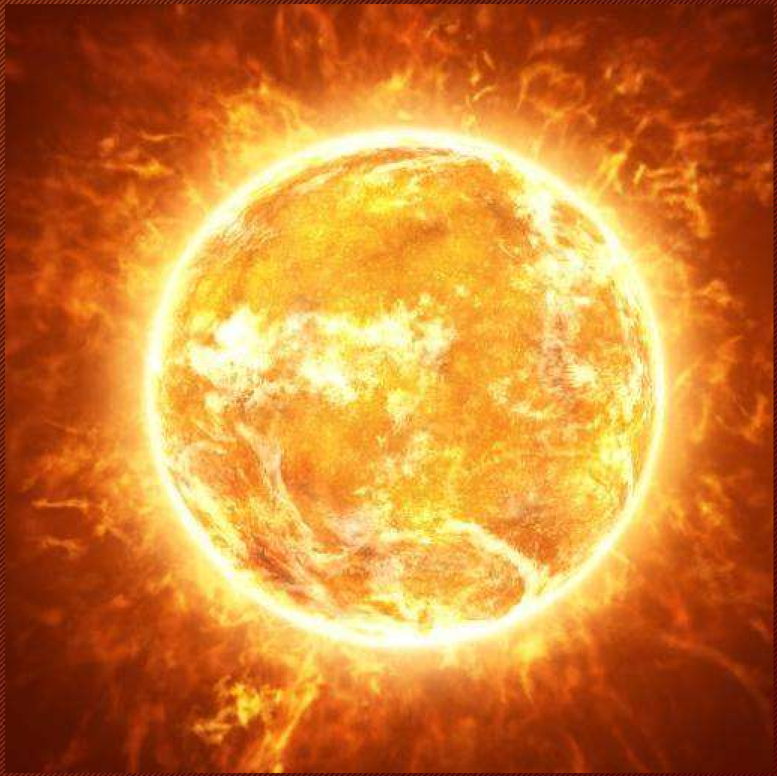
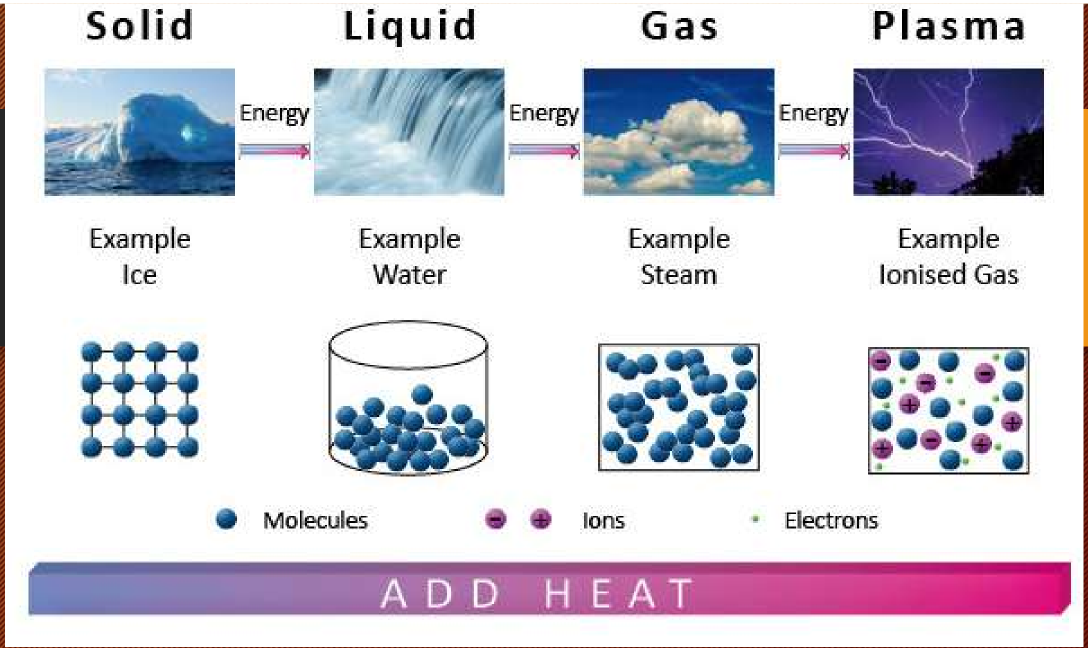
The Sun

Properties of the Sun

- largest object in the solar system, in both diameter and mass.
- The Sun contains more than 99 percent of all the mass in the solar system.



