

Apparent Motion

How do celestial objects appear to move across the sky?

Geocentric Universe

NOT THE MODEL OF OUR SOLAR SYSTEM

- Idea that Earth was at the center of the solar system.
- Stars all rotate around the Earth on a single large sphere at 15°/hour
- Planets travel on smaller spheres around their own larger sphere in epicycles

Apparent Motions

Problems with the Geocentric Model:

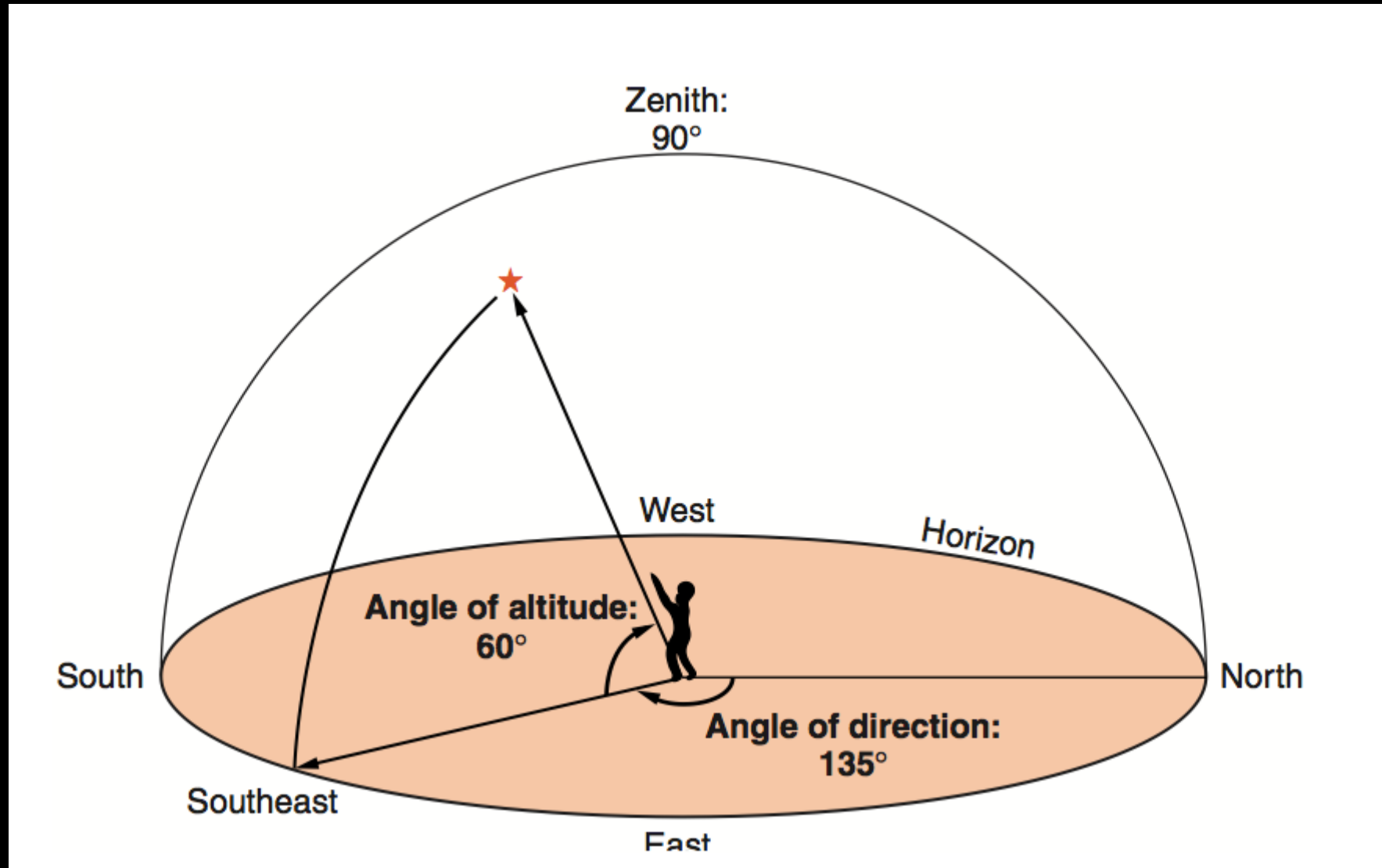
- Locations of the planets could not accurately be predicted
- Changes in the apparent diameter of the Moon and Sun could not be explained



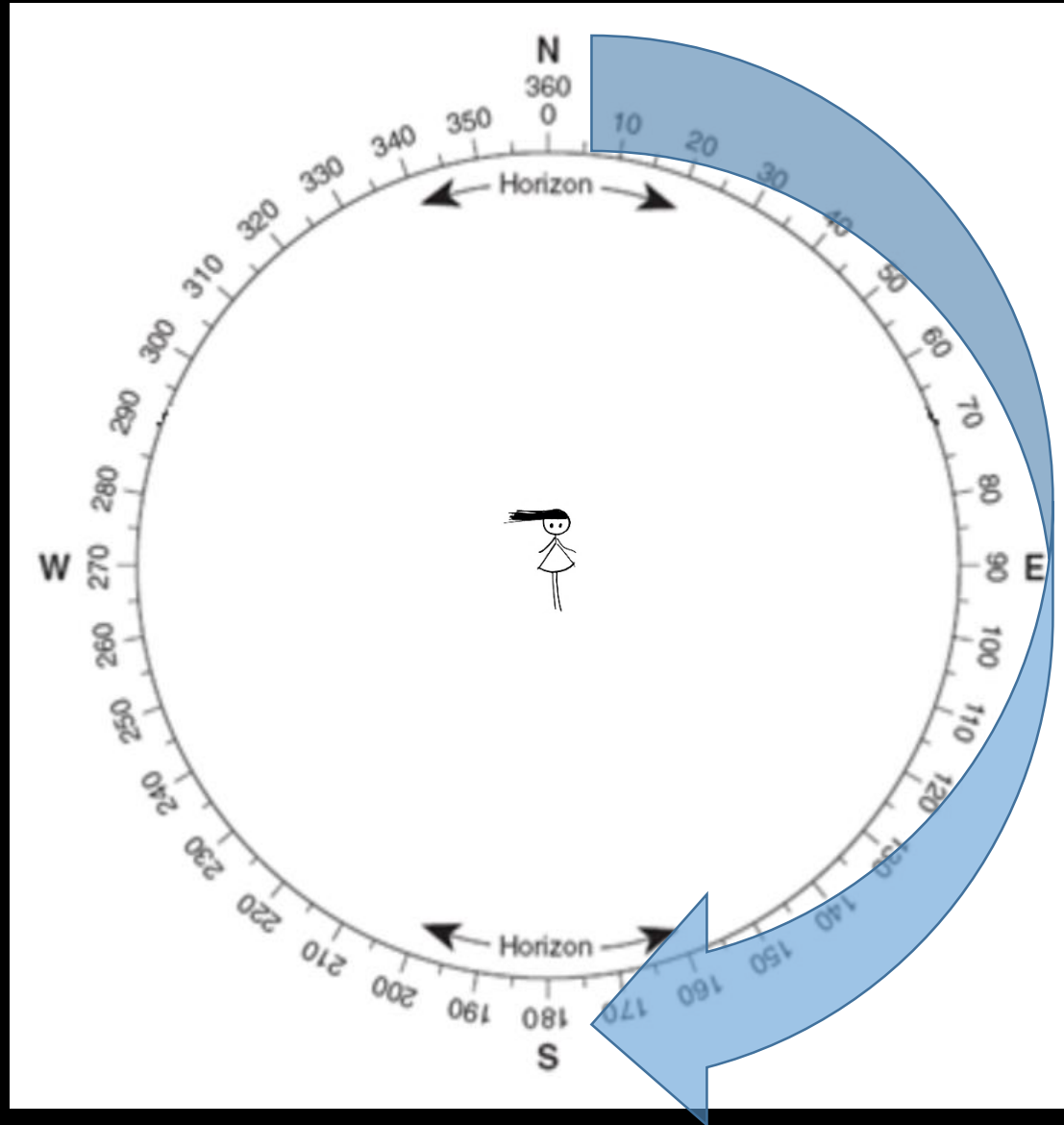
Apparent Motions

- Celestial Object - Any of the natural objects that can be seen in the sky.
- Apparent Motion - the way in which celestial objects appear to move across the sky.

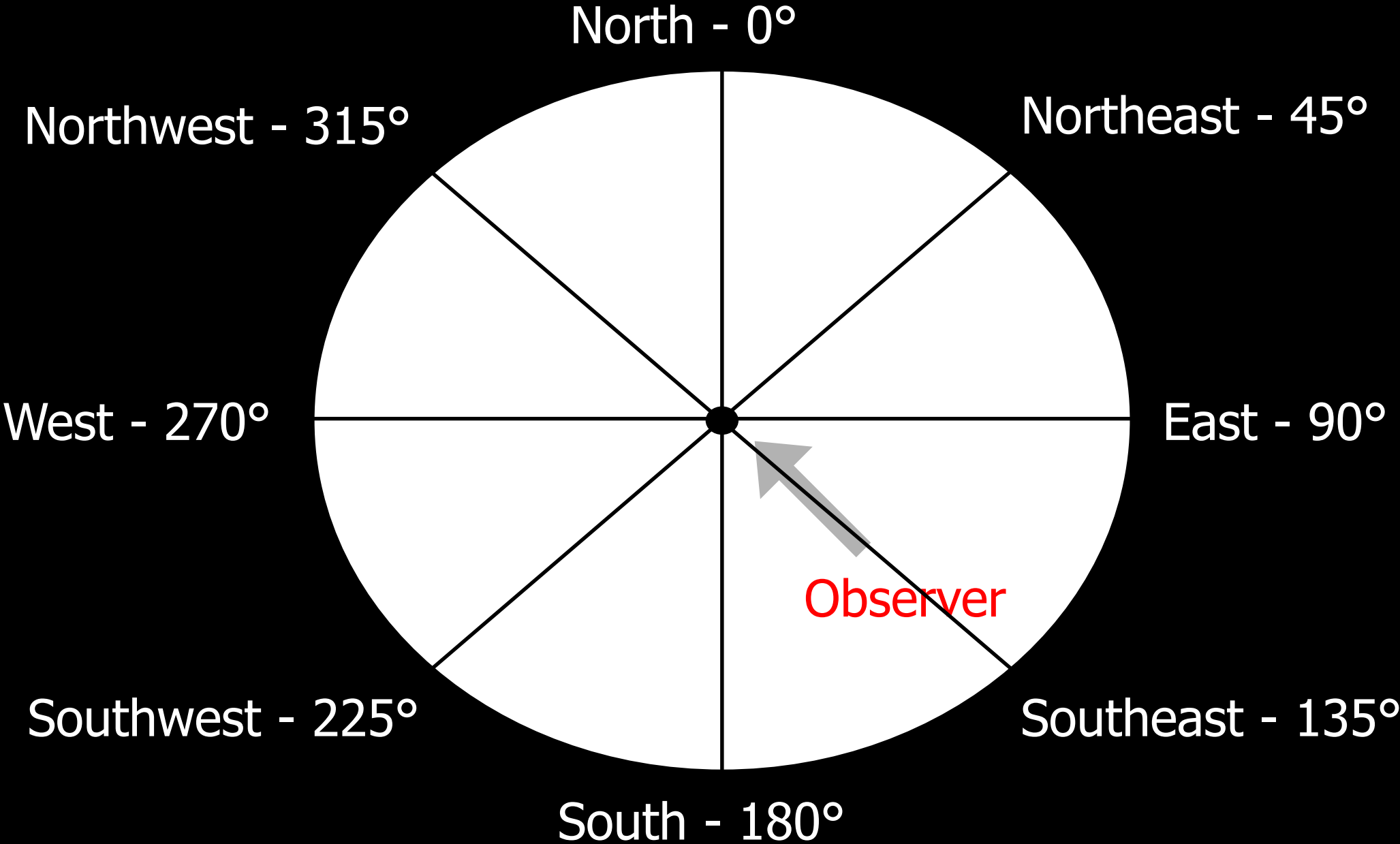
Celestial Sphere - the visible portion of the sky that celestial objects appear to travel on



Horizon- the edge of the visible portion of the celestial sphere.



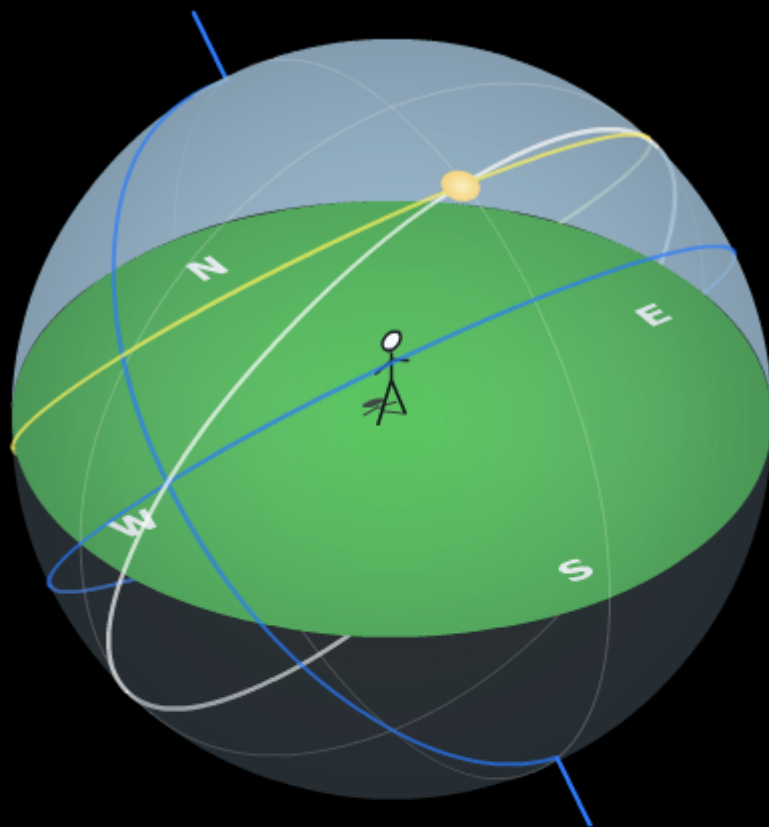
Azimuth Directions



Zenith - highest point on the celestial sphere which is directly over the observer.



