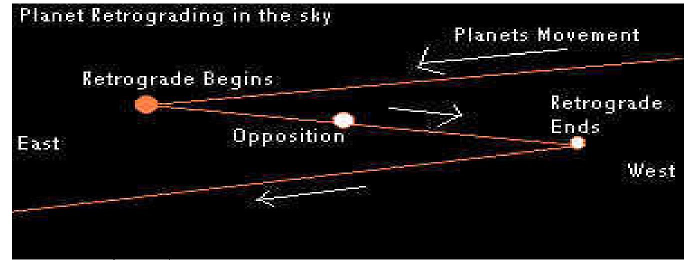
Regents Earth Science – Unit 5: Astronomy

Models of the Universe

Earliest models of the universe were based on the idea that the Sun, Moon, and planets all orbit the Earth

- models needed to explain how the planets appeared to "wander" against the background stars

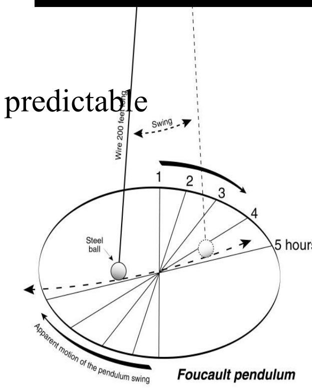


Retrograde Motion – backward (westward) motion of a planet

- models also needed to explain terrestrial motions

Foucault Pendulum - a freely swinging pendulum that appears to change direction in a predictable way over a period of time

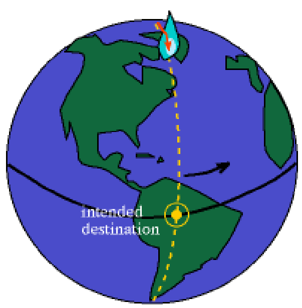
- pendulum *does not change direction*
- Earth rotates beneath the pendulum causing the apparent change in direction
- proof that the *Earth rotates*

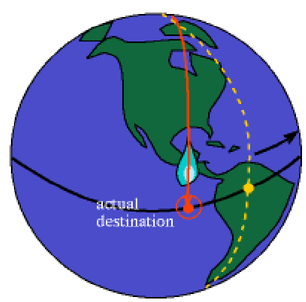


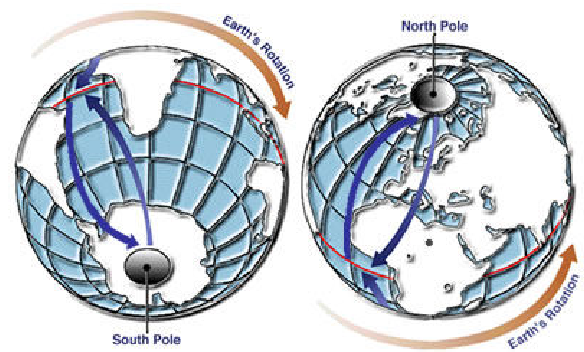
Foucault pendulum

Coriolis Effect - the apparent curved paths of projectiles, winds, and ocean currents

- actual paths are straight
- Earth rotates beneath the projectiles and winds making the paths appear to curve
- in **Northern Hemisphere** - paths curve to the **right**
- in **Southern Hemisphere** - paths curve to the **left**







Southern Hemisphere Northern Hemisphere

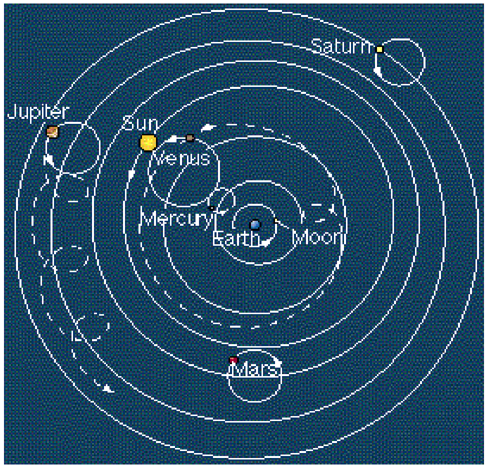
Geocentric Model of the Universe

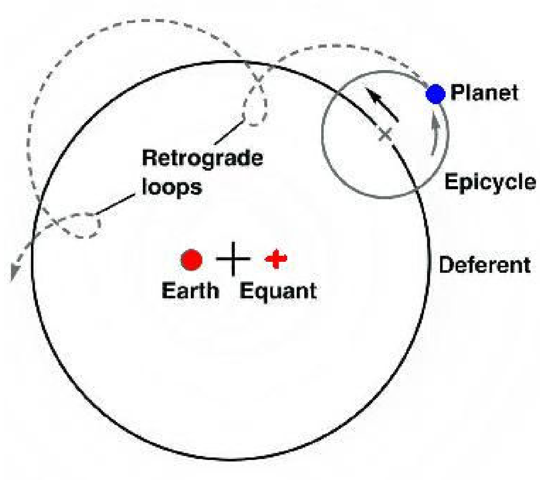
Geocentric - Earth centered

- Earth is at the center of the universe and does not move
- Sun, moon, and stars revolve around the Earth

Planets revolve around the Earth while revolving on a small circle called and **epicycle**

- **epicycle** – a small circle each planet moves around on
- **deferent** – larger circle the epicycle is centered on and moves around the Earth





- this is a very complex model!!

