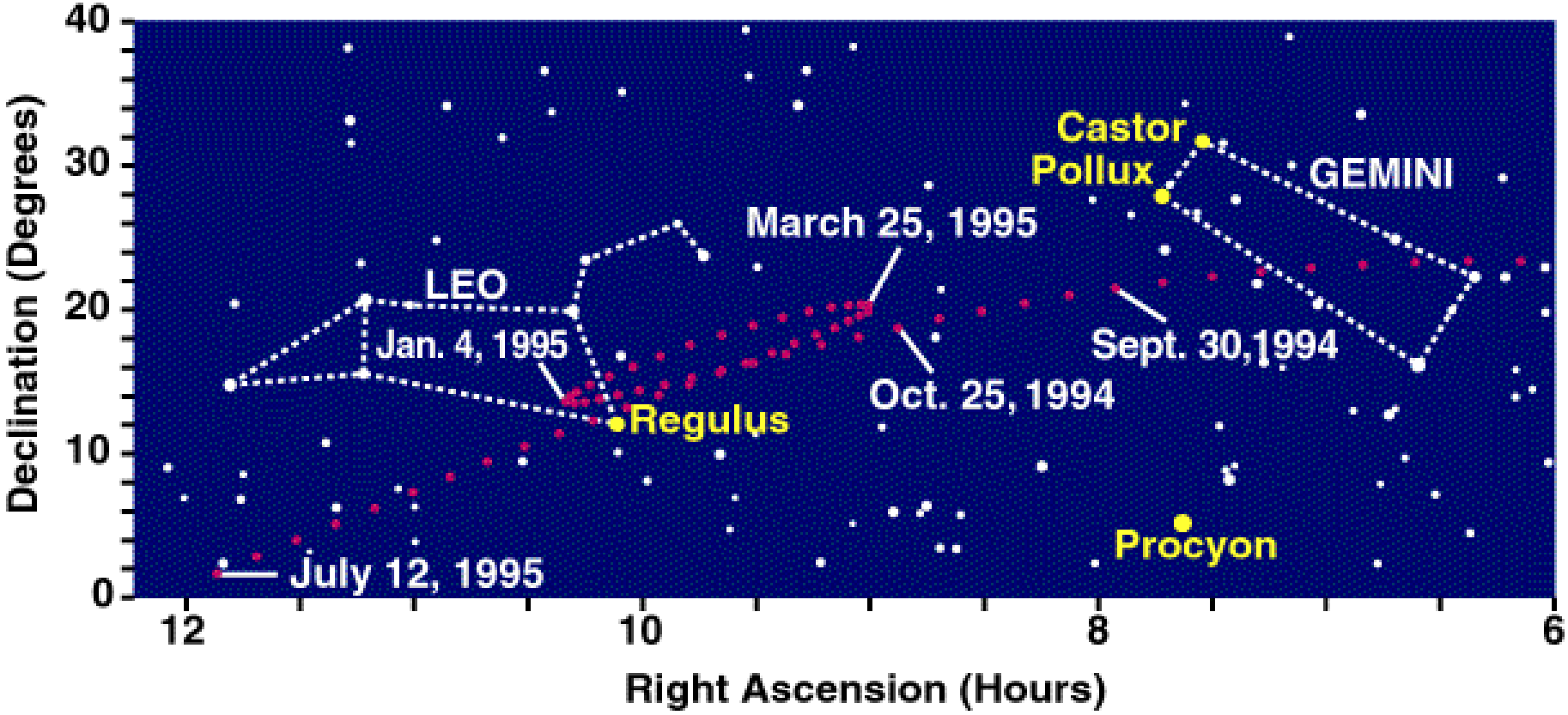
Retrograde motion occurs when an inner planet passes by an outside planet and the outside planet appears to go "backwards" in the sky for a few weeks (this doesn't happen in a night)

Click for Animation

The movement is **apparent**—Mars does NOT really move like that in space. The position of mars shifts against the backdrop of distant stars.