All objects (except Polaris) appear to move across the celestial sphere from east to west at 15° /hour or $360^{\circ}/24$ hours.



Information

The horizon diagram is shown for an observer at latitude 40.8° N on 27 May at 12:00 (12:00 PM).

advanced

sun's hour angle: 0h 2m
sidereal time: 4h 21m
equation of time: 2:49
☐ show analemma

sun's altitude: 70.6°
sun's azimuth: 182.0°
sun's right ascension: 4h 19m
sun's declination: 21.4°

Time and Location Controls

the day of year: 27 May

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |

the time of day: 12:00



the observer's latitude: 40.8° N



Animation Controls

start animation

animation mode:

☒ continuous ☐ loop day
☐ step by day

animation speed: 3.0 hrs/sec



☐ use lower quality graphics when animating to improve performance

General Settings

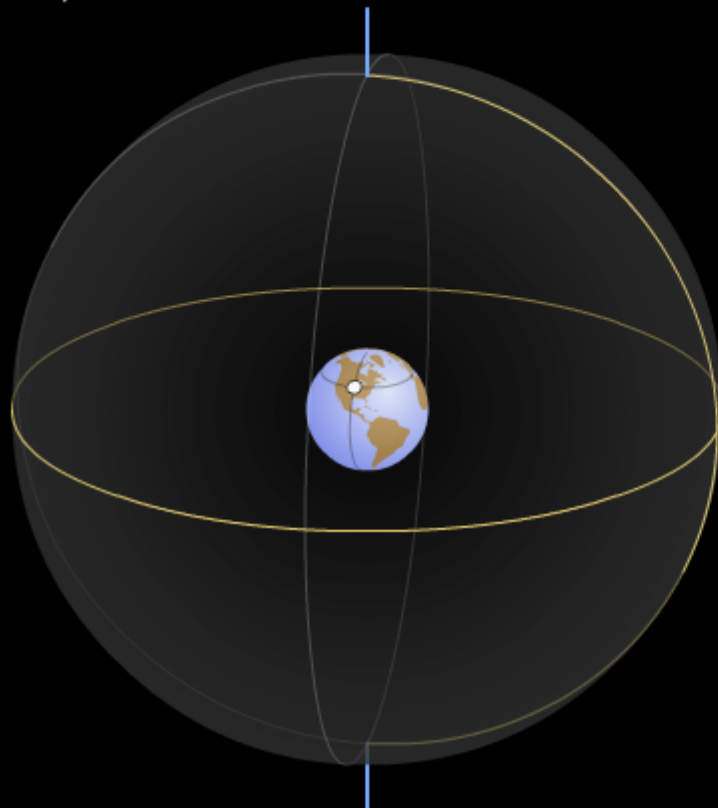
- ☒ show the sun's declination circle
- ☒ show the ecliptic
- ☐ show month labels
- ☒ show underside of celestial sphere
- ☒ show stickfigure and its shadow

dragging the sun's disk changes the ...

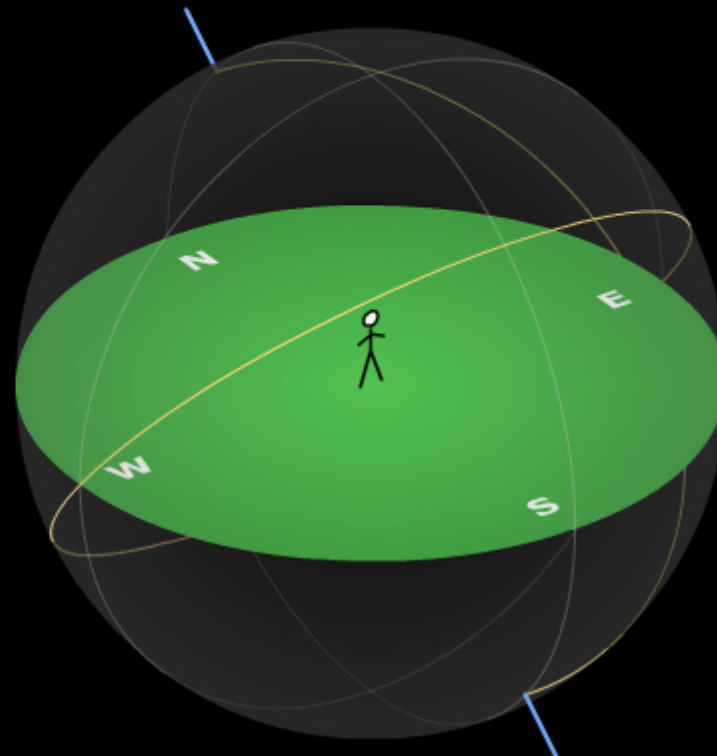
- ☒ time of day
- ☐ day of year

- Star Trails - long exposure photos of stars as they move across the sky.
- Circumpolar Stars - stars that move around a polar star. (POLARIS)
- Polar Star - star directly above the North or South Pole.

celestial sphere view

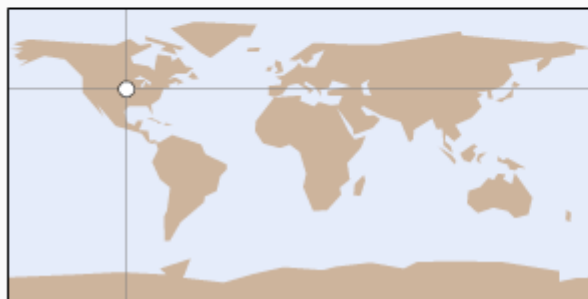


horizon diagram view

Observer's
Location

latitude: 40.8 ° N ▼

longitude: 96.7 ° W ▼



Animation Controls

start animation

animate continuously ▼

animation rate:



slower

faster

Appearance Settings

- ☐ show labels
- ☒ show 0h circle
- ☒ show celestial equator
- ☒ show underside of horizon diagram
- ☐ show never rise region
- ☐ show rise and set region
- ☐ show circumpolar region
- ☐ show the angle between the celestial equator and horizon

Star Controls

star patterns... ◀

add star randomly

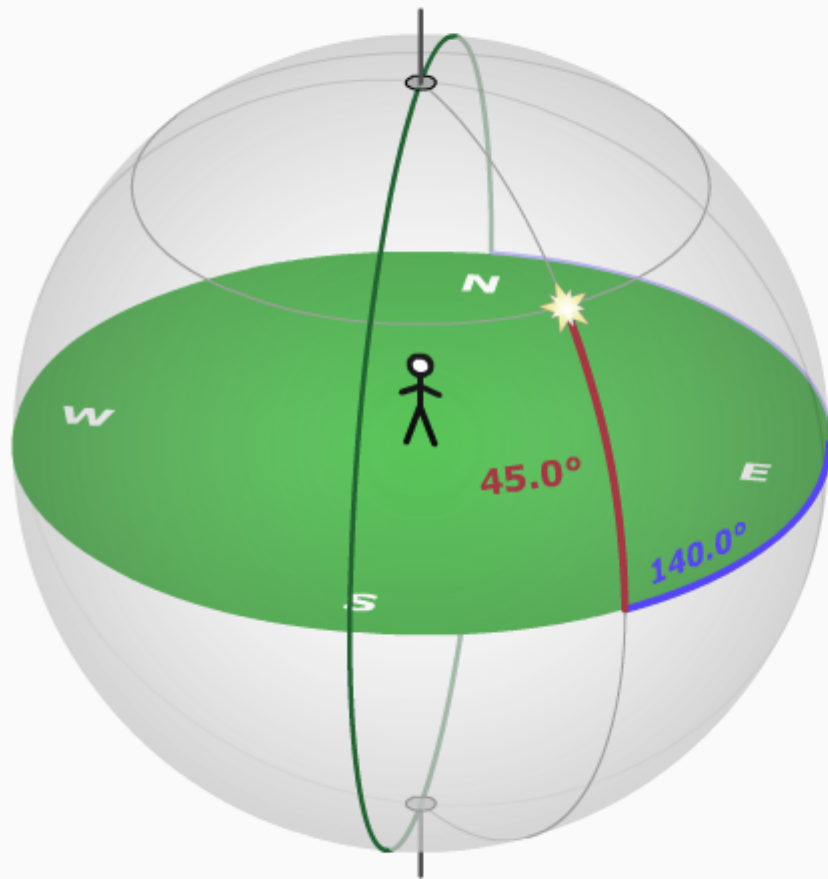
remove all stars

- ☒ no star trails
- ☐ short star trails
- ☐ long star trails

reset star trails

- Locating positions on the celestial sphere uses angular coordinates:
- Altitude - angular distance above the horizon (0° to 90°)
- Azimuth - angular distance along the horizon measured from due north (0° to 360°)

The Horizon Diagram



Star Position

az: 140.0 °



alt: 45.0 °

*you can also change the star's position by dragging it*

Labels

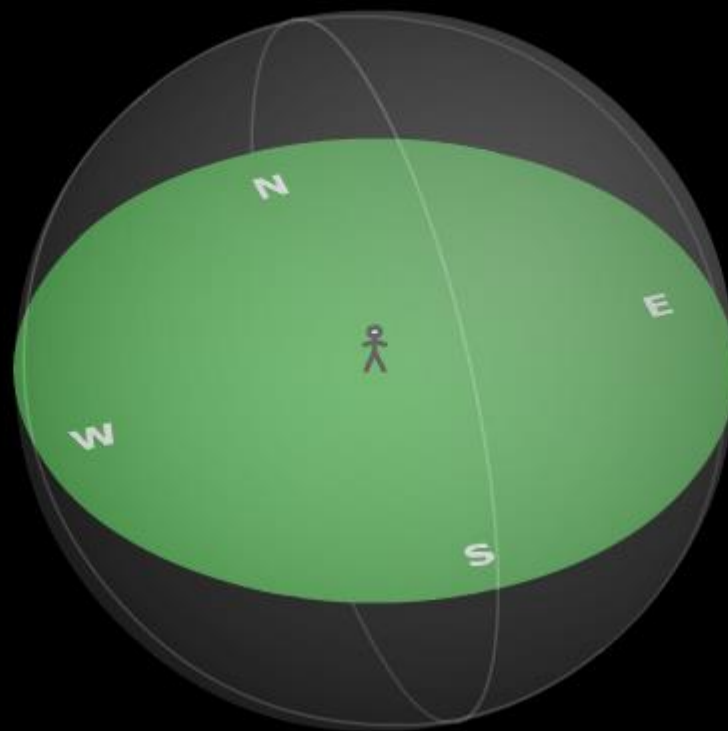
[show all](#)[hide all](#)

Individual label visibilities:

- ☐ Zenith
- ☐ Horizon Plane
- ☐ Nadir
- ☐ Meridian

The Sun's path changed both its position and length with the season

- The greater the Sun's path the more amount of daylight hours an area receives.
- The shorter the Sun's path the less amount of daylight hours an area received.



Latitude

41.0° N

90° S

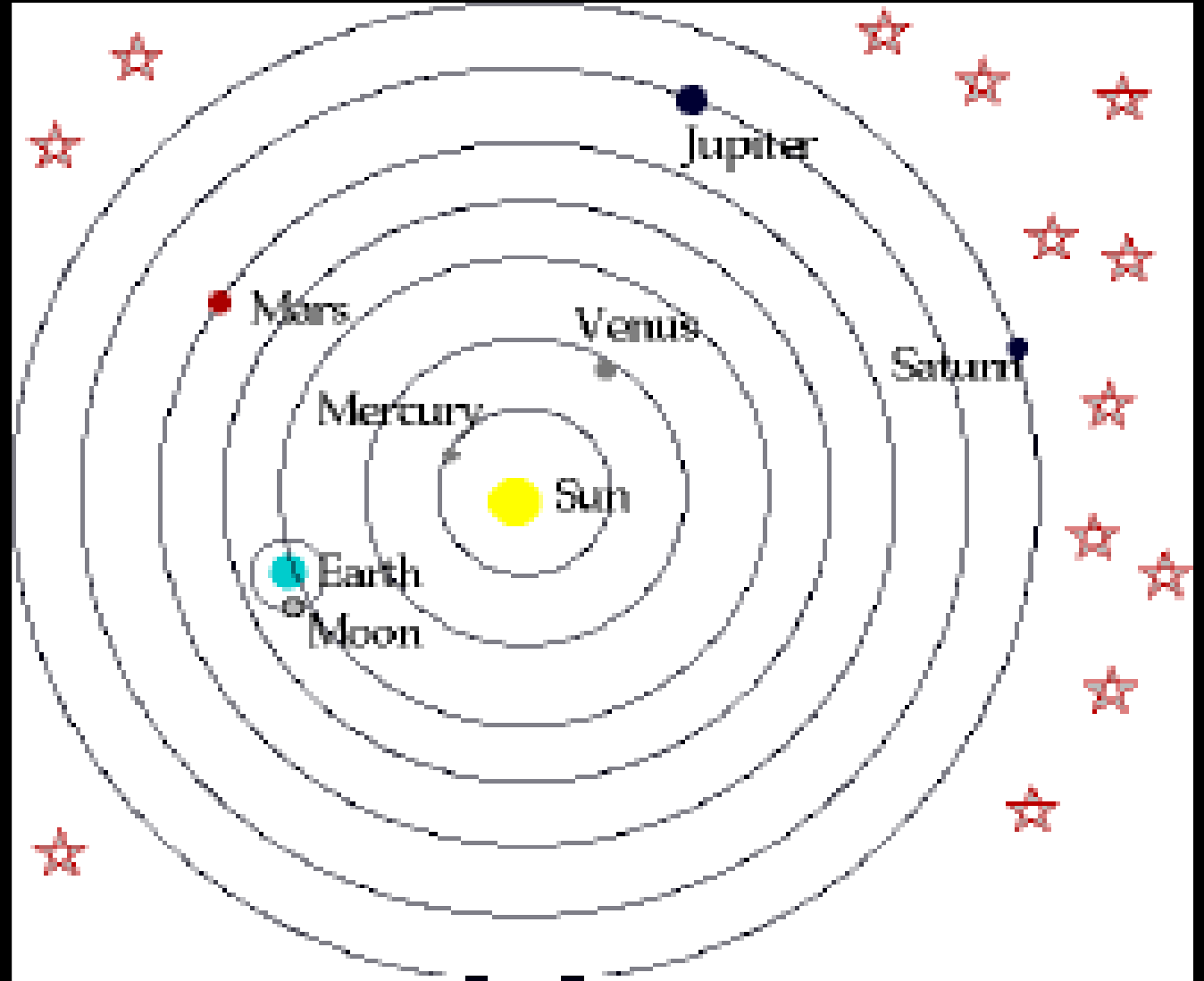
90° N



Actual Motions

In the Heliocentric model how do the planets move around our Sun?