Geocentric model **cannot** explain:

- movement/rotation of a pendulum (Foucault Pendulum)
- curved path of projectiles (Coriolis Effect)
- phases of planets Mercury and Venus

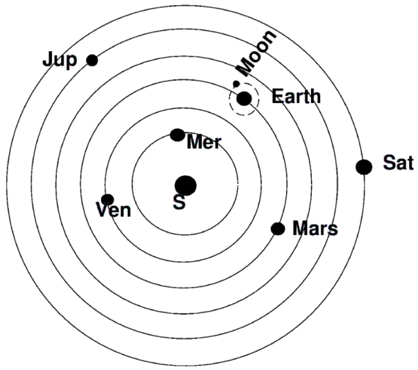
Heliocentric Model of the Universe

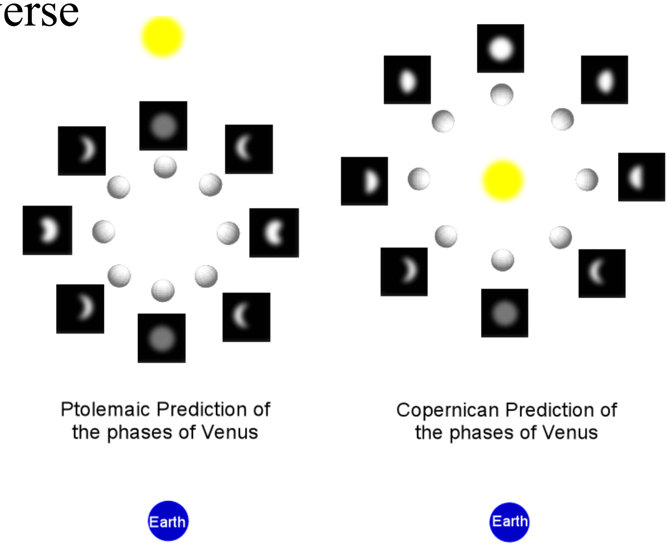
Heliocentric - sun centered

- Sun is at the center of the solar system and the Earth and other planets revolve around the Sun
- stars are fixed (not moving) far away

Heliocentric model successfully explains:

- retrograde motion of the planets
- coriolis effect
- foucault pendulum
- phases of Mercury and Venus



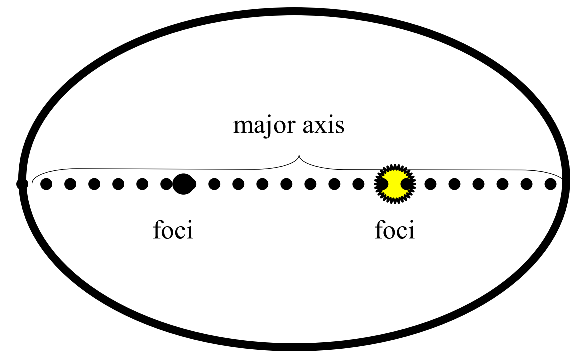


Ptolemaic Prediction of the phases of Venus

Copernican Prediction of the phases of Venus

Kepler's Laws of Planetary Motion

Law #1 (Law of Ellipses) - the orbit of each planet is an ellipse with the sun at one foci



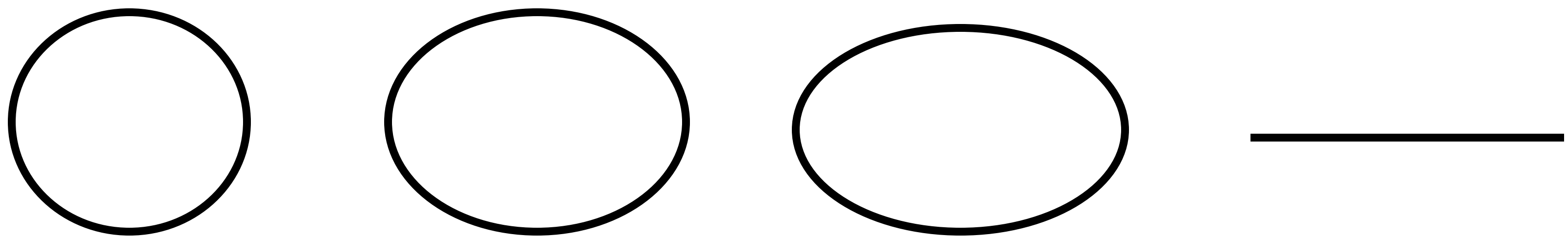
- **eccentricity** - measure of the shape of an ellipse (how oval it is)

Reference Tables p. 1

$$\text{Eccentricity} = \frac{\text{distance between foci}}{\text{length of major axis}}$$

$$E = \frac{d}{L}$$

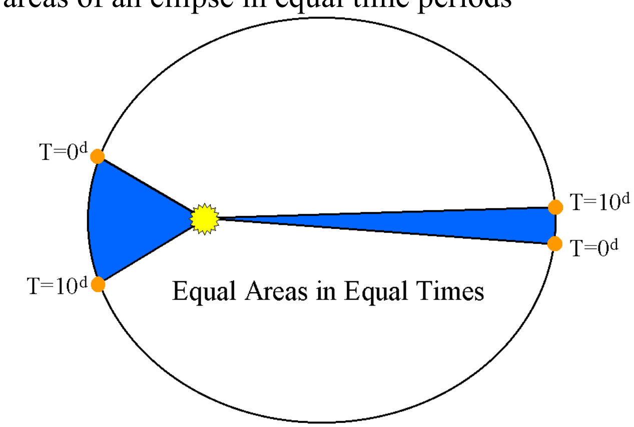
As the distance between foci increases, the shape of an ellipse will become more oval



E = 0.0 (circle) E = 0.25 E = 0.5 E = 1.0 (line)