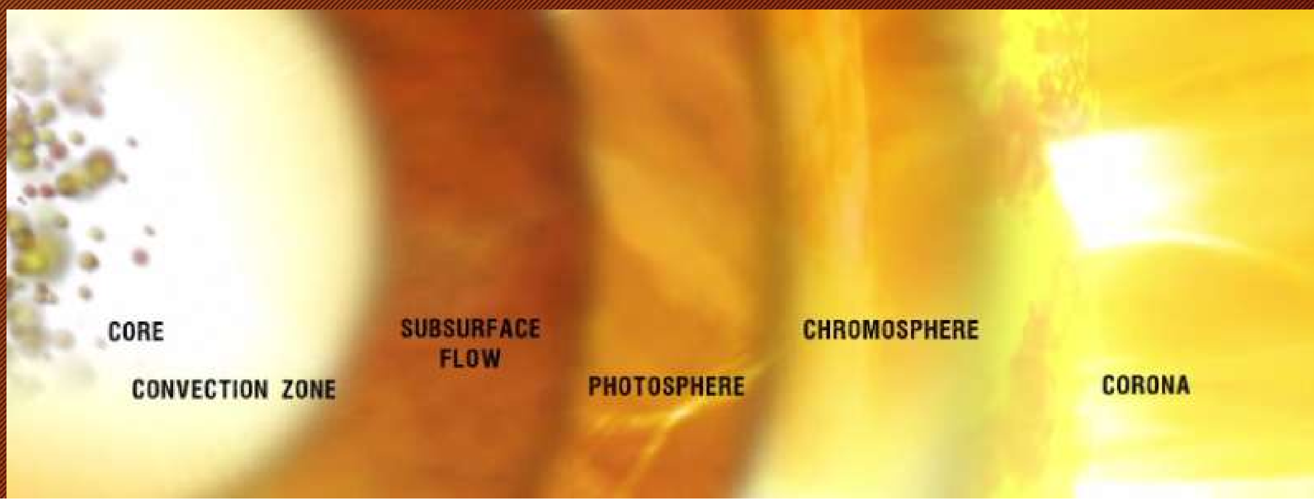
Properties of the Sun



- The Sun's interior is gaseous throughout because of its high temperature
- At this temperature, all of the gases are completely ionized. This means that the interior is composed only of atomic nuclei and electrons, in the state of matter known as plasma.

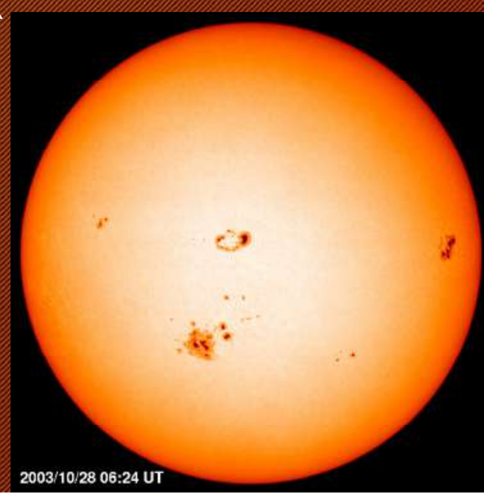
The Sun's "Atmosphere"