- Heliocentric Model - **current** model of the solar system where the Sun is at the center.
- All planet revolve around the Sun which is in the center.





Rotation

- the movement of an object in a circular motion around a line of axis

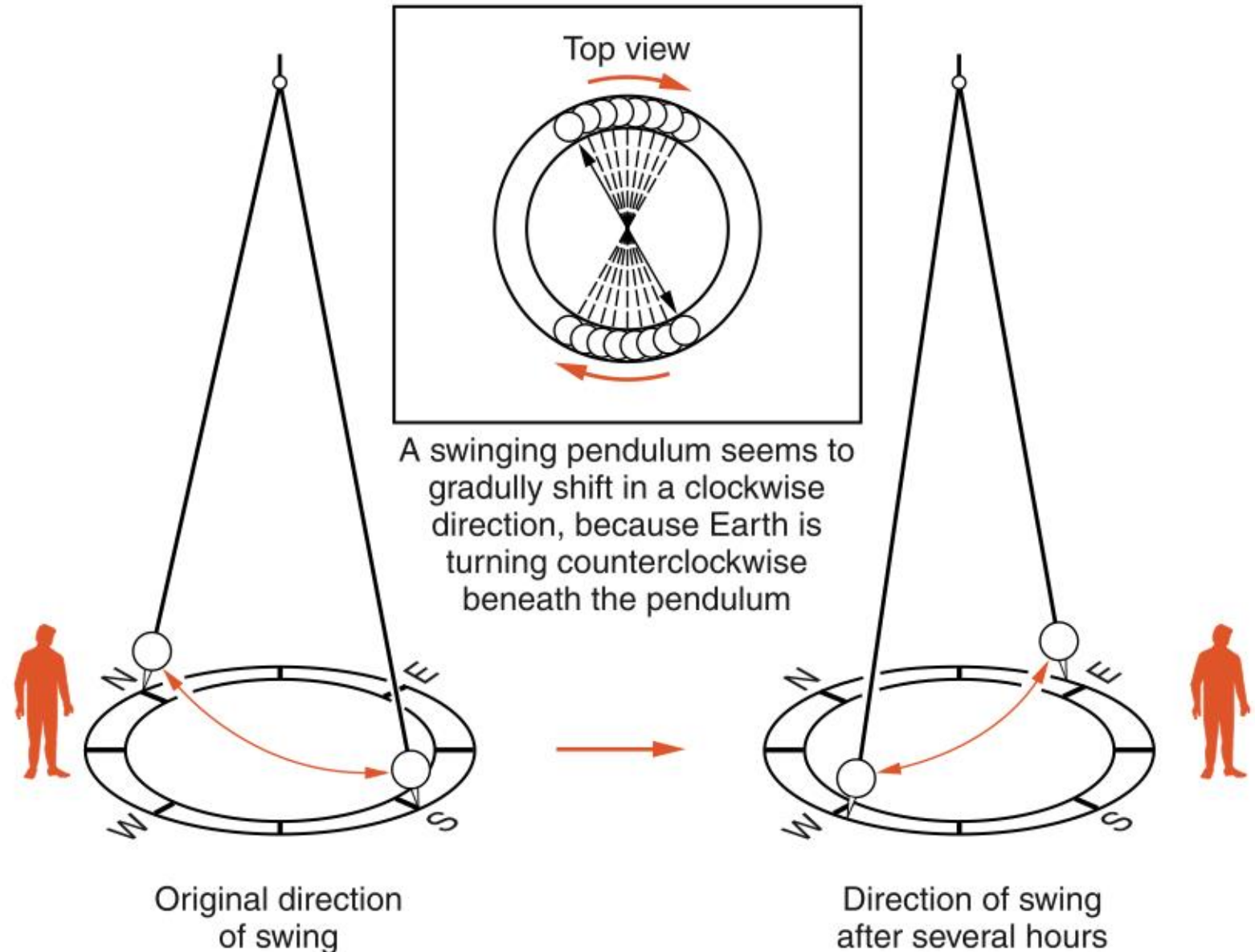
- Period of Rotation - amount of time to make one complete rotation

Example: Earth rotates 360° in 24 hours or 15° /hour

Earth's axis of rotation is tilted 23.5°

Evidence of Rotation

- **Foucault Pendulum**
large pendulum that when allowed to swing freely changes its path due to Earth's rotation.



Coriolis Effect - the tendency of all particles on Earth's surface to be deflected from a straight line

- **N. Hemisphere to the right**
- **S. Hemisphere to the left**



0 %

Loading

Revolution - the motion of one body **around** another in an orbit

Period of Revolution - the amount of time required to orbit the Sun one time

Example: Earth orbits the Sun in **365.25** days

Evidence of Revolution

- **Parallelism of Earth's Axis - Earth's tilted axis of 23.5° is always pointed to the same location in the sky giving us our different seasons.**
- **Seasons**

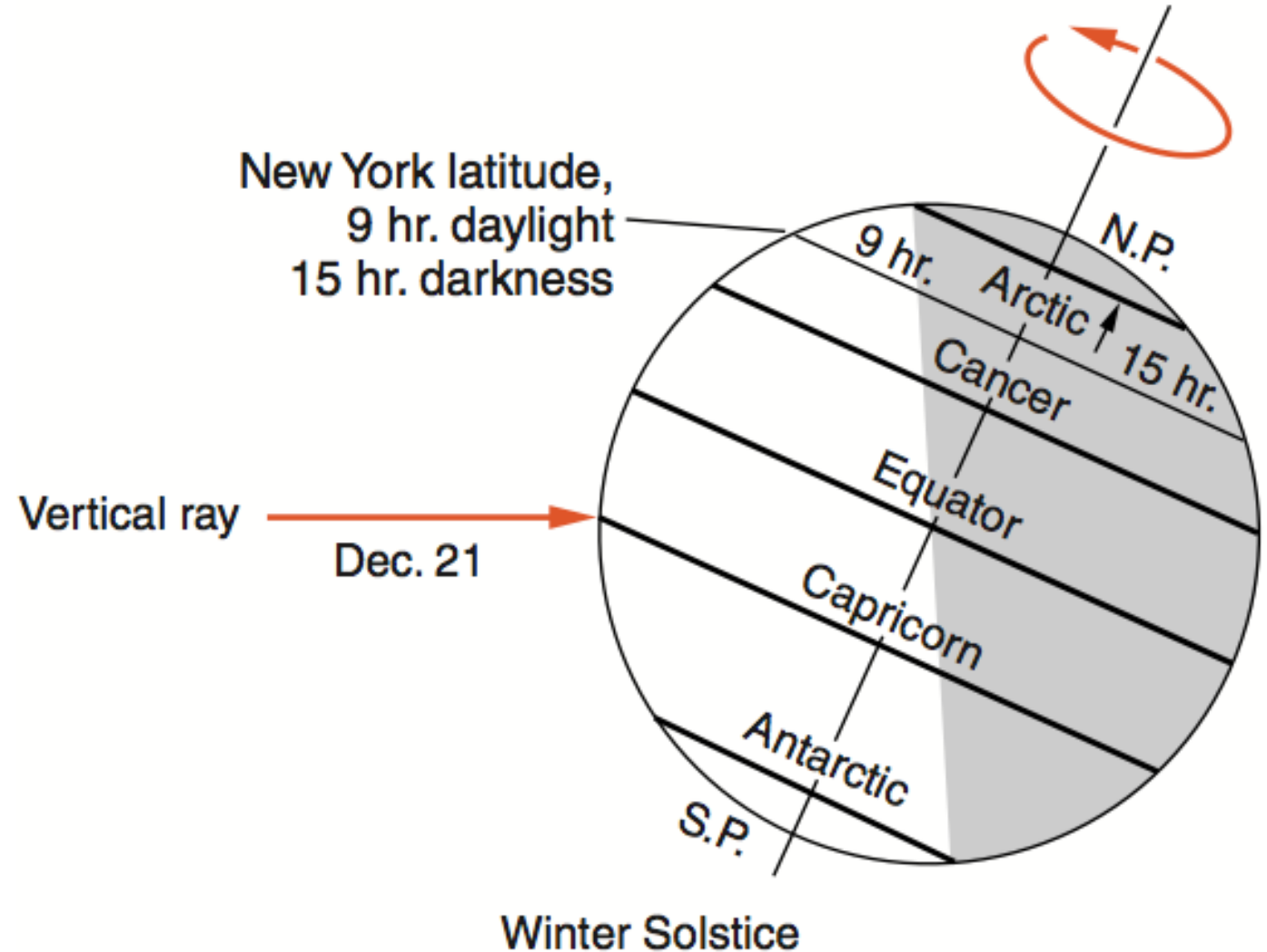


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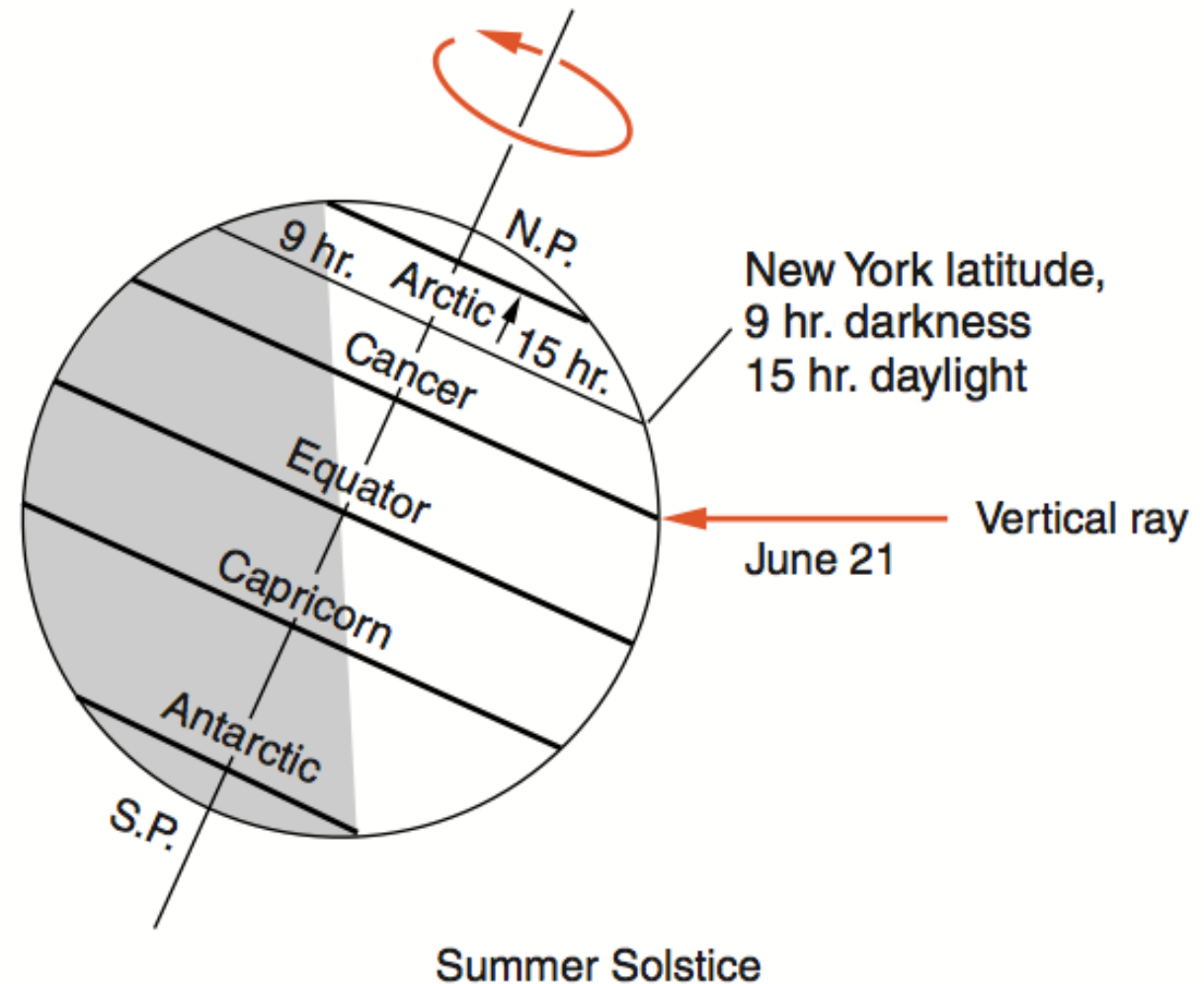
Winter Solstice