Law #2 (Law of equal Areas) - a planet sweeps out equal areas of an ellipse in equal time periods

- as a planet orbits the sun, its orbital speed changes
- fastest when closest to the sun (**perihelion**)
- slowest when furthest from the sun (**aphelion**)



All objects have mass and therefore gravity

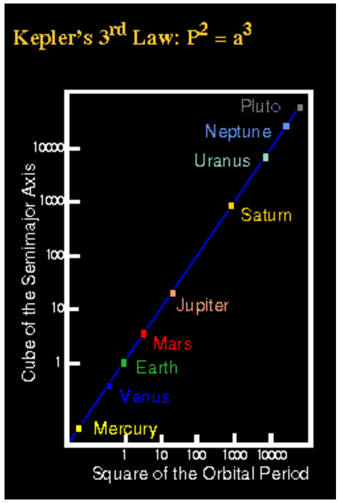
- the more mass an object has, the greater the force of gravity it exerts on other objects
- the closer a planet is to the sun, the greater the force of gravity the sun exerts on the planet and the faster the planet will move in orbit

Kepler's Laws of Planetary Motion

Reference Tables p. 15

Law #3 (Orbital Periods) - the farther a planet is from the sun, the longer the period of time of revolution

- farther planets have longer orbital paths and slower orbital speeds
- closer planets have shorter orbital paths and faster orbital speeds



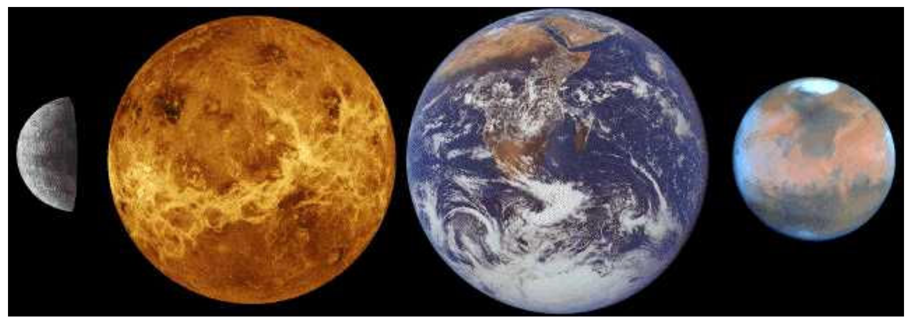
Solar System Data

Object	Mean Distance from Sun (millions of km)	Period of Revolution	Period of Rotation	Eccentricity of Orbit	Equatorial Diameter (km)	Mass (Earth = 1)	Density (g/cm^3)	Number of Moons
SUN	—	—	27 days	—	1,392,000	333,000.00	1.4	–
MERCURY	57.9	88 days	59 days	0.206	4,880	0.553	5.4	0
VENUS	108.2	224.7 days	243 days	0.007	12,104	0.815	5.2	0
EARTH	149.6	365.26 days	23 hr 56 min 4 sec	0.017	12,756	1.00	5.5	1
MARS	227.9	687 days	24 hr 37 min 23 sec	0.093	6,787	0.1074	3.9	2
JUPITER	778.3	11.86 years	9 hr 50 min 30 sec	0.048	142,800	317.896	1.3	16
SATURN	1,427	29.46 years	10 hr 14 min	0.056	120,000	95.185	0.7	18
URANUS	2,869	84.0 years	17 hr 14 min	0.047	51,800	14.537	1.2	21
NEPTUNE	4,496	164.8 years	16 hr	0.009	49,500	17.151	1.7	8
PLUTO	5,900	247.7 years	6 days 9 hr	0.250	2,300	0.0025	2.0	1
EARTH'S MOON	149.6 (0.386 from Earth)	27.3 days	27 days 8 hr	0.055	3,476	0.0123	3.3	—

Solar System

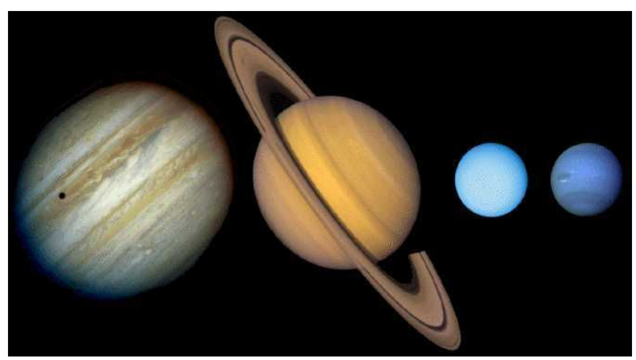
Terrestrial Planets – planets similar to the Earth

- Mercury, Venus, Earth, Mars
  - small
  - rocky
  - dense
  - close to the Sun
  - few/no moons
  - slow rotation



Jovian Planets – gas giant planets

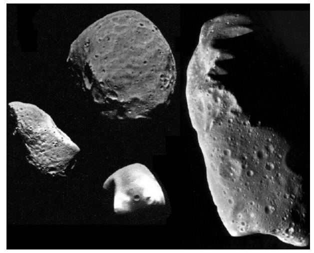
- Jupiter, Saturn, Uranus, Neptune
  - made of gas (mostly hydrogen and helium)
  - large
  - low density
  - far from the Sun
  - many moons
  - rings

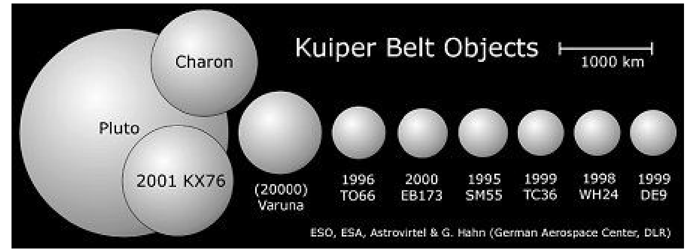


Solar System

Minor bodies of the solar system include:

- asteroids
- comets (have high eccentricity orbits, develop a tail that points away from the Sun when orbiting close to the Sun)
- "icy asteroids"

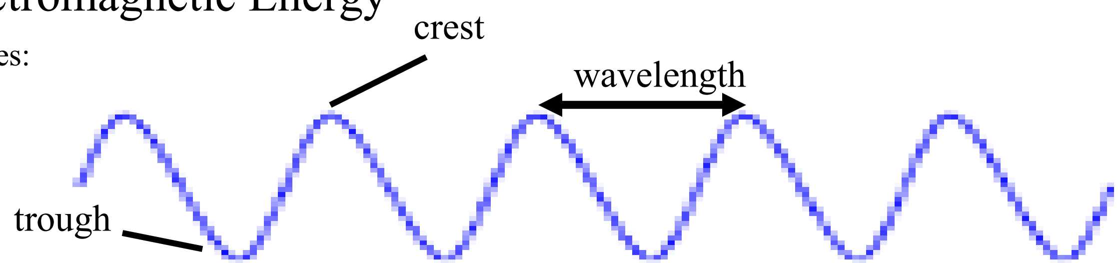




Electromagnetic Energy

Energy from the sun is emitted in the form of transverse waves:

- **wavelength** - distance from crest to crest (peak to peak) in a wave
- **frequency** - number of wavelengths in a given unit of time (cycles/second)

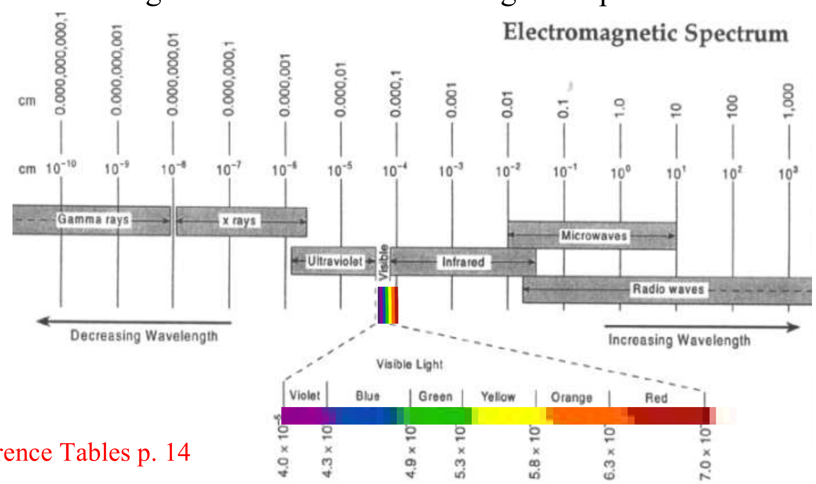


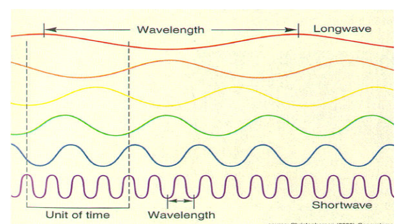
Electromagnetic Spectrum

absolute zero - the coldest anything can be (0°K)

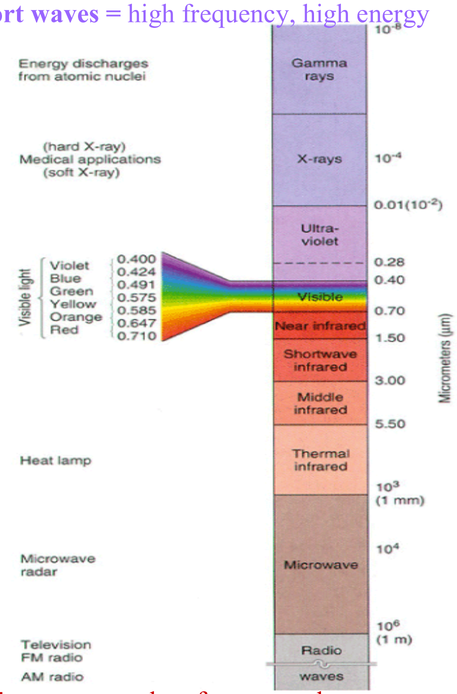
- anything above absolute zero will radiate energy in the form of waves – the more energetic something is, the shorter the wavelength radiated

Visible light is a small region of the entire electromagnetic spectrum:





short waves = high frequency, high energy



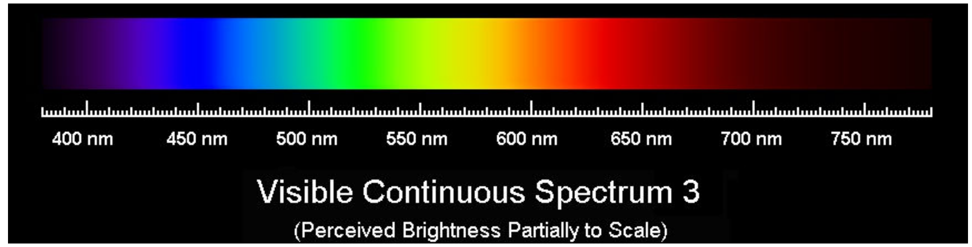
long waves = low frequency, low energy

- Reference Tables p. 14

Types of Spectra

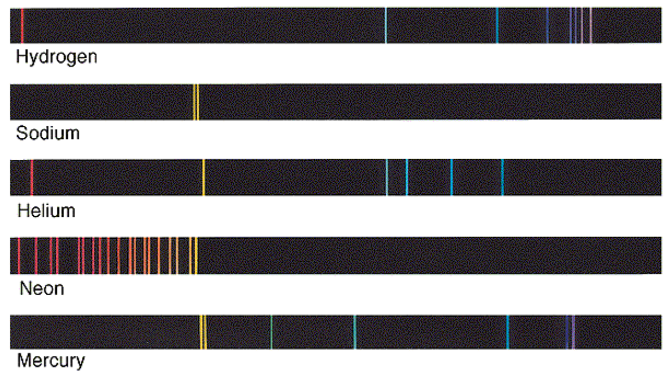
1. Continuous Spectrum - unbroken band of colors, contains all wavelengths

- produced by a hot, glowing solid, liquid, or gas (under pressure)



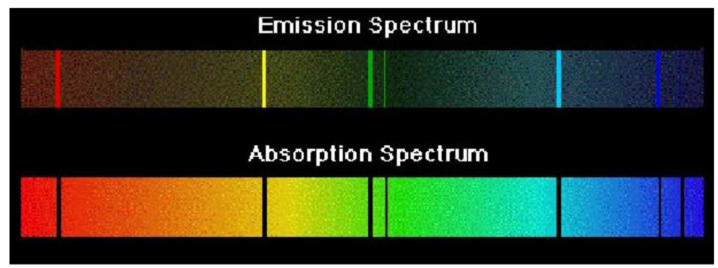
2. Bright Line (Emission) **Spectrum** - different wavelengths appear as bright lines on the spectral field based on each individual element's *fingerprint*

- produced by an element in the form of a glowing gas/vapor



3. Dark Line (Absorption) **Spectrum** - a continuous spectrum with dark lines where wavelengths have been absorbed

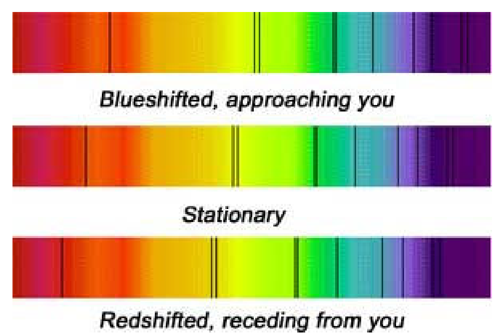
- lines have the same fingerprint as in a bright line spectra
- produced by light that produces a continuous spectrum passing through a cooler gas



Doppler Effect

Doppler Effect - apparent change in the wavelength of light as an object moves towards or away from an observer

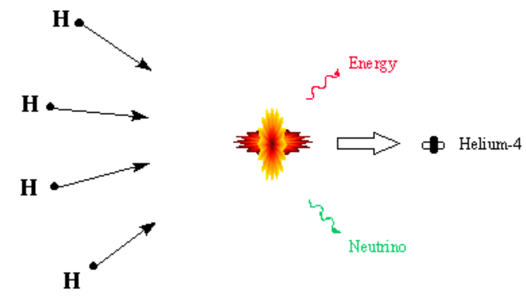
- moves *towards* - object is blue-shifted (shorter wavelength)
- moves *away* - object is red-shifted (longer wavelength)



Stars

Stars produce energy deep within their cores through the process of **nuclear fusion**

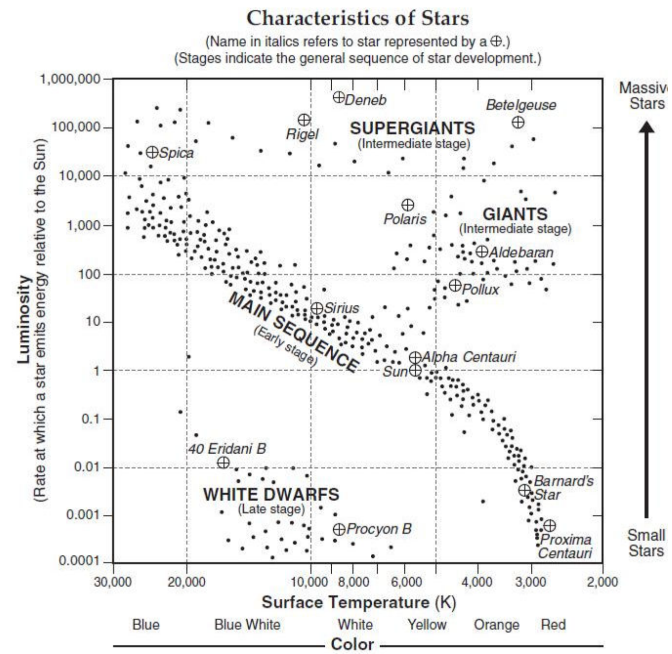
- hydrogen is converted into helium under extreme temperatures and pressures found in the core of a star
- stars that fuse H to He in their cores are **Main Sequence Stars**



Star Classification

Stars are classified based on their **temperature** (color) and **luminosity** (energy output - how bright they really are)

Reference Tables p. 15



Sun is a yellow main sequence star

- most stars are main sequence stars
- for **Main Sequence**:
  - hot stars are blue - live short lives - burn fuel fast
  - cool stars are red - live long lives - burn fuel slow