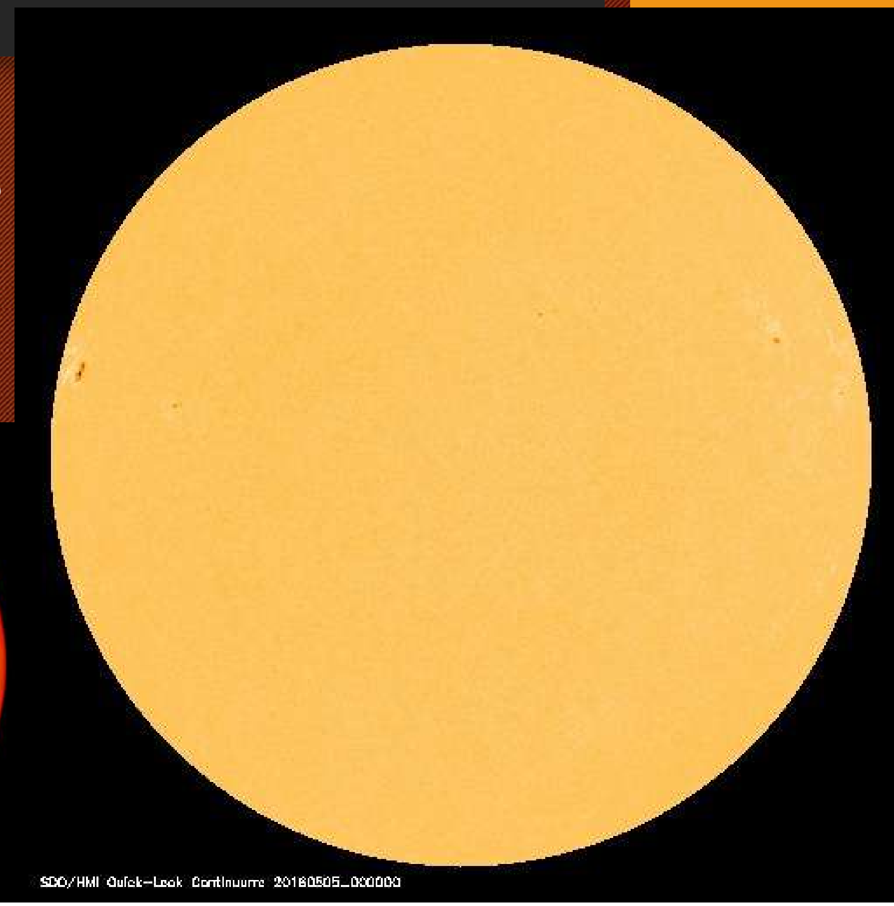
- The outer regions of the sun
- organized into layers, like a planetary atmosphere separated into different levels, and each layer emits energy at wavelengths resulting from its temperature.



Photosphere

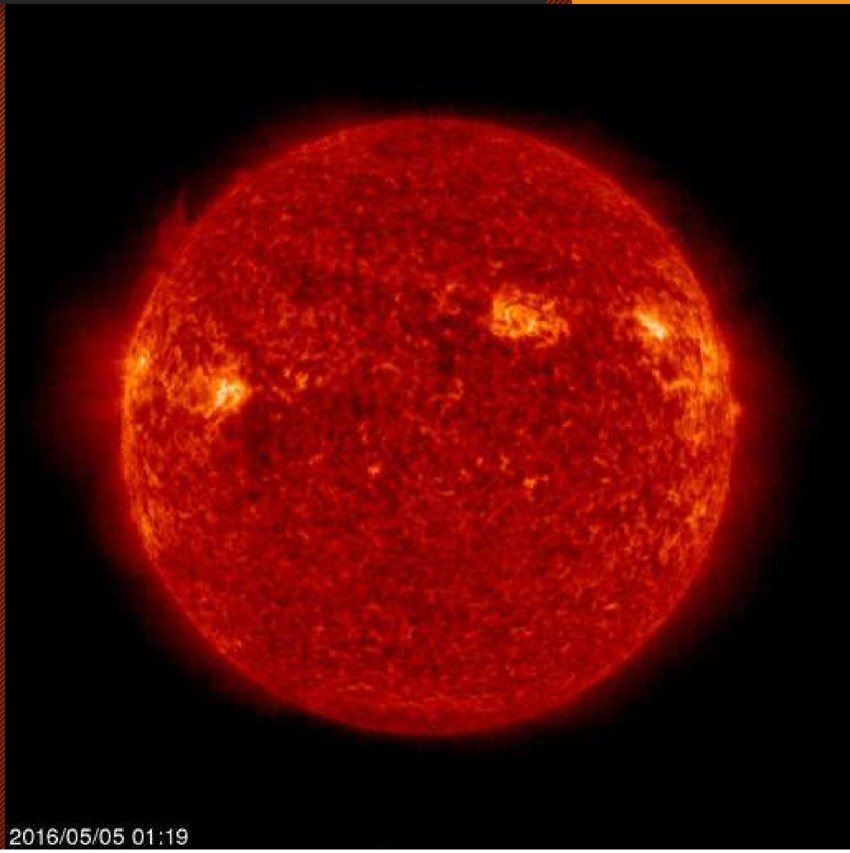
- The photosphere is the innermost layer of the Sun’s atmosphere and is also its visible surface. It has an average temperature of 5800 K and is about 400 km thick