- first day of winter (December 21) in the N. Hemisphere
- Earth's Northern Hemisphere is tilted away from the Sun.
- **Shortest** day of the year in NYS.
- **Greatest** orbital velocity.
- The Earth is **CLOSER** to the Sun.
- **CLOSER FASTER WINTER**



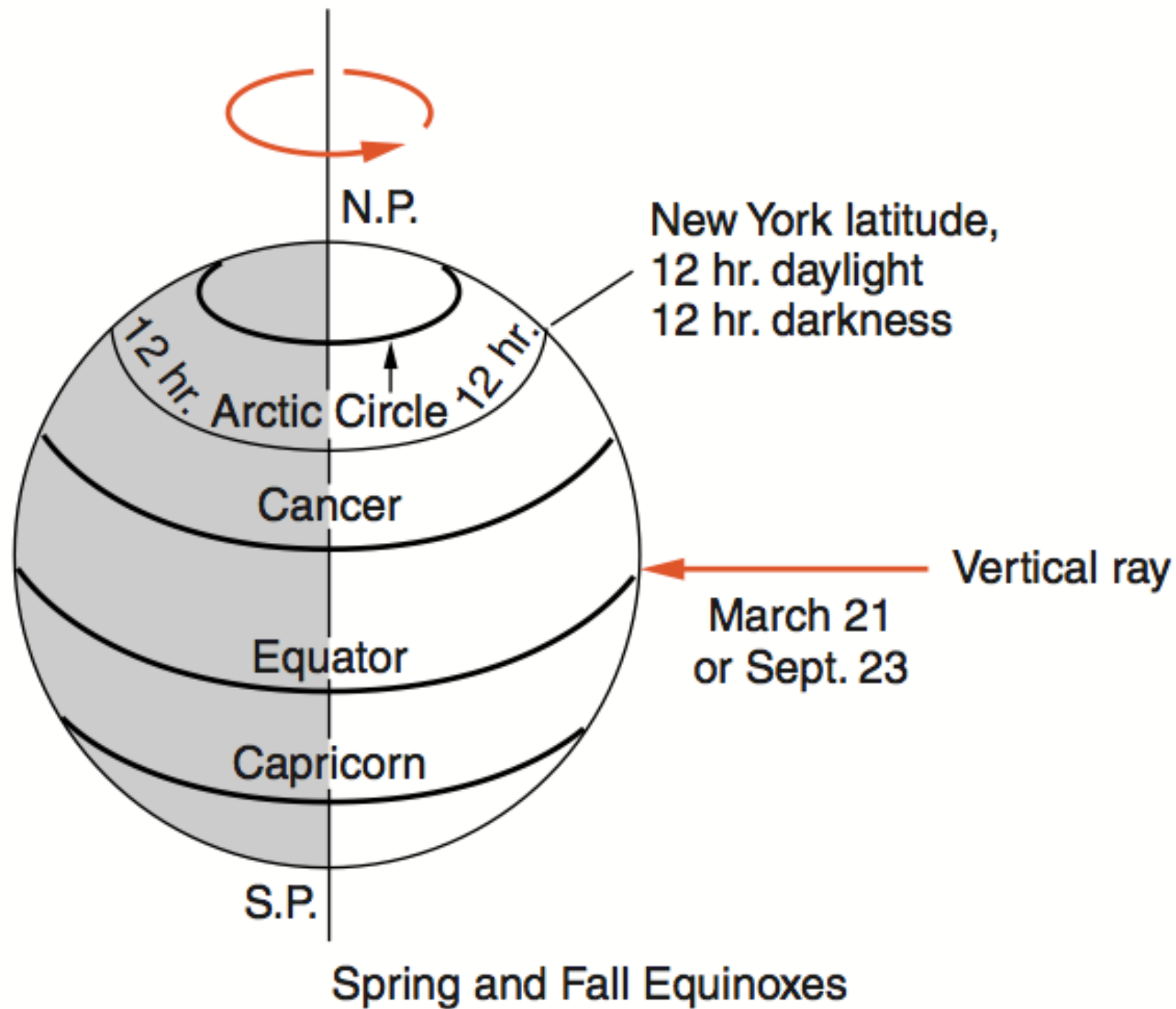
Summer Solstice –

- first day of summer (June 21) in the N. Hemisphere
- Earth's Southern Hemisphere is tilted towards from the Sun.
- **Longest** day of the year in NYS.
- **Slowest** orbital velocity.
- Earth is **FARTHEST** from the sun.



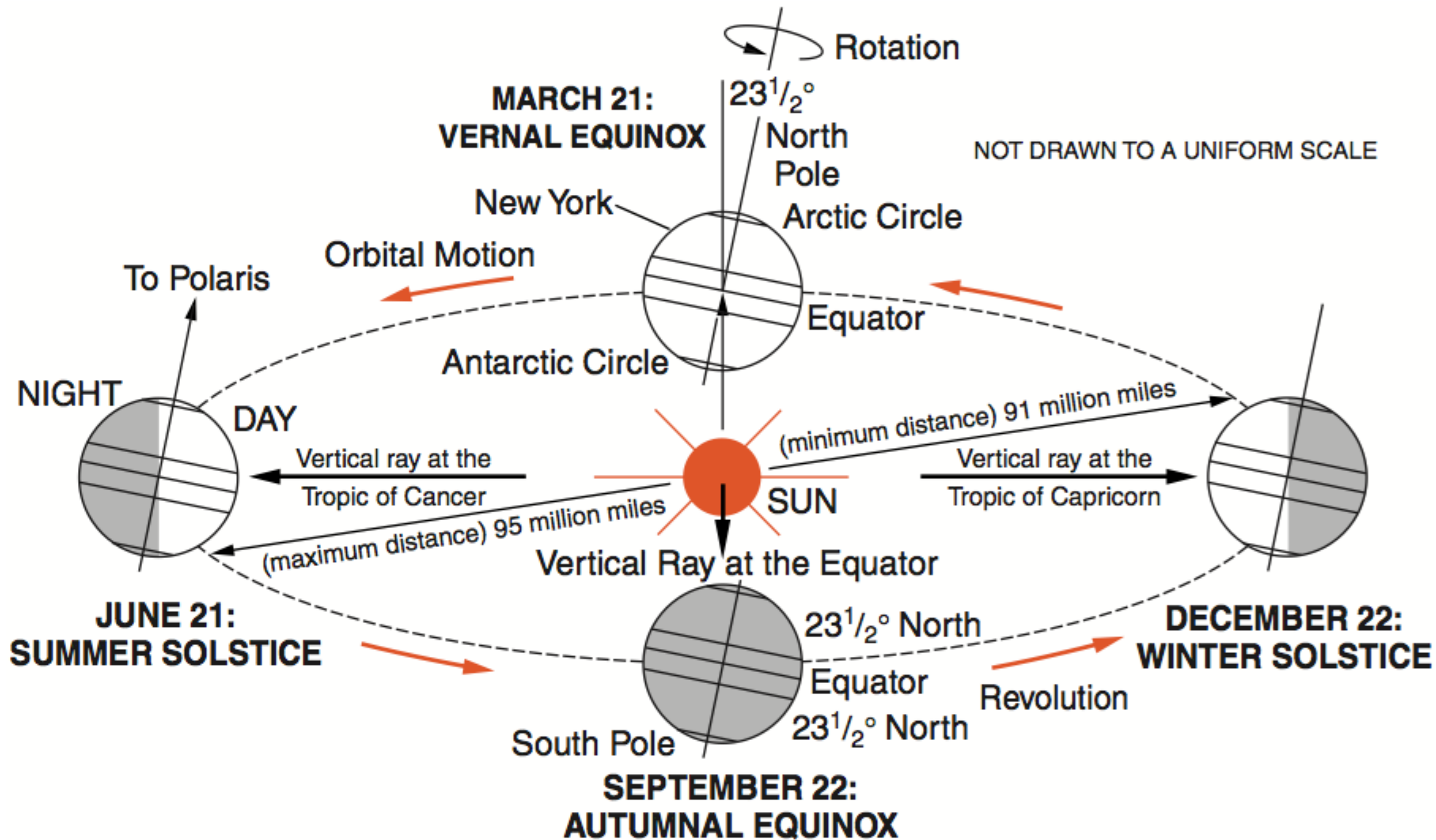
- Vernal (Spring)Equinox - first day of spring (March 21) in the N. Hemisphere when there are equal amounts of day and night
- Autumnal Equinox –

first day of fall (September 23) in the N. Hemisphere when there are equal amounts of day and night



Reason for the Seasons (add this to the back page of your notes)

1. Tilt of Earth's Axis
2. Revolution around the Sun
3. Parallelism of Earth's Axis
4. Latitude
5. Not distance to the Sun...We are closer to the Sun in the WINTER

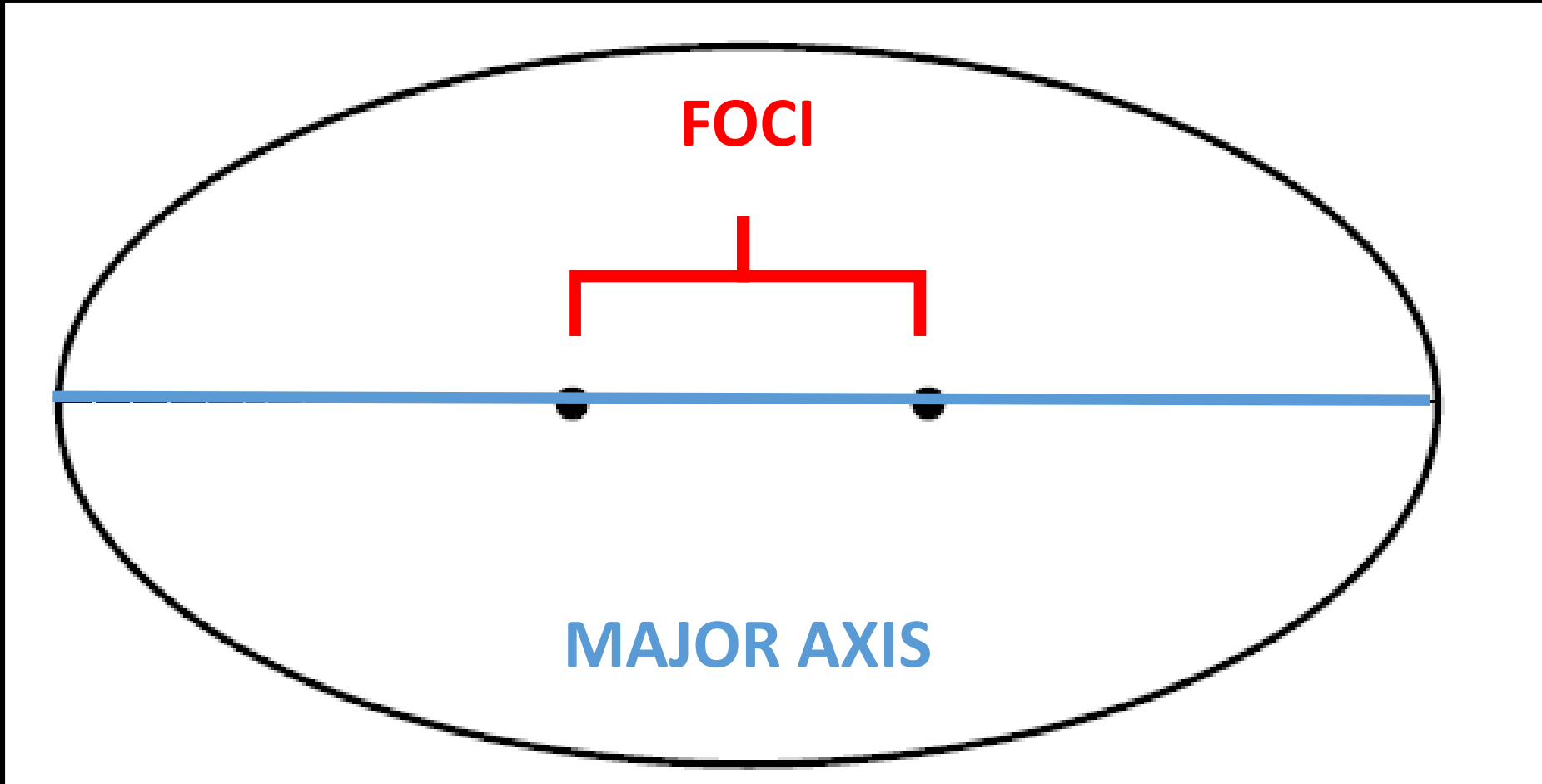


SHAPE OF EARTH'S ORBIT AROUND THE SUN

- Ellipse –
the oval shape of a planet's orbits.
- Eccentricity –
the degree of flatness or "ovalness" of an ellipse.
- Eccentricity of a perfect circle is 0
- Eccentricity of a flat line is 1