Red Giants are low temperature, high luminosity because they are large in size

Supergiants have very high luminosities because they are very large

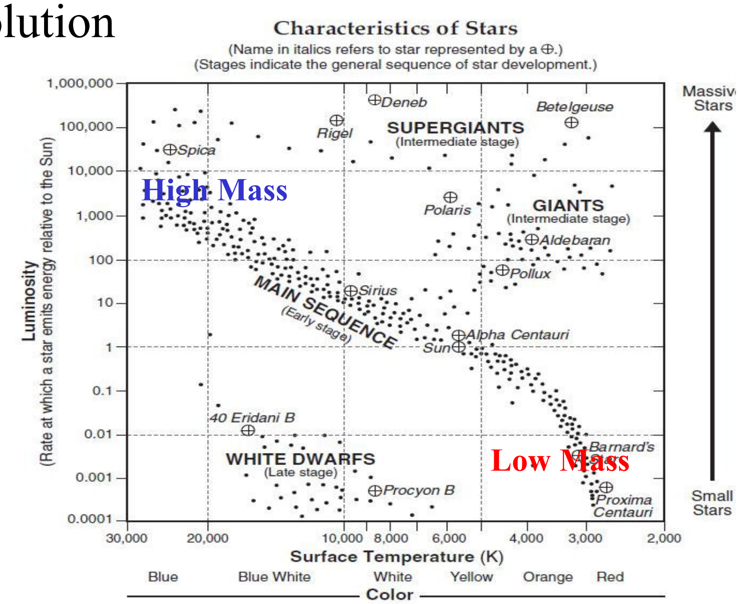
White Dwarfs have high temperatures, but low luminosities because they are very small in size

Star Evolution

Nebula - cloud of gas and dust

- nebula contract and condense under the influence of gravity
- contraction causes temperatures and pressures to rise
- eventually forms a **protostar** (not a true star)

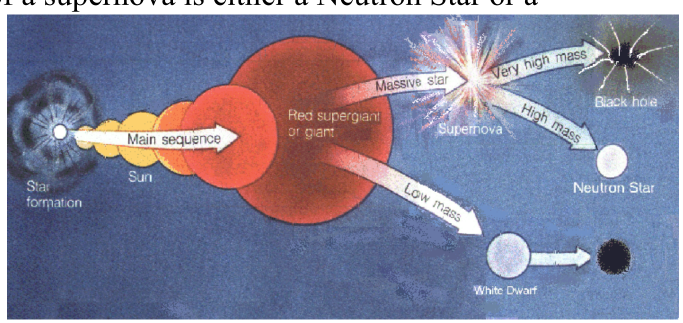
Stellar Evolution

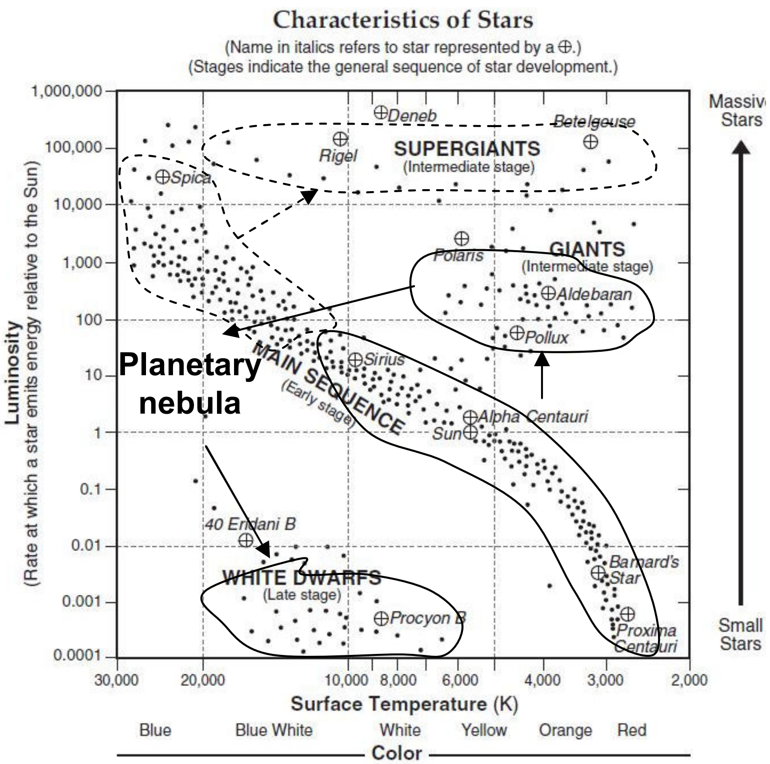


- when temperatures and pressures are great enough to fuse hydrogen into helium, the protostar becomes a true star and appears on the main sequence

- **mass** determines where on the main sequence a star will be

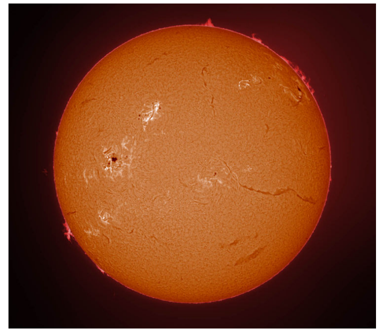
- when low mass stars run out of hydrogen fuel in their cores, fusion stops
  - core contracts and heats
  - outer layers expand and cool
  - a low mass star becomes a **Red Giant**
  - Red Giants eventually expel their outer layers of gas (**Planetary Nebula** stage) and leave behind their exposed hot, small core
  - this core is a **White Dwarf** star
  - white dwarfs cool over time and become Black Dwarf stars
- high mass stars evolve to become **Supergiant** stars
  - Supergiants will explode in an event called a **Supernova**
  - the remnant of a supernova is either a Neutron Star or a **Black Hole**