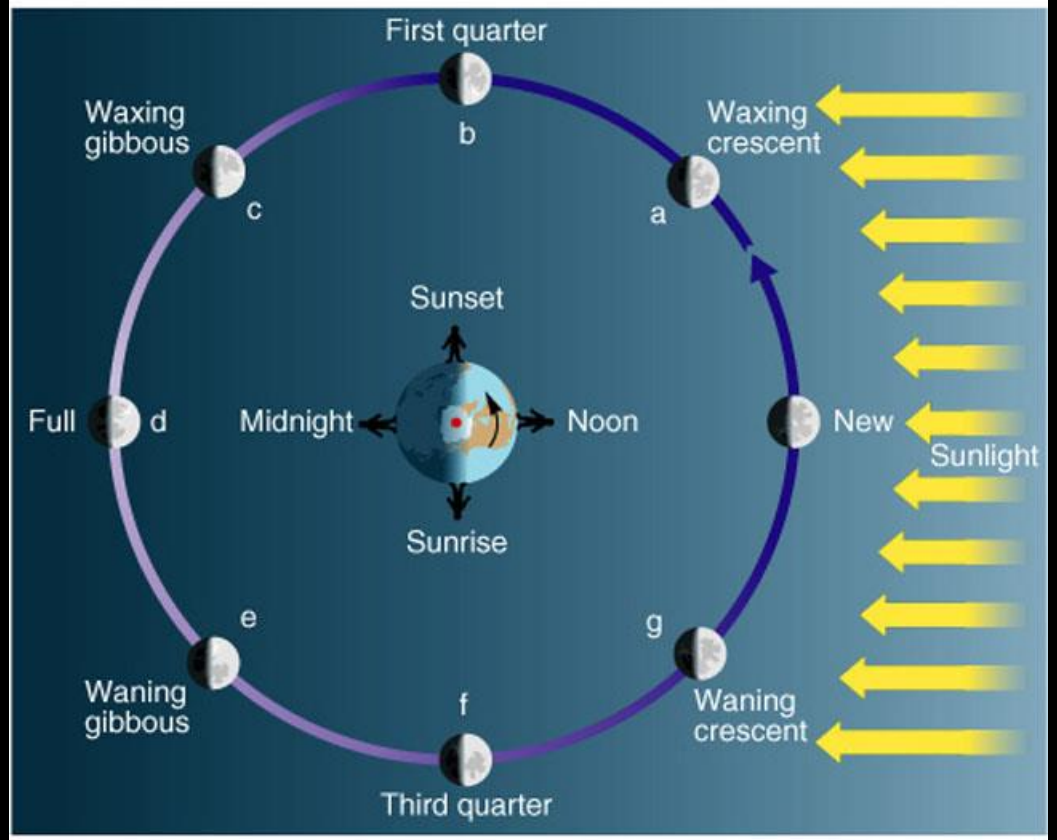
Mars in Retrograde Motion



PHASES OF THE MOON AND ECLIPSES

Phases of the Moon

a



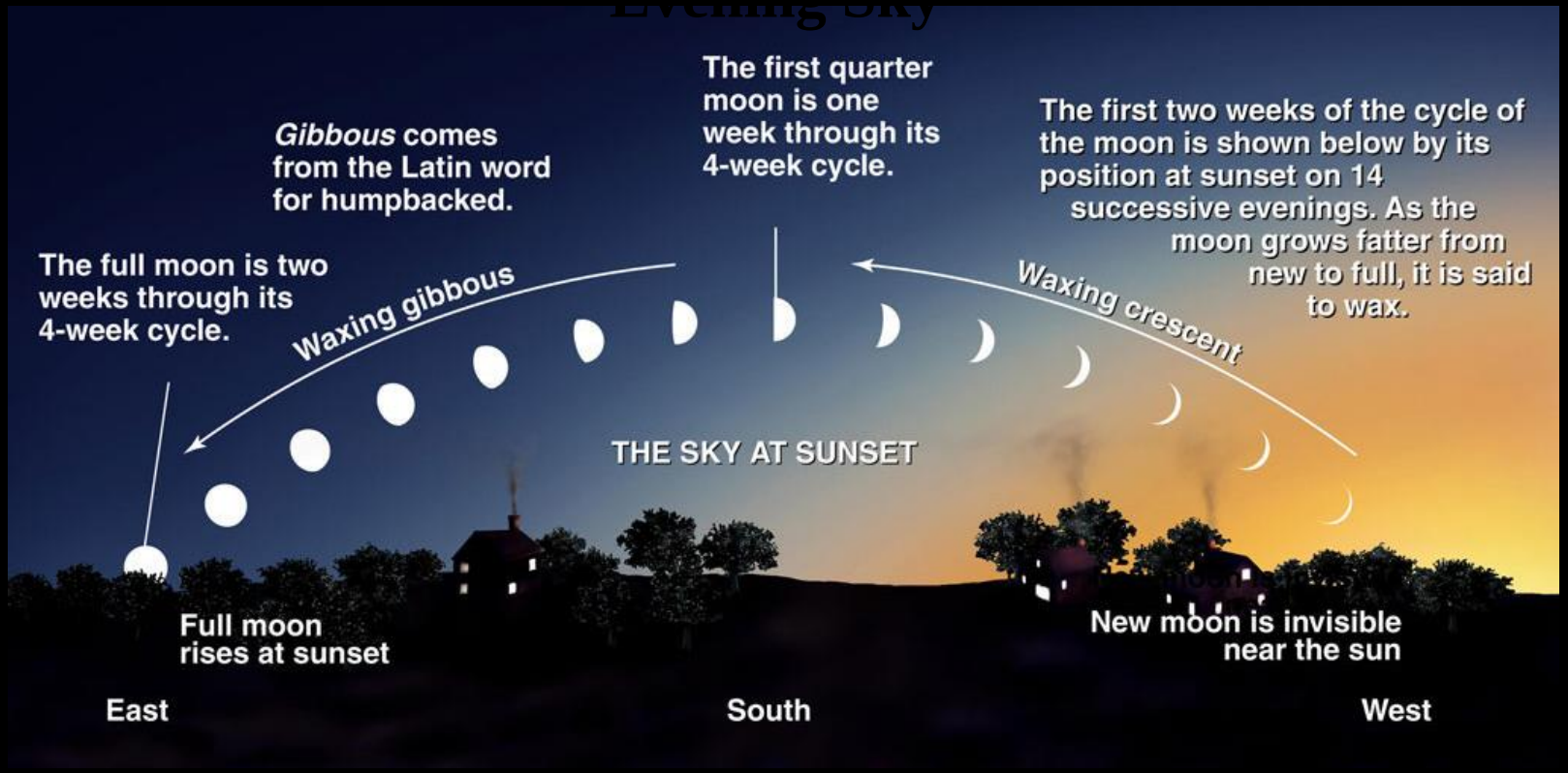
b

Phases of the moon occur because we see only a portion of the lit side of the moon from different angles