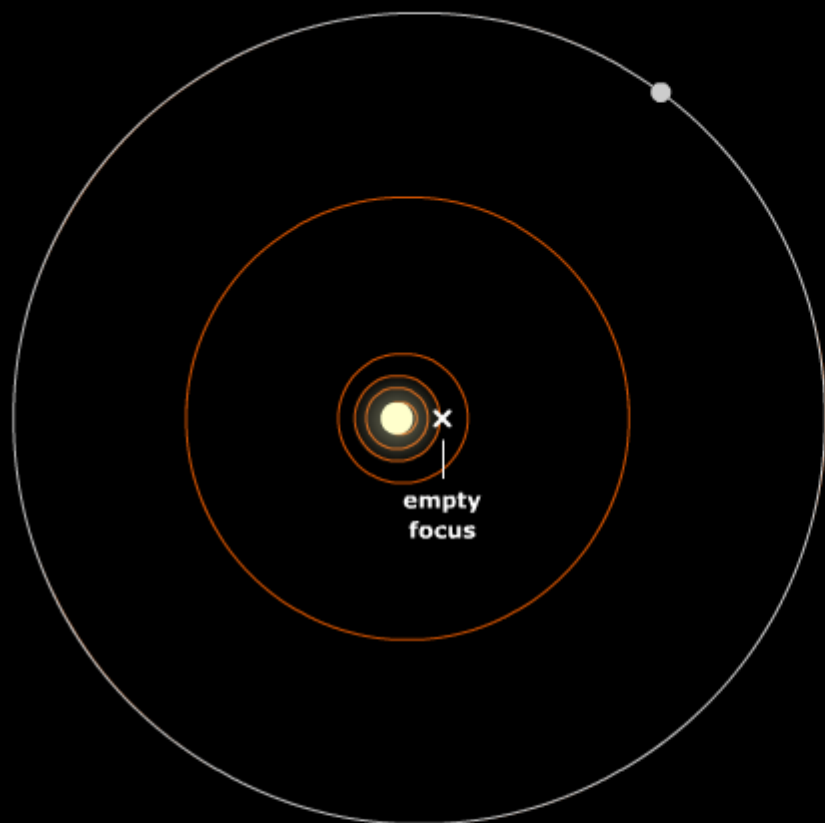
Parts of an Ellipse:

- Foci - two fixed center points of an ellipse
- Major Axis - longest straight lined distance across an ellipse



- **Calculating Eccentricity: Use the formula from the E.S.R.T**
- **eccentricity = $\frac{\text{distance between foci}}{\text{length of major axis}}$**

No units for eccentricity



5 AU

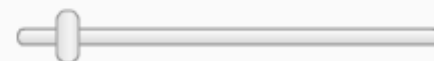
Orbit Settings

set parameters for: Saturn

semimajor axis (AU) 9.54

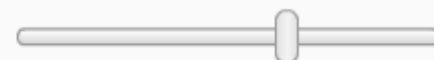


eccentricity 0.056



Animation Controls

animation rate (yrs/s) 0.18



Visualization Options

- ☒ show solar system orbits
- ☐ show solar system planets
- ☐ label the solar system orbits
- ☐ show grid

Kepler's 1st Law

Kepler's 2nd Law

Kepler's 3rd Law

Newtonian Features

- ☒ show empty focus
- ☐ show semiminor axis
- ☐ show center
- ☐ show semimajor axis
- ☐ show radial lines

$$r_1 + r_2 = 2 \times a$$
$$9.86 \text{ AU} + 9.22 \text{ AU} = 19.1 \text{ AU}$$

The Solar System

What does our solar system look like?

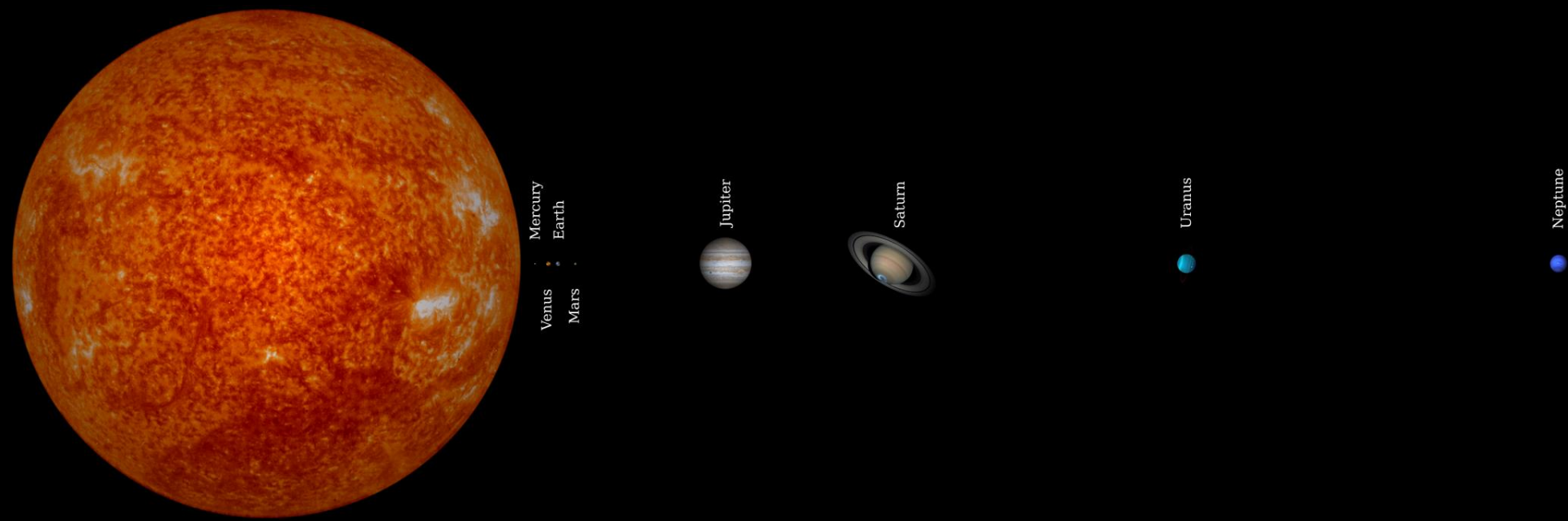
The Solar System

Solar System –

all the objects that orbit the Sun under its gravitational influence

The Sun accounts for 99% of the mass in the solar system.

Goal: Students will develop a sense of scale in the Universe.



Terrestrial Planets –

solid surfaced planets with smaller diameters and higher densities that are close to the Sun

Mercury



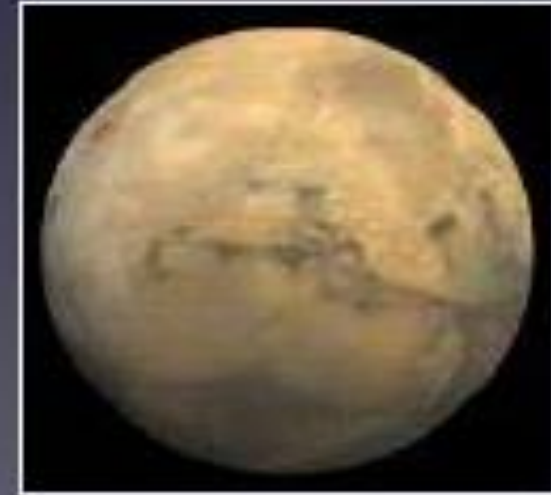
Venus



Earth



Mars



Celestial Object	Mean Distance from Sun (million km)	Period of Revolution (d=days) (y=years)	Period of Rotation at Equator	Eccentricity of Orbit	Equatorial Diameter (km)	Mass (Earth = 1)	Density (g/cm ³)
SUN	—	—	27 d	—	1,392,000	333,000.00	1.4
MERCURY	57.9	88 d	59 d	0.206	4,879	0.06	5.4
VENUS	108.2	224.7 d	243 d	0.007	12,104	0.82	5.2
EARTH	149.6	365.26 d	23 h 56 min 4 s	0.017	12,756	1.00	5.5
MARS	227.9	687 d	24 h 37 min 23 s	0.093	6,794	0.11	3.9

Jovian Planets –

gaseous planets with **larger** diameters and **lower** densities that are farther from the Sun.

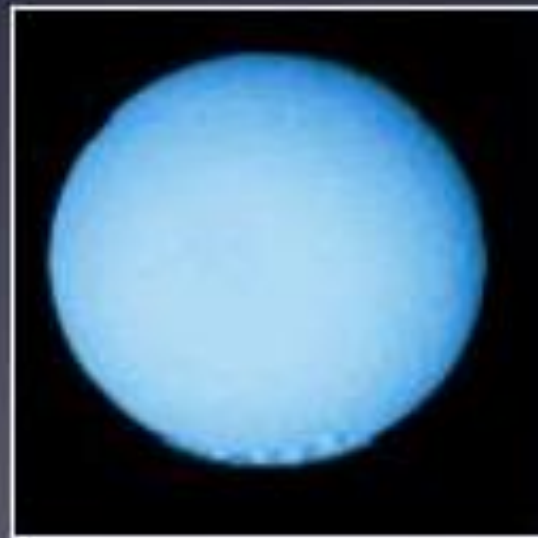
Jupiter



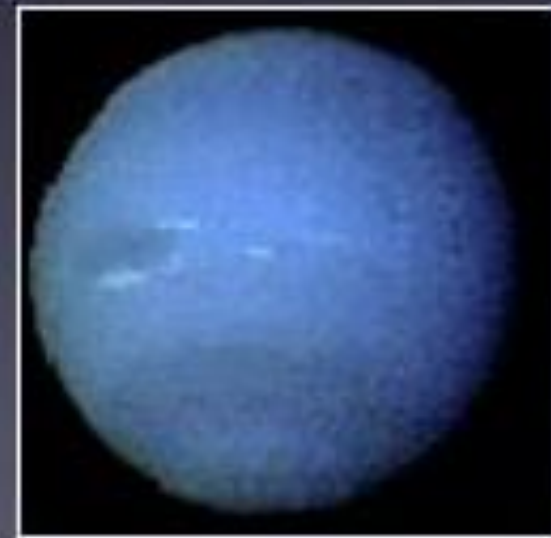
Saturn



Uranus



Neptune



Celestial Object	Mean Distance from Sun (million km)	Period of Revolution (d=days) (y=years)	Period of Rotation at Equator	Eccentricity of Orbit	Equatorial Diameter (km)	Mass (Earth = 1)	Density (g/cm ³)
JUPITER	778.4	11.9 y	9 h 50 min 30 s	0.048	142,984	317.83	1.3
SATURN	1,426.7	29.5 y	10 h 14 min	0.054	120,536	95.16	0.7
URANUS	2,871.0	84.0 y	17 h 14 min	0.047	51,118	14.54	1.3
NEPTUNE	4,498.3	164.8 y	16 h	0.009	49,528	17.15	1.8
EARTH'S MOON	149.6 (0.386 from Earth)	27.3 d	27.3 d	0.055	3,476	0.01	3.3

- Asteroids - solid rocky or metallic bodies that independently orbit the Sun
- A large percentage of the thousands of known asteroids are between Mars and Jupiter
- Concentrated in a belt called the Asteroid Belt

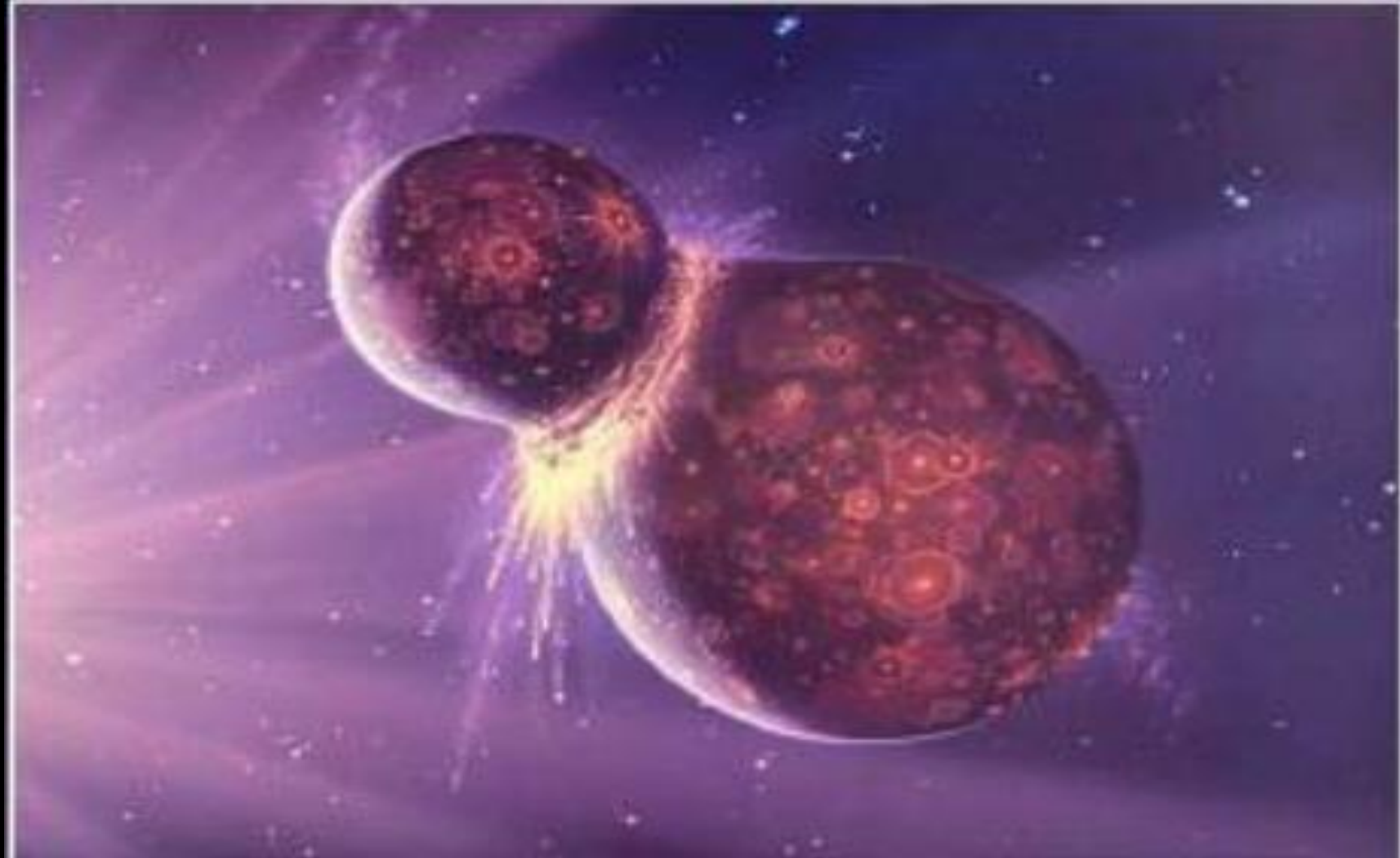


- **Moon** - a body that orbits a planet or asteroid as they orbit the Sun
- There are 63 known moons in our solar system