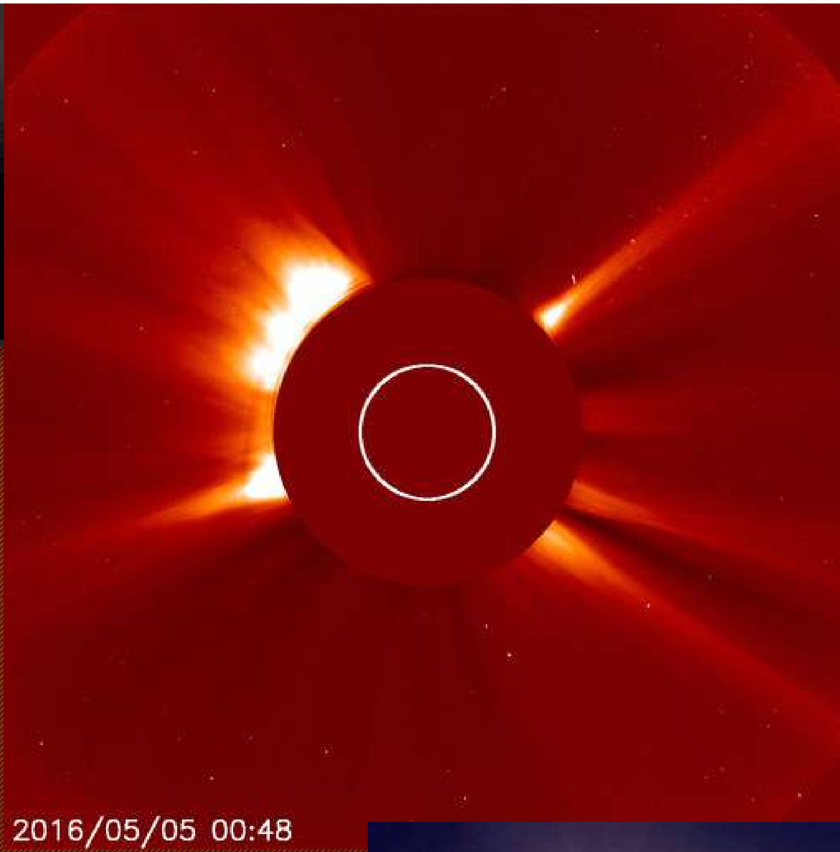
Chromosphere

- Outside the photosphere is the chromosphere, which is approximately 2500 km thick and has a temperature of nearly 30,000 K.
- Usually, the chromosphere is visible only during a solar eclipse, but astronomers can use special filters to observe it when the Sun is not eclipsed.