Half the moon is <u>always</u> lit and half the moon is always dark, but we might only see a portion of the lit side

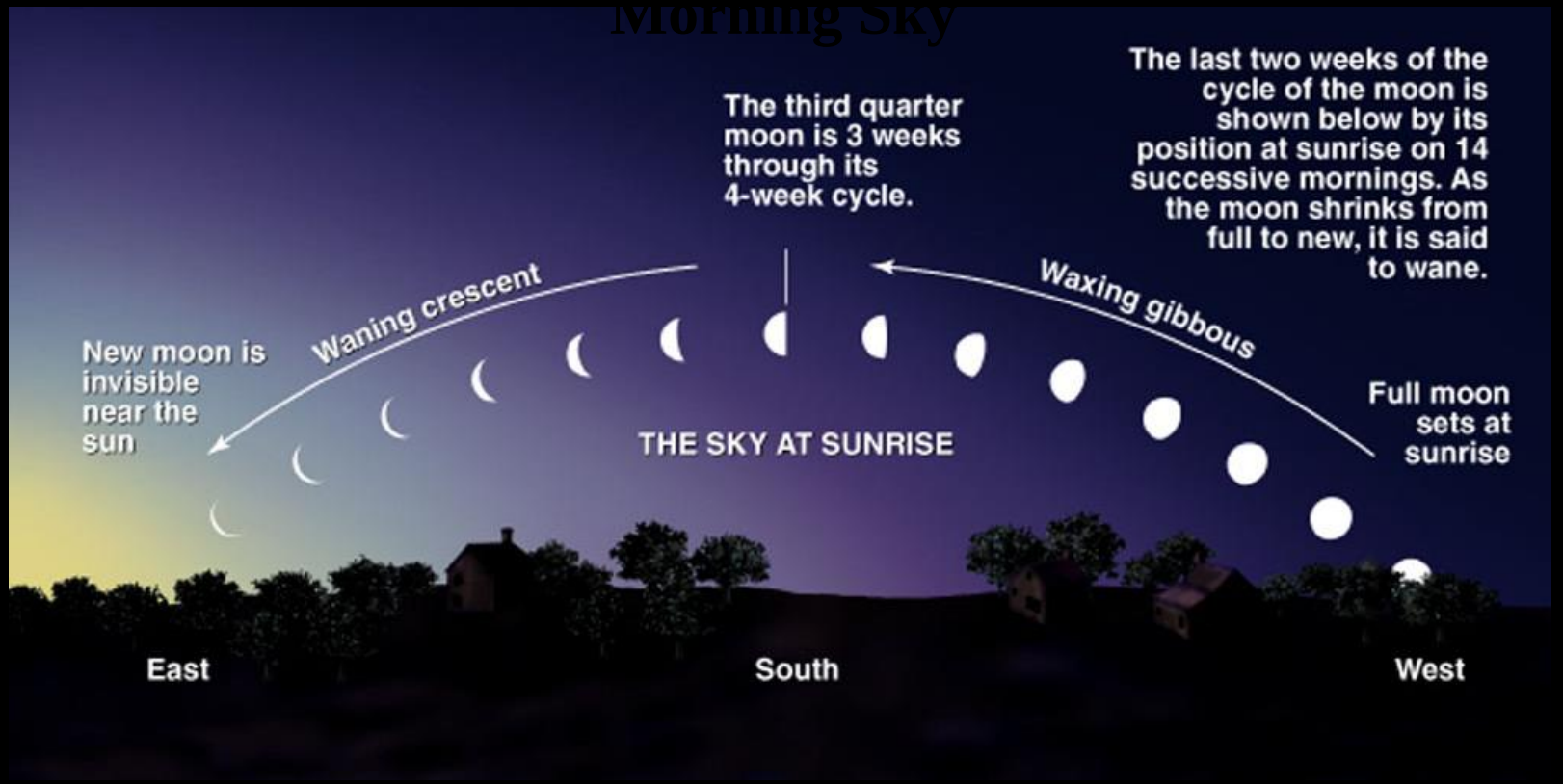
Phases of the Moon are NOT because of the Moon going in and out of shadows