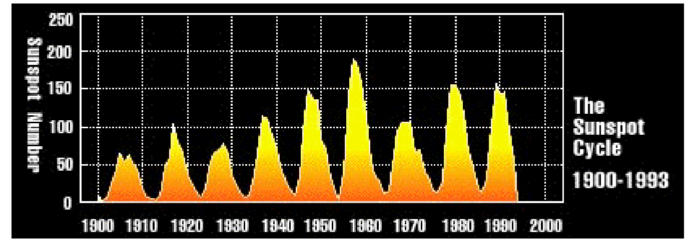




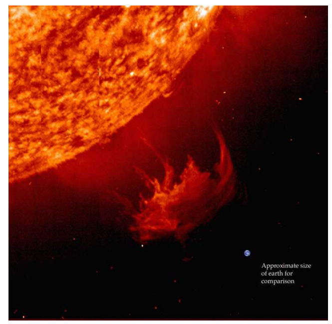
Sun

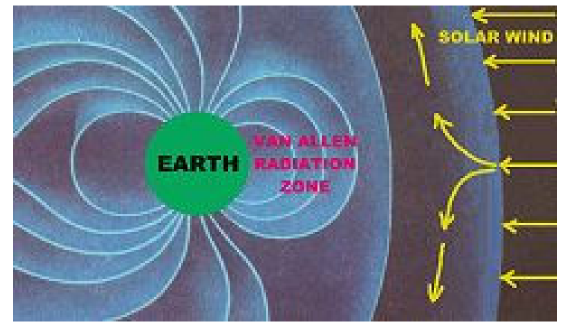
- our sun is an average yellow star
- the Sun produces energy by the process of nuclear fusion in its core
- the sun's outer atmosphere "the corona" can be seen during a total solar eclipse
- the Sun has sunspots (cooler, dark in color) - spots associated with the its magnetic field
- these increase and decrease in a cyclic pattern





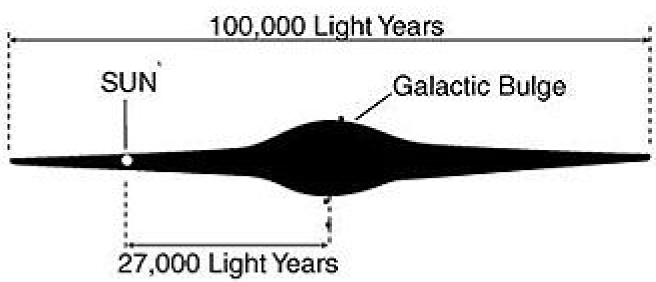
- the sun also ejects gigantic "flares" of energy that are thrown out into space
- these flares can interfere with radio and tv communications on earth
- much of the sun's solar wind and energy is diverted from earth by our own magnetic field
- this interaction creates the aurora borealis

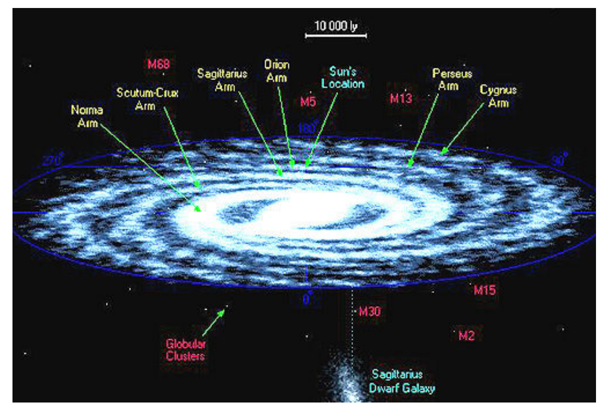


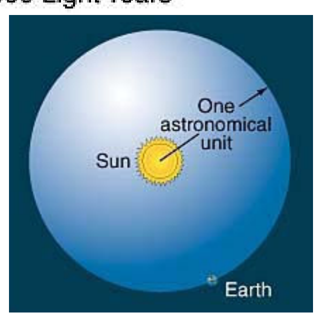


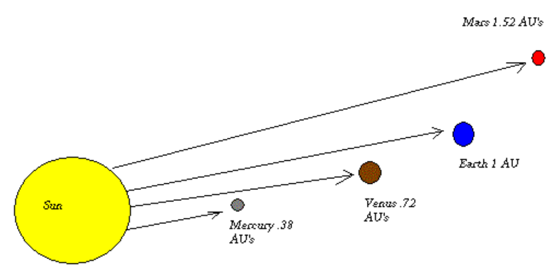
Space Distances

- because things are so far apart in space, most space distances are measured in "**light years**" (the distance light can travel in one year)
- light travels about 300,000km/sec, so it travels about 6,000,000,000,000 kilometers per year
- within our own solar system, distances are much smaller than in the universe
- scientists measure distances using the unit "**astronomical unit"**
- one astronomical unit (AU) equals the distance from the sun to earth