Earth's Moon

- **After an impact with a large asteroid a portion of the Earth created the Moon.**

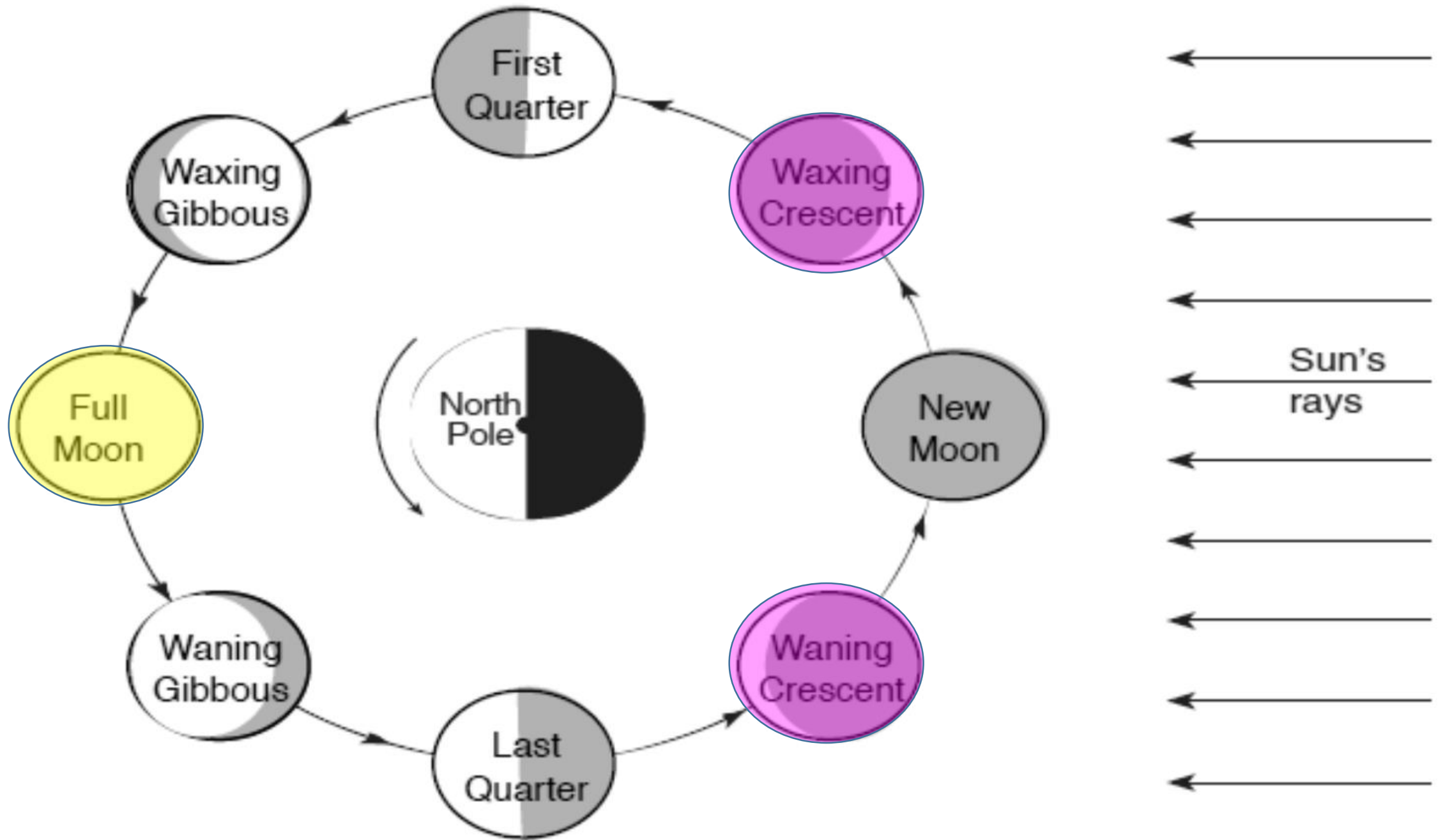


- The Moon orbits the Earth in an elliptical orbit once every 27.3 days while it appears to change shape.
- THE MOON ROTATES AT THE SAME RATE IT REVOLVES (the reason why we always see the same side of the moon).
- The cycle of phases is longer with 29.5 days

Moon Phases

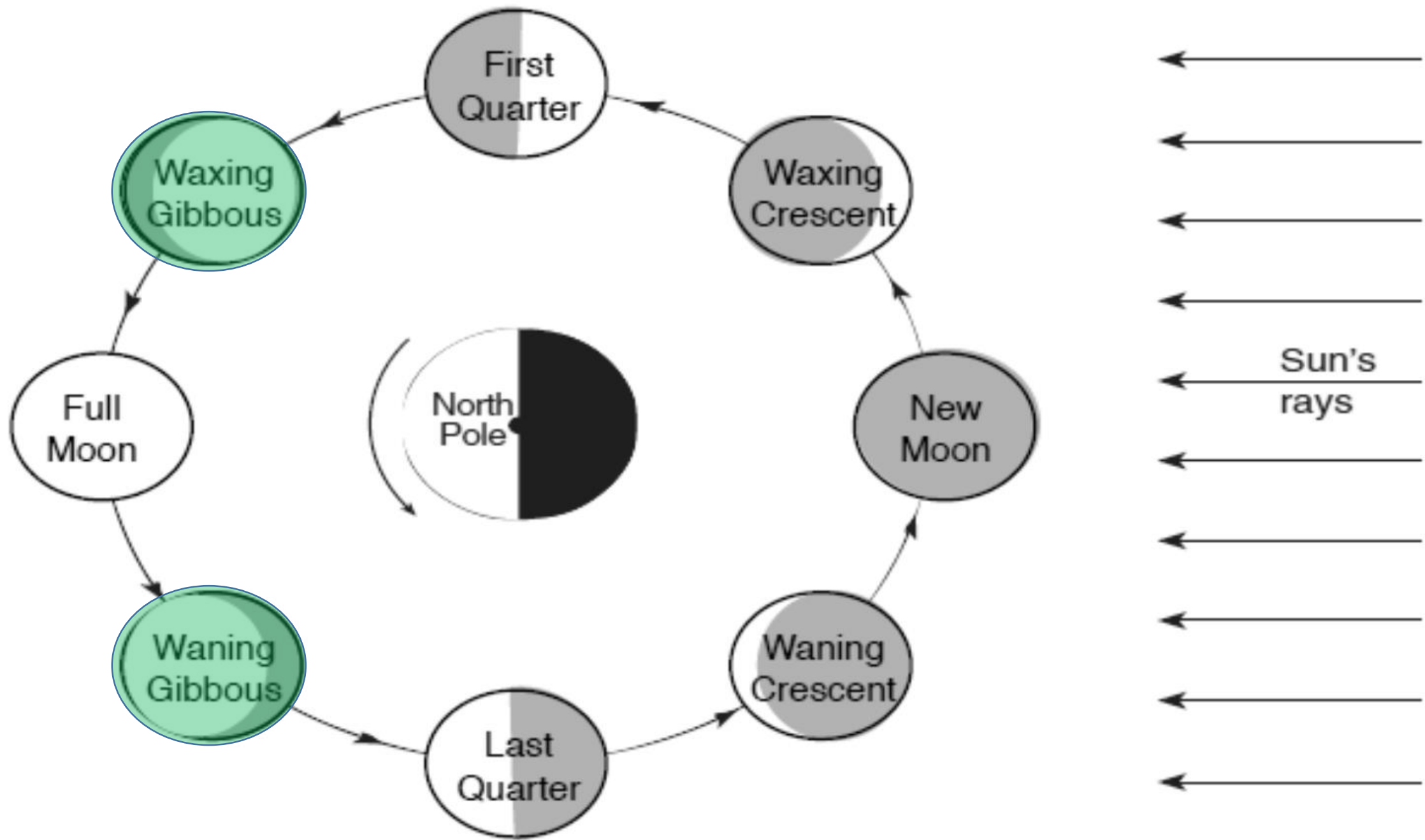
- **Crescent Moon** - phase that is part way between a half moon and new moon or between new moon and half moon
- **Full Moon** - phase that appears as an entire circle in the sky.





Gibbous Moon –

- phase that is part way between a full moon and half moon or between a half moon and full moon.



New Moon - phase where no part is visible from the Earth.



- Waxing Moon - to increase in size gradually.
Becomes MORE illuminated (from right to left).
- Waning Moon - to decrease in size gradually.
Becomes LESS illuminated (from right to left).



- Comet - “dirty snowball” mainly composed of solids that easily change to a gas when heated
- As the solids melt they leave a trail behind known as a comets tail.



- **Meteoroid** - small fragment that orbits the Sun
- **Meteorites** - a rock that leaves a visible streak as they pass through our atmosphere and strike Earth.



Evolution

- 5 billion years ago a large dust cloud left over from an exploded star started to condense
- Most of the mass was concentrated to the center and formed the Sun
- The other concentrations formed the planets

- When the Sun became too massive it ignited under its own mass in a violent explosion.
- The explosion blew most of the gasses off the inner planets and pushed most of the debris between Mars and Jupiter

Galaxies and Stars

What does our galaxy look like and what types of stars exist inside?

Galaxy

- A collection of billions of stars and various amounts of gas held together by gravity.
- Average galaxies have around 100 billion stars.

Galaxies have been classified by the following shapes:

Irregular



Elliptical

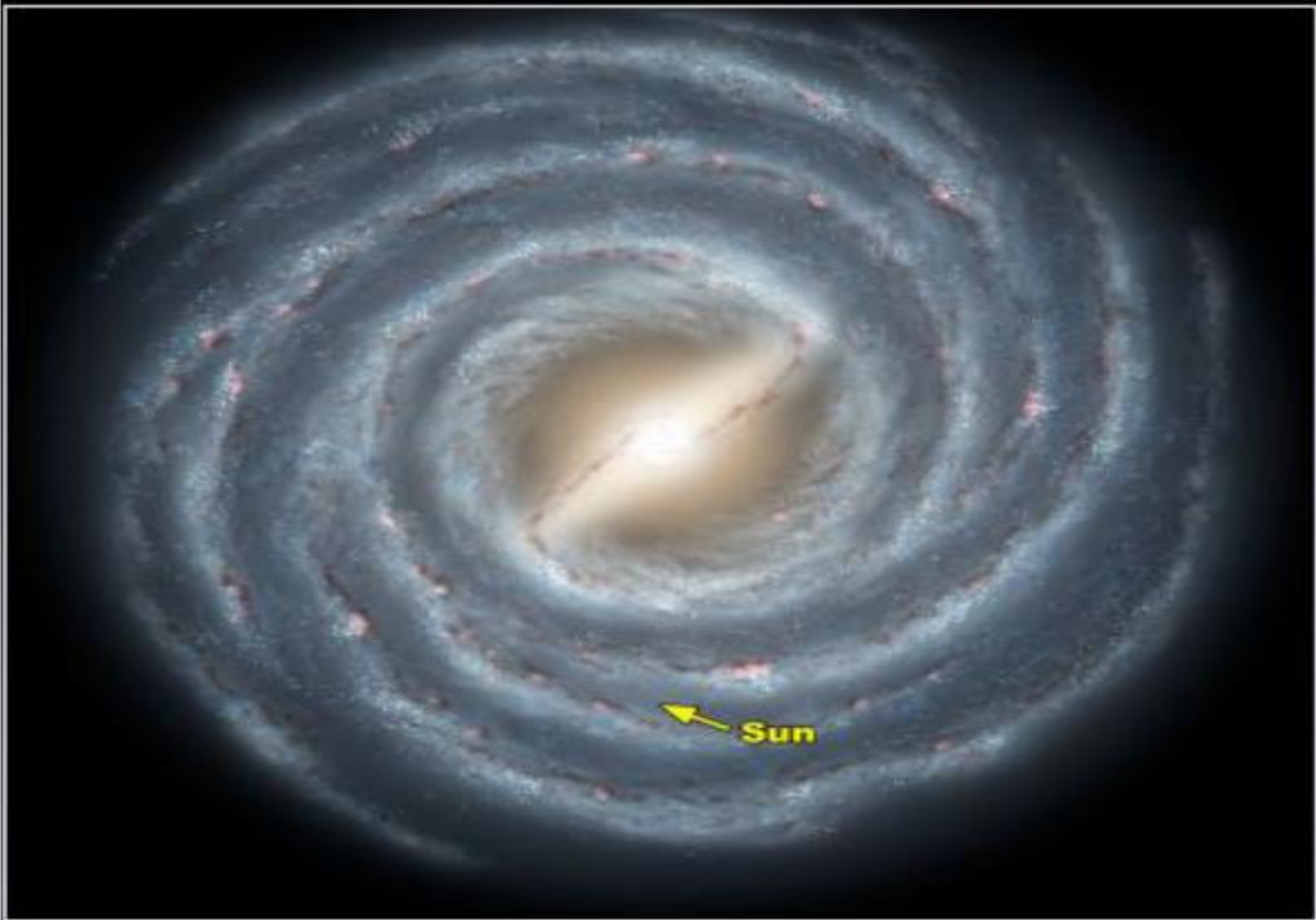


Spiral



Milky Way Galaxy - our solar system is part of a spiral shaped galaxy with 200 billion stars.