The Phases of the Moon—notice that the lit side must always face the sun



New Moon → First Quarter → Full Moon

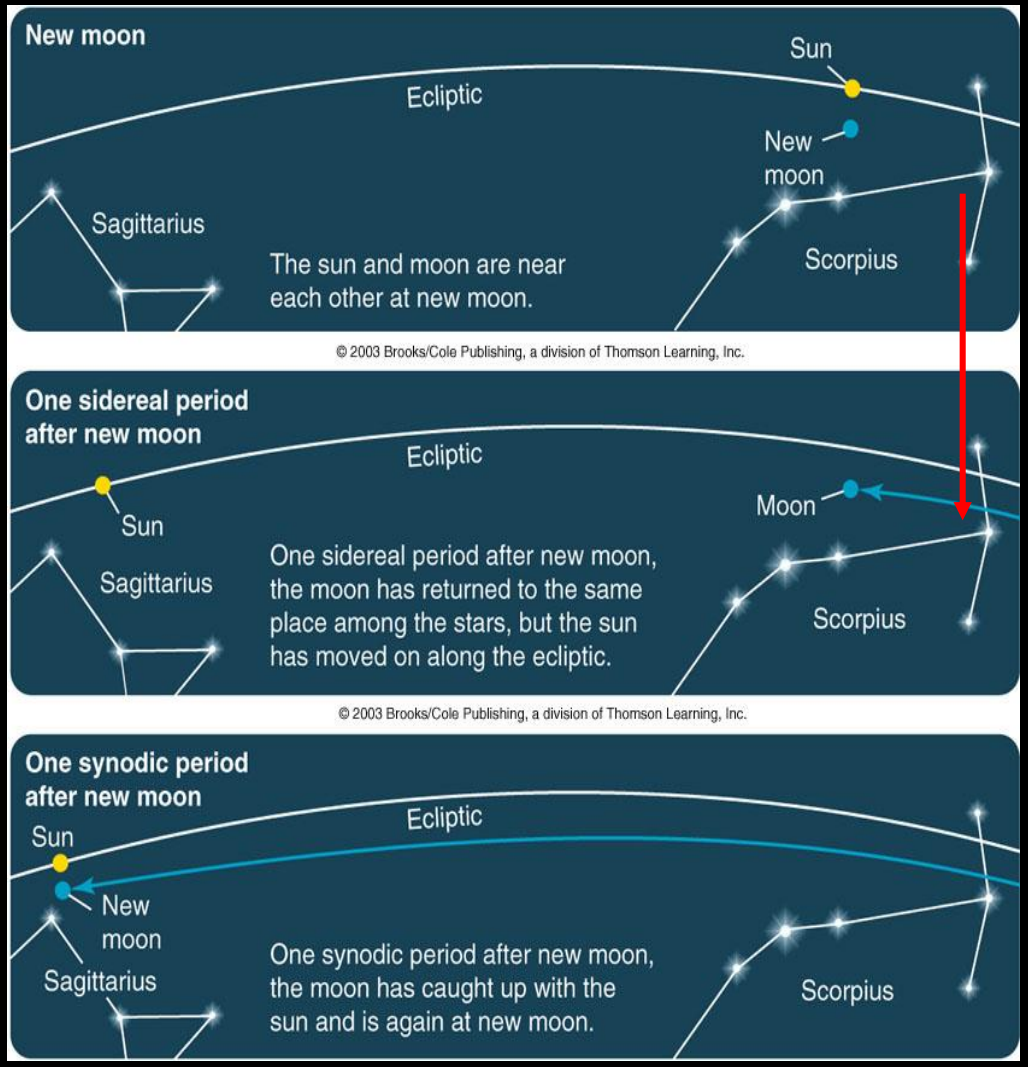
The Phases of the Moon—notice that the lit side must always face the sun