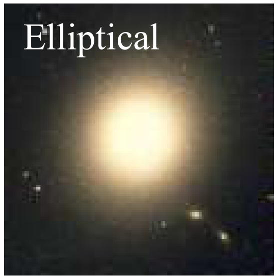




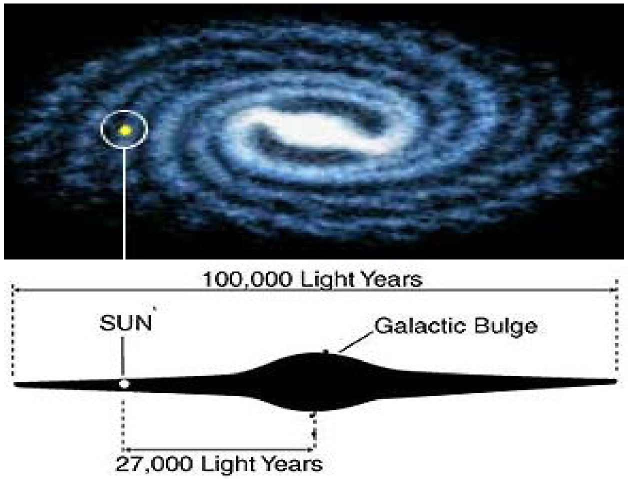
Galaxies

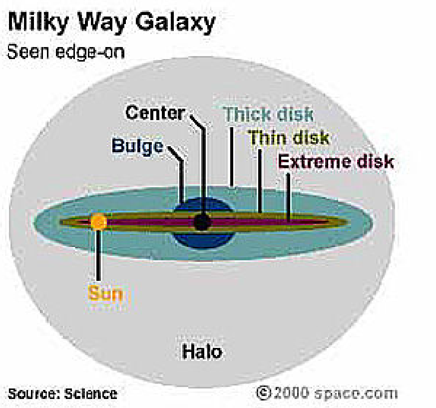
Galaxy - billions of stars held together by gravity

- categorized by shape:
  1. Spiral
  2. Elliptical
  3. Irregular



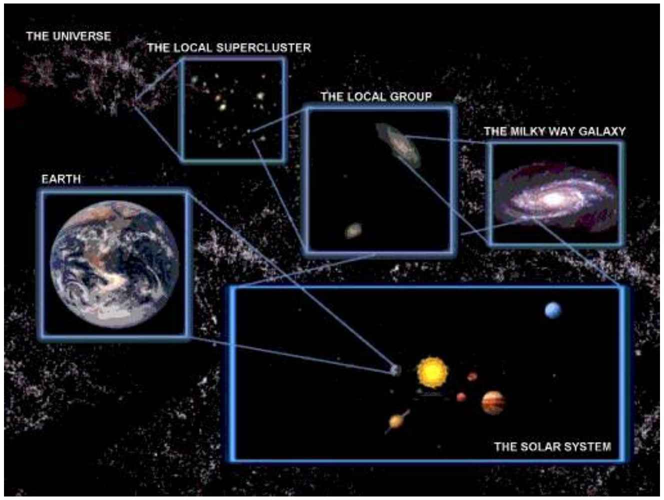
- **Milky Way** - the galaxy our solar system is part of
  - it is a spiral galaxy
  - sun is located 2/3 out from the center in the spiral arms



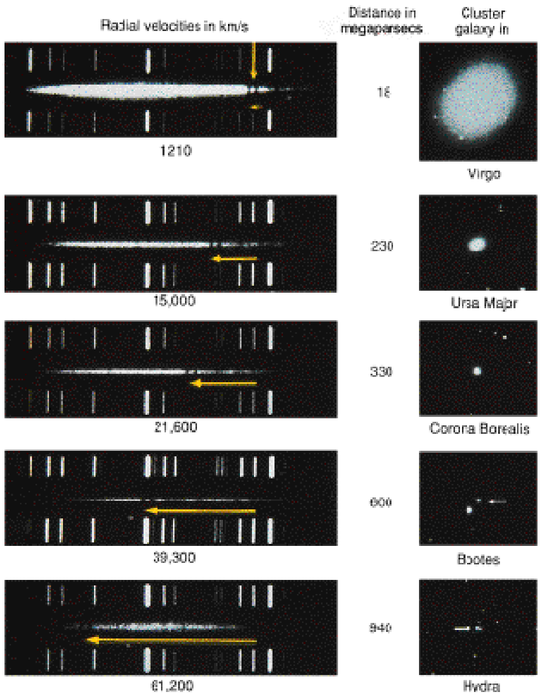


Scale of the Universe

- the Earth is a small part of our solar system
- our solar system is a small part of the our galaxy (the Milky Way)
- the Milky Way is a small part of a local group of galaxies
- this local group of galaxies is a small part of a local supercluster of galaxies which is a small part of the universe



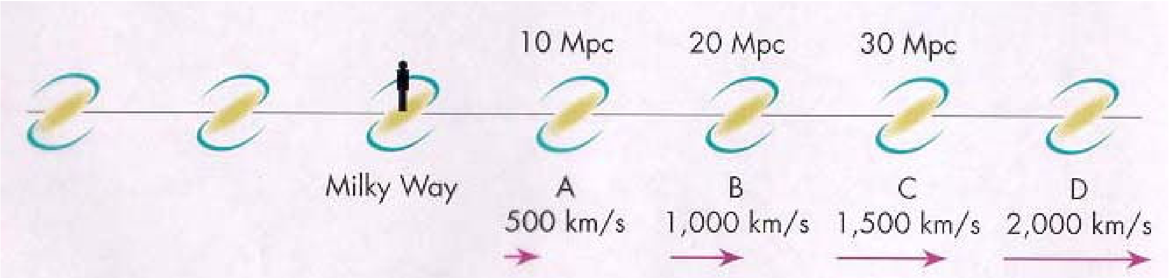
Universe



The spectrum of galaxies are red-shifted (shifted to longer wavelengths)

- galaxies are moving away from us
- galaxies furthest away are redshifted more than galaxies close to us
- galaxies furthest away are moving away from us fastest

All galaxies move away from the Milky way and each other



- the universe is expanding!!!

We see microwave background radiation in all directions of the sky

- evidence that the universe was at one time smaller, hotter and denser
- evidence that the universe began with a **Big Bang**