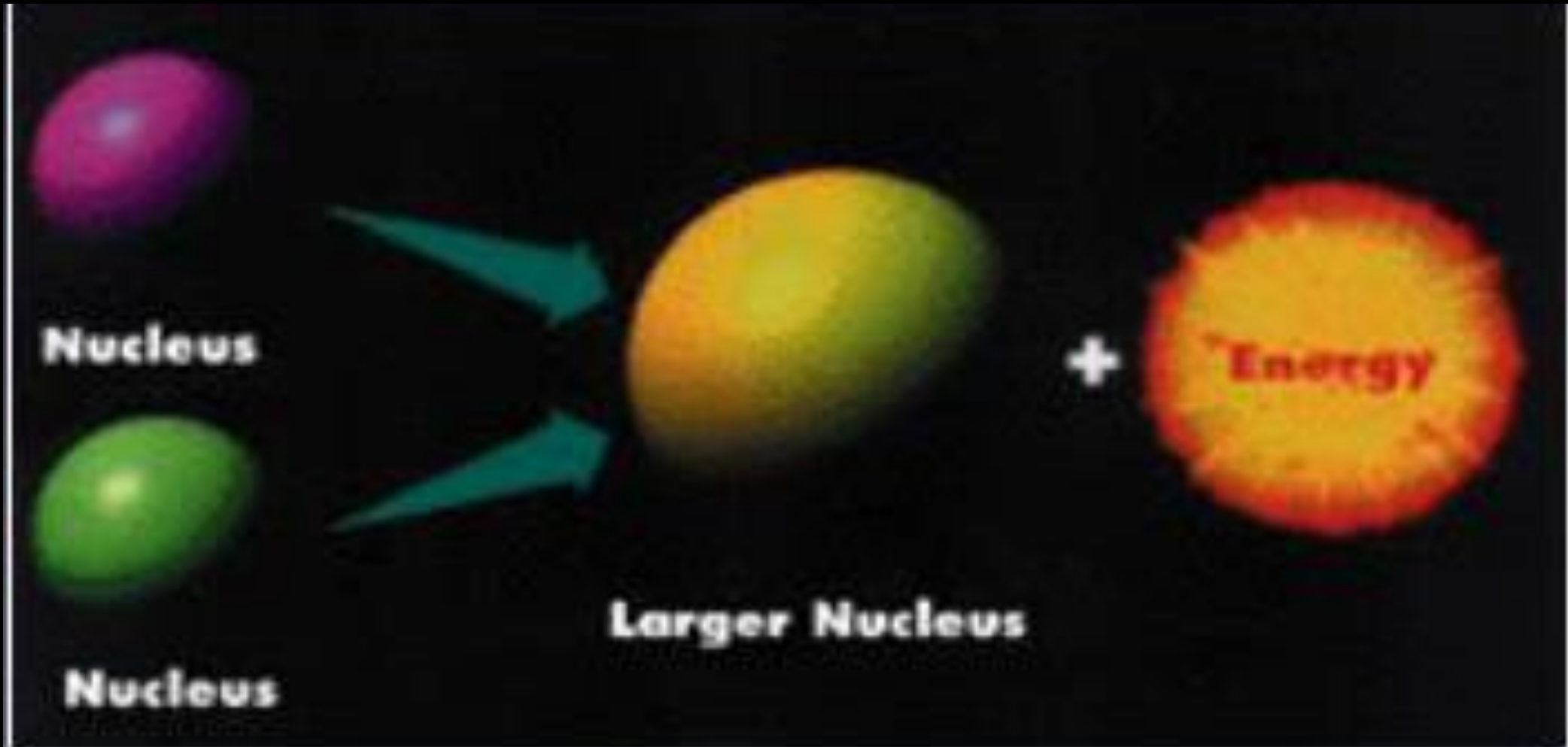




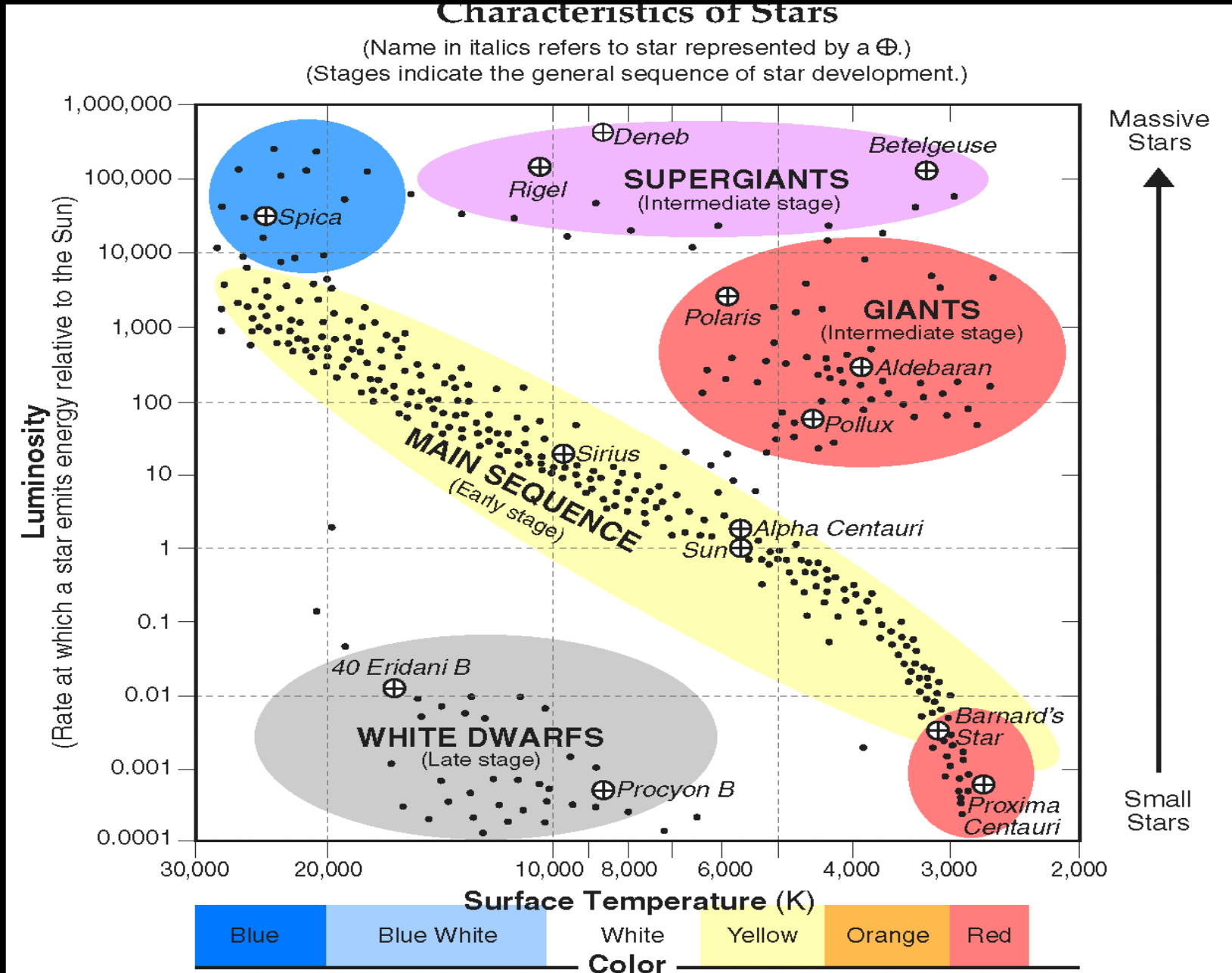
- Star - large ball of gas held together by gravity that produces tremendous amounts of energy and shines.
- Make up the majority of known matter in the galaxy.



- **Nuclear Fusion** - the combining of smaller elements to form the nuclei of larger elements.
- The Sun converts hydrogen nuclei into helium nuclei



- **Luminosity** - a measure on how **bright** a star is compared to our **Sun**.



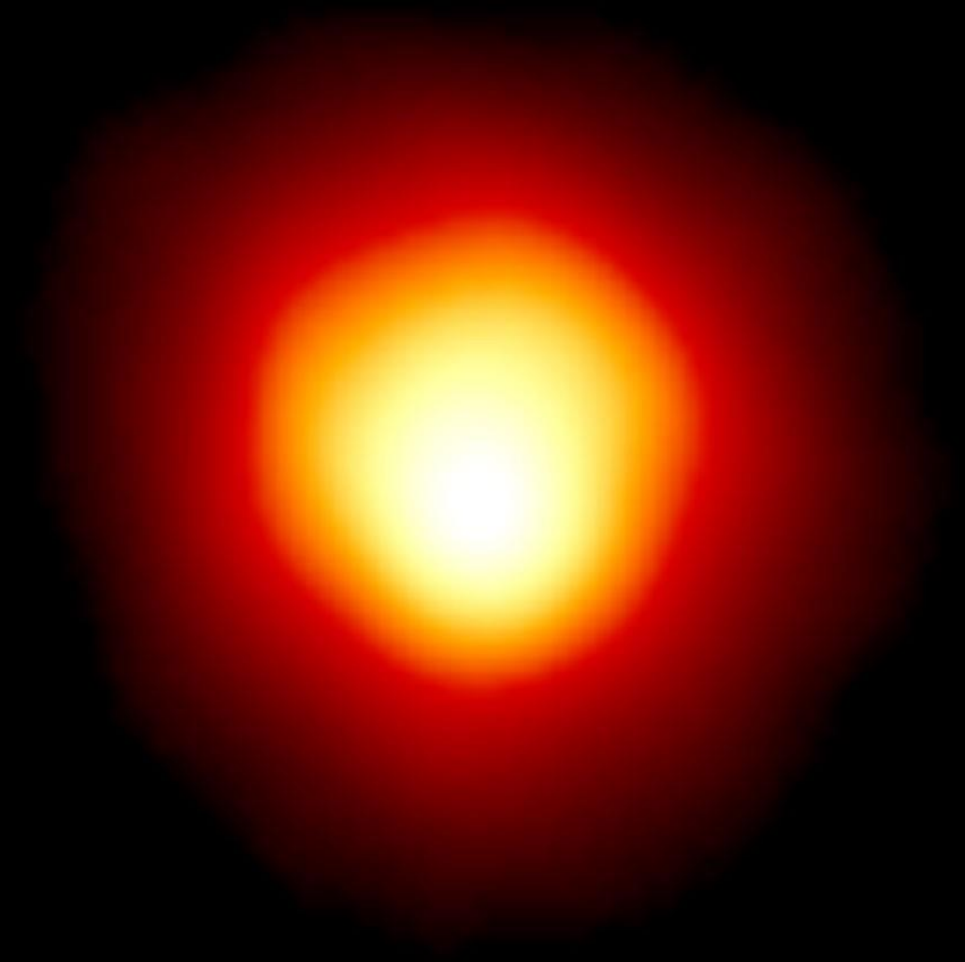
Stars have a life cycle and undergo stellar evolution

- Stars originate from a cloud of dust and gases
- Gravity causes them to clump together and form larger balls of dust and gases
- When gravitational contraction creates enough heat they ignite and start nuclear fusion