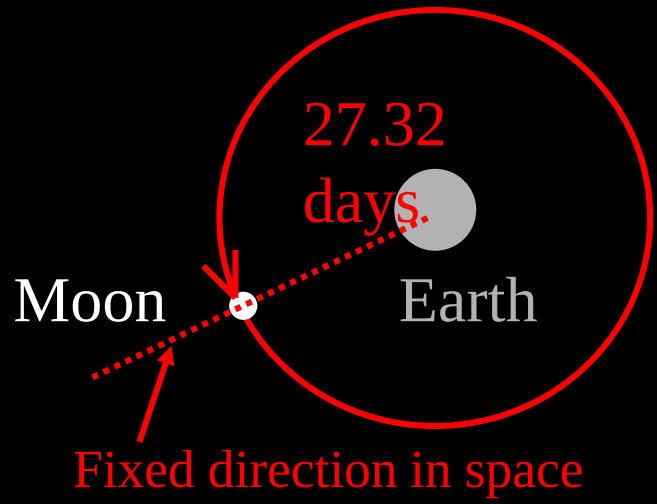


Full Moon → Third Quarter → New Moon

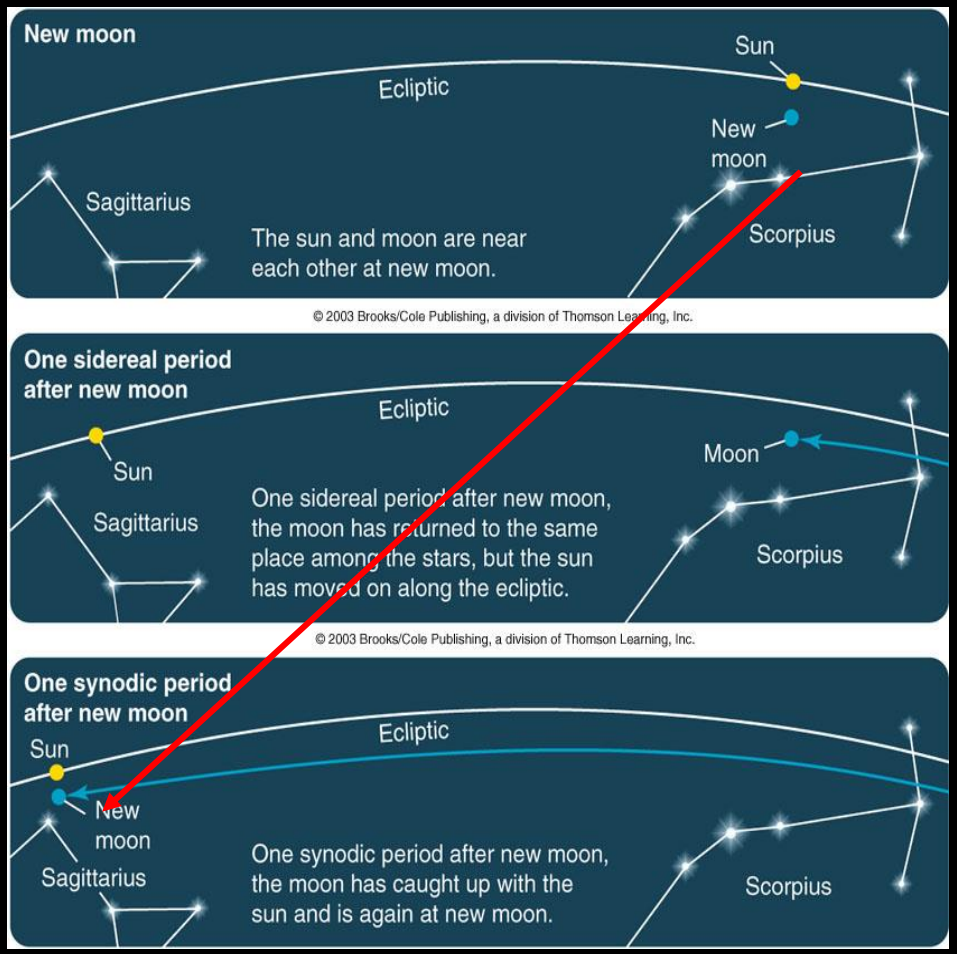
The Phases of the Moon

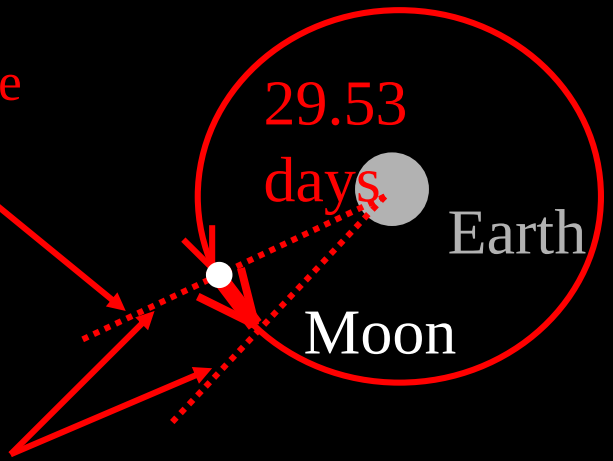
- The Moon orbits Earth in a **sidereal period** of 27.32 days.





The Phases of the Moon





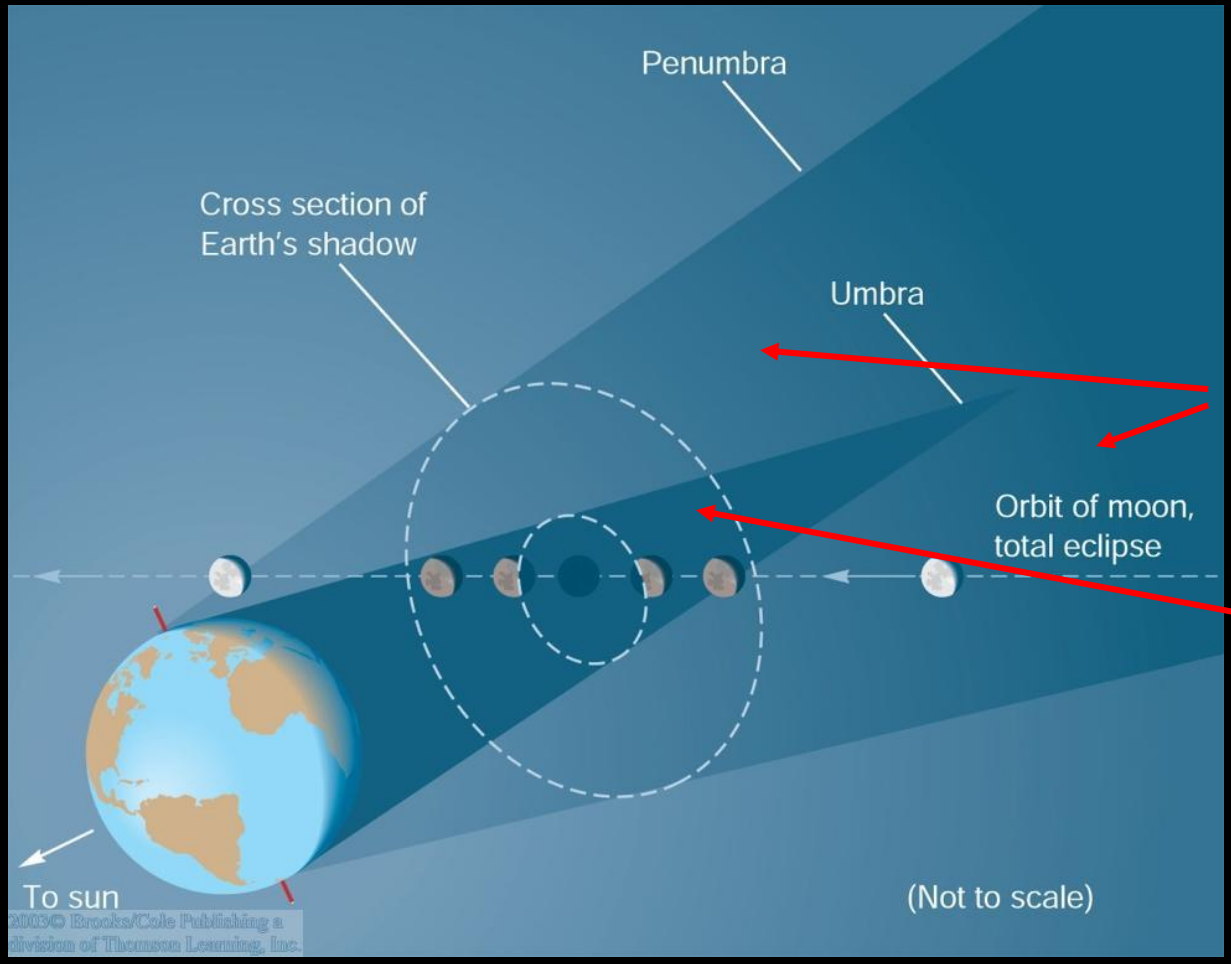
Earth orbits around Sun =>
Direction toward Sun changes!