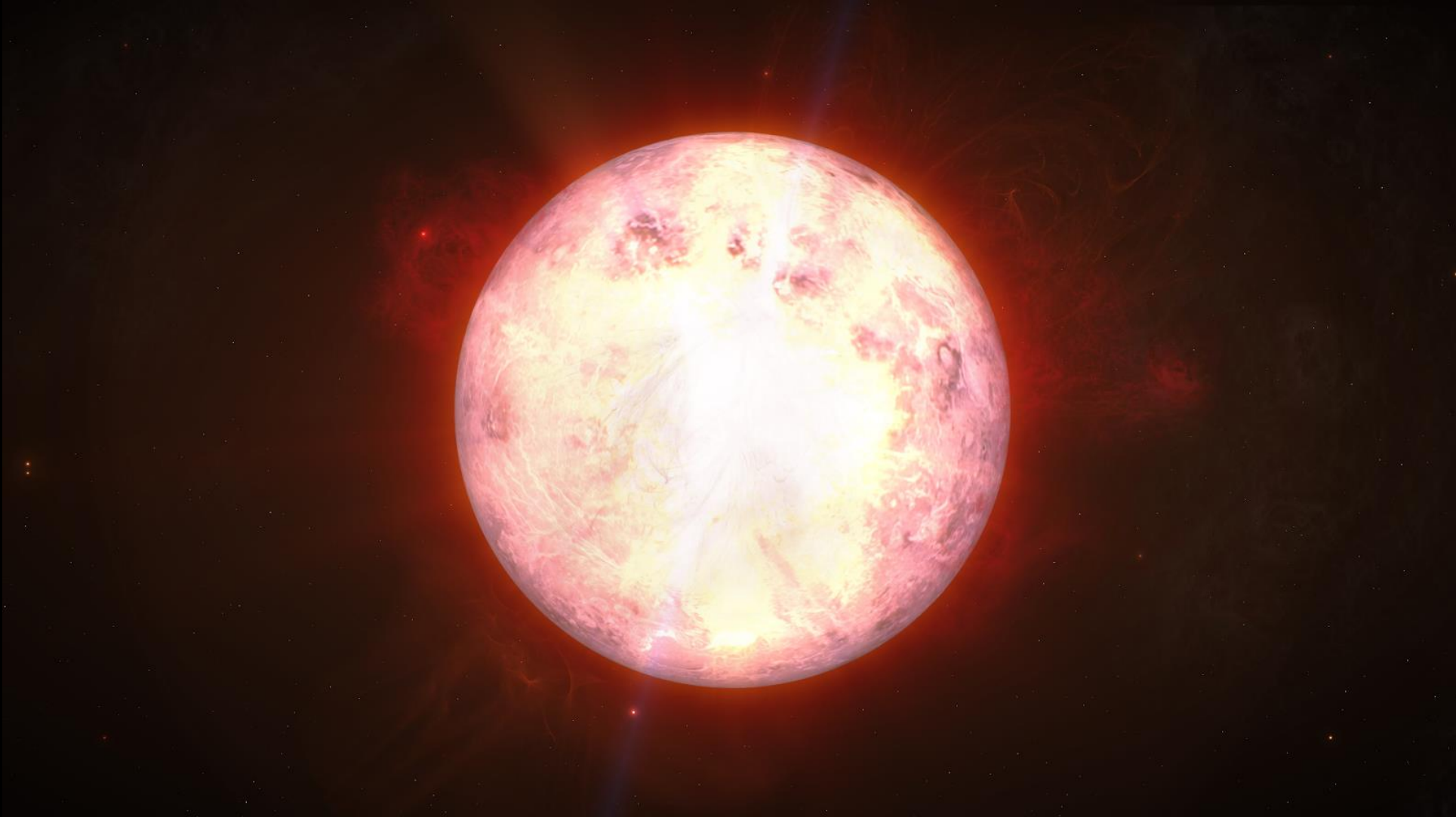
Main Sequence Star

- Average size, temperature, and luminosity stars
- 90% of the known stars spend their life on the main sequence.
- The Sun is apart of the main sequence.

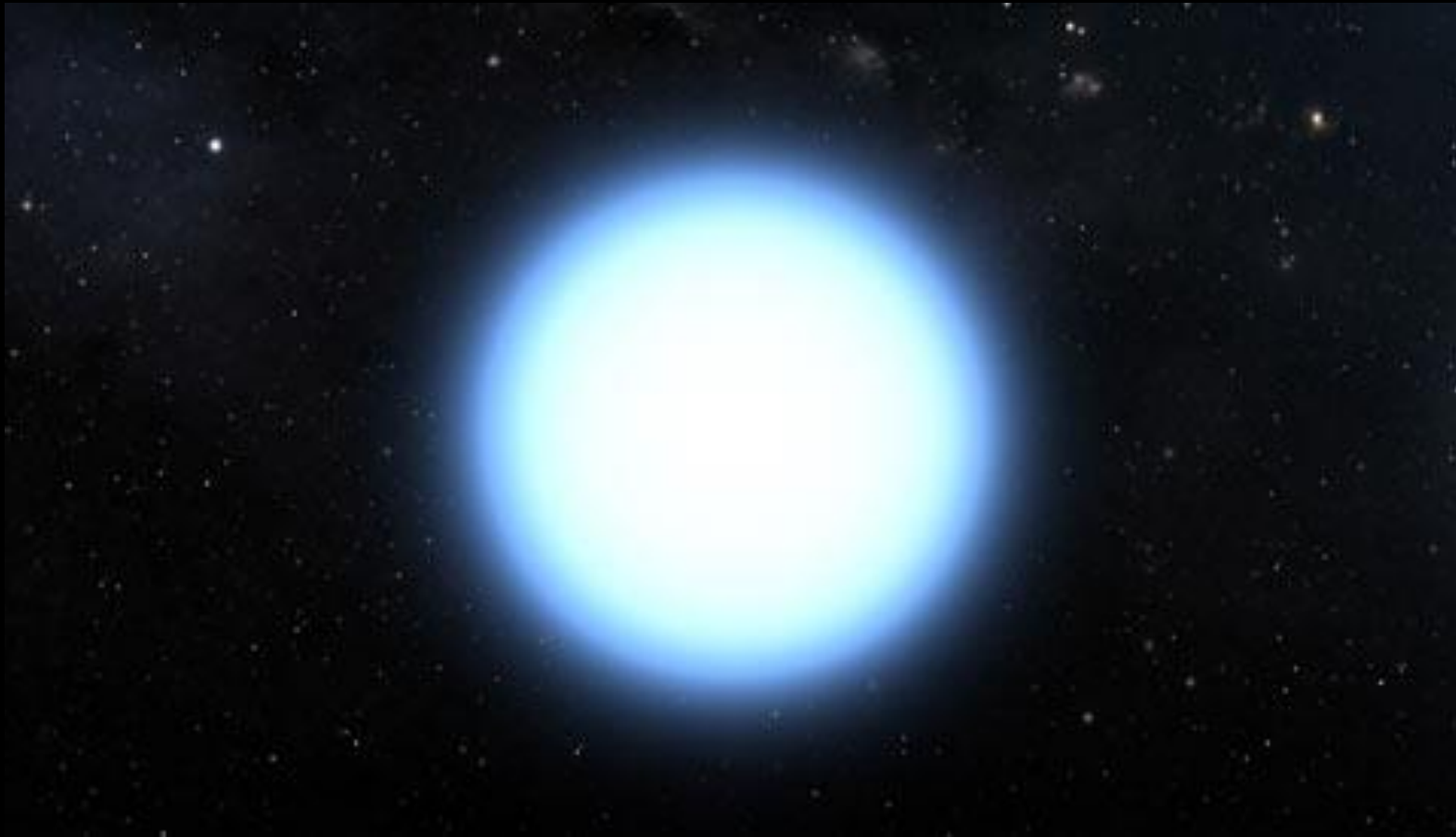
Red Giant Stars - A luminous easily seen star that is in a late phase of stellar evolution.



Super Giant Stars - star with an extremely high temperatures in the late stages of its stellar evolution.



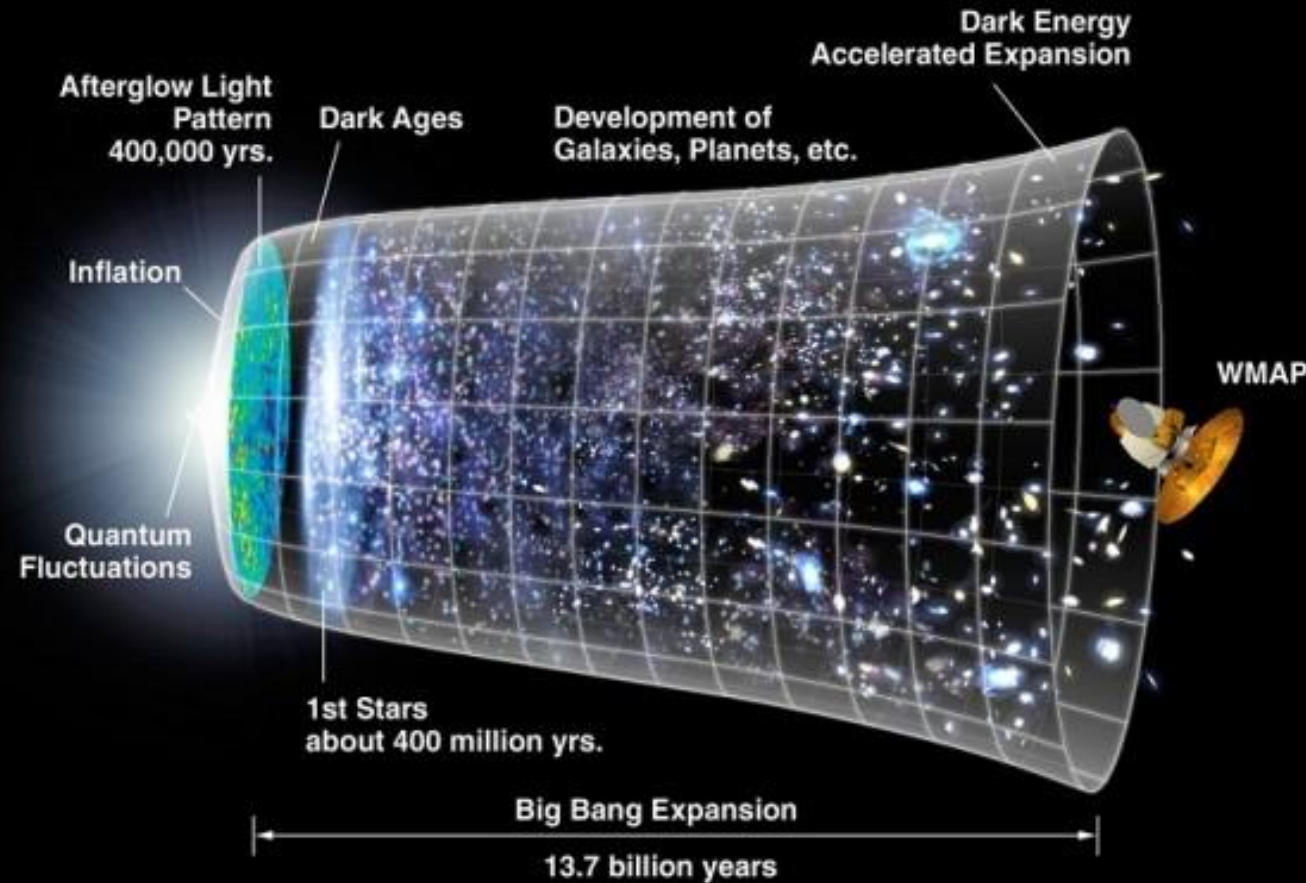
White Dwarf Stars - Earth sized star with a low luminosity and a hot surface.



The Universe

When and where did the universe originate?

- **Universe** - all the space, matter, and energy that exists in any place.
- Scientist all agree that the universe is extremely vast and between 10-17 billion years ago came to creation with the big bang.



Big Bang

States that all matter and energy started out concentrated in a small area and after a gigantic explosion, matter began to organize into subatomic particles and atoms.

Evidence of the Big Bang

1. **Background Radiation** - left over energy created by the explosion found in all parts of the universe.

Scientists have found evidence of long wave radiation (microwaves) that come from all directions in the universe

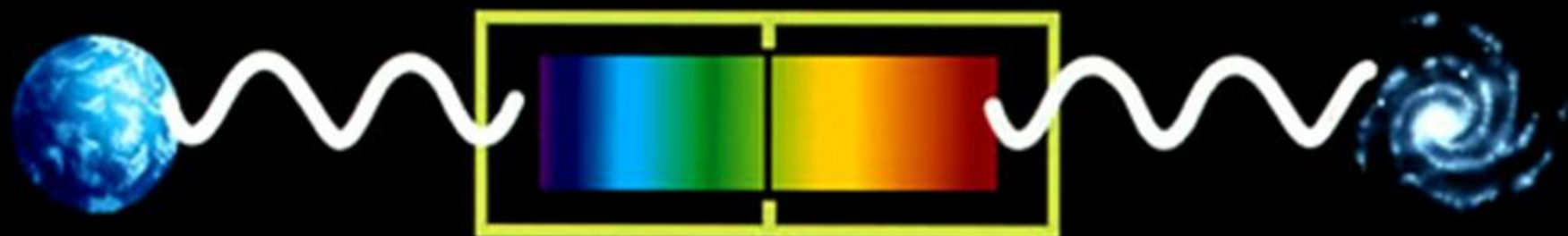
Evidence of the Big Bang

2. **Doppler Effect** - the apparent wave length shifting of electromagnetic energy caused by the relative motion between the energy source and the observer.

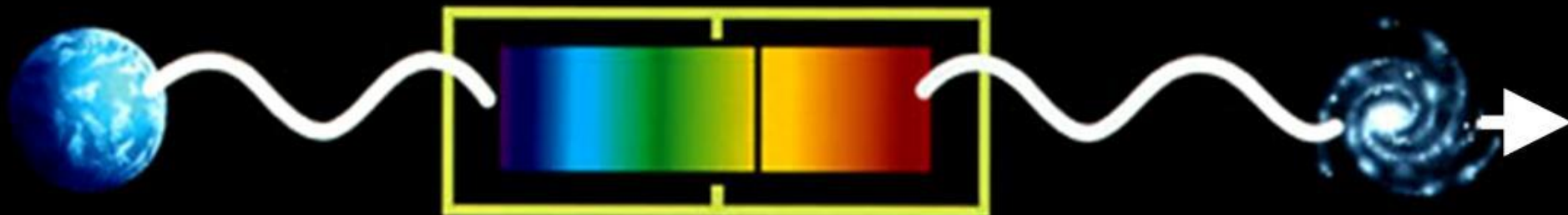
- Each element gives off an electromagnetic spectral line and when scientists study energy coming off a celestial object they can infer which elements are in these objects as well as its direction of movement
- •Example: Hydrogen's Spectrum

- Positions of the colored lines shift as they studied stars and galaxies
- **Blue Shift** - when Earth and the celestial object are coming close together the spectral lines move towards the blue wavelength.
- **“BLUE IS TO”**
- **Red Shift** - when Earth and the celestial object are moving apart the spectral lines move towards the red wavelength.

A light source
at rest



The spectrum
of a receding
light source is
redshifted



The spectrum of
an approaching
light source is
blueshifted