- The Moon's *synodic period* (to reach the same lunar phase) is 29.53 days (~ 1 month).

Solar eclipse or lunar eclipse?

Solar eclipse or lunar eclipse?

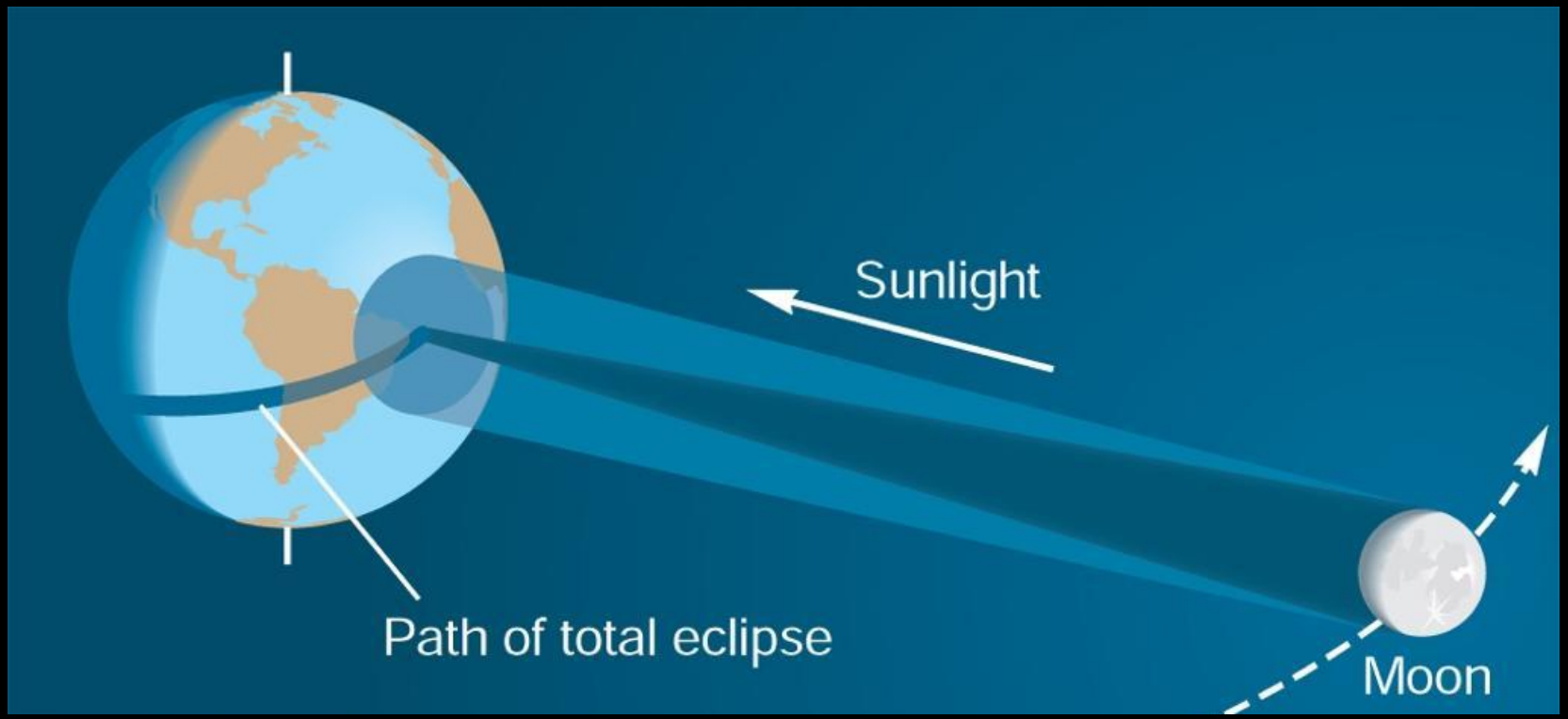
Lunar Eclipses: Earth's shadow falls across Moon



partial shadow is the **Penumbra**, and a zone of full shadow is the **Umbra**

If the entire surface of the moon enters the Umbra, the lunar eclipse is total.

Solar Eclipses: Moon's shadow falls across Earth

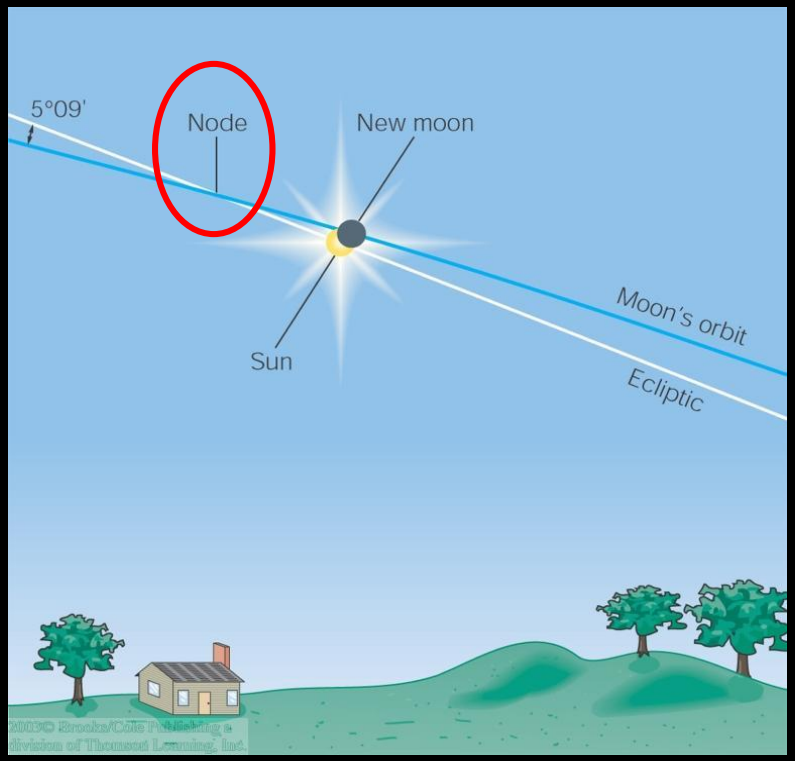


The sun appears approx. as large in the sky (same angular diameter ~ 0.5^0) as the moon.

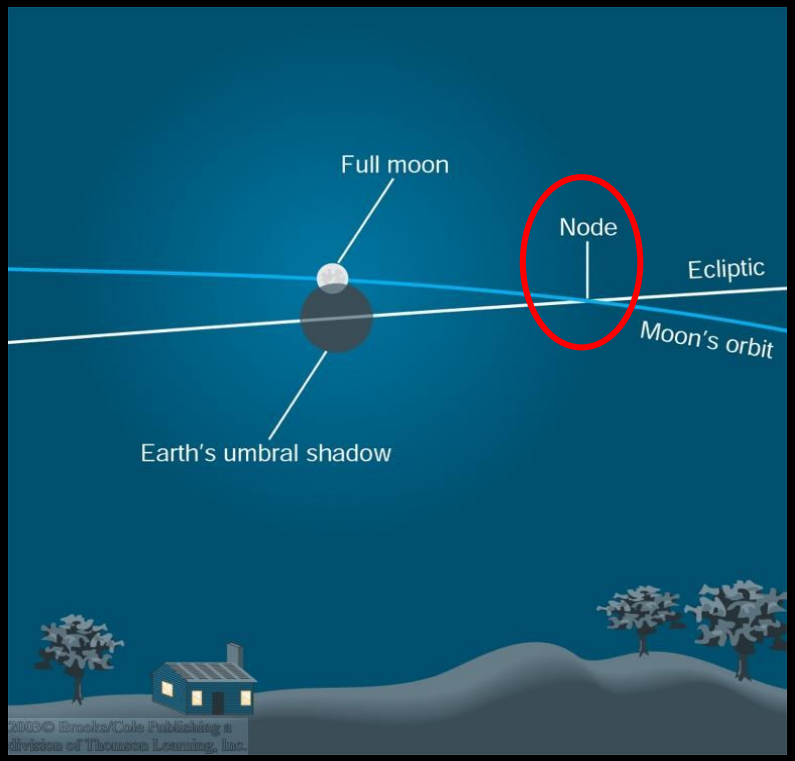
→ When the moon passes in front of the sun, the moon can cover the sun completely, causing a total solar eclipse.

Conditions for Eclipses

The moon's orbit is inclined against the ecliptic by ~ 5^0.



A solar eclipse can only occur if the moon passes a node near new moon.



A lunar eclipse can only occur if the moon passes a node near full moon.