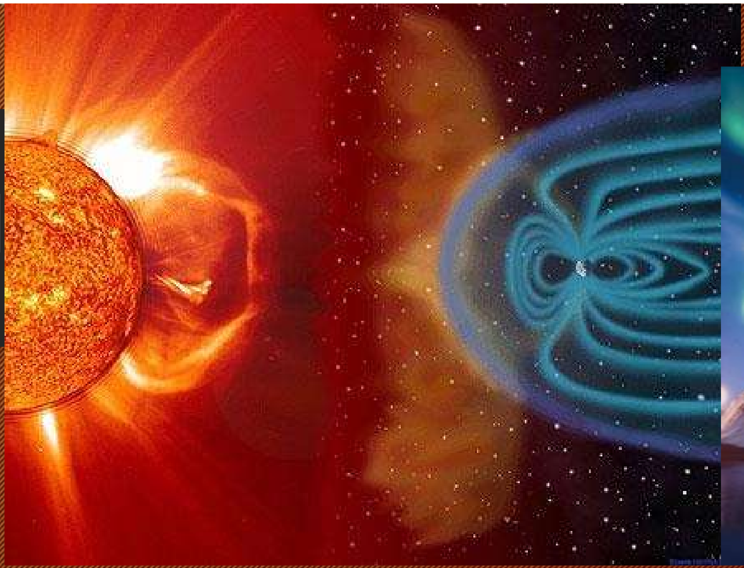


The Corona

- The outermost layer of the Sun
- extends several million kilometers from the outside edge of the chromosphere and has a temperature range of 1 million to 2 million K
- The density of the gas is very low, which explains why the corona is so dim
- can be seen only when the photosphere is blocked by either special instruments, as in a coronagraph, or by the Moon during an eclipse.



Solar Wind

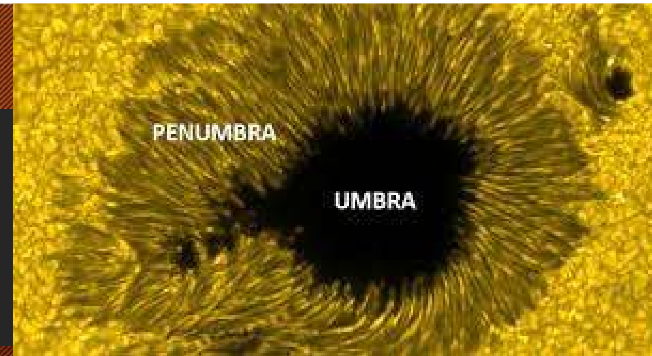


- Gas flows outward from the corona at high speeds
- As this wind of charged particles (ions), flows outward through the entire solar system, it bathes each planet in a flood of particles
- Charged particles in the solar wind are deflected by Earth’s magnetic field
- The high-energy particles collide with gases in Earth’s atmosphere and cause the gases to give off light, called the aurora.

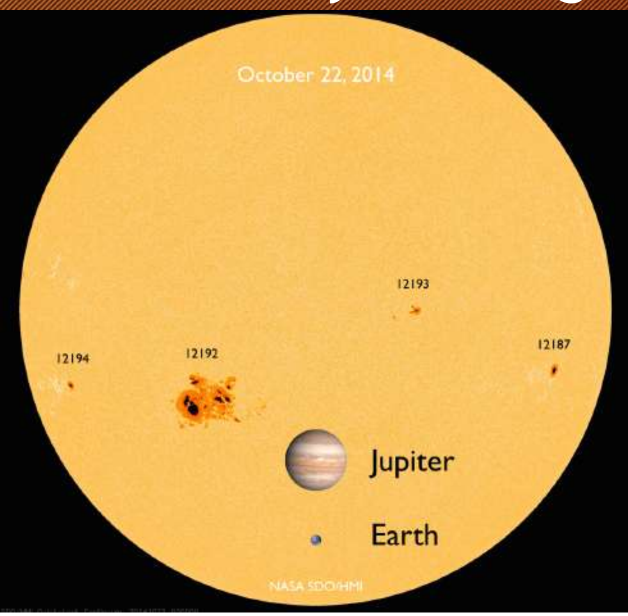
Solar Activity

- The Sun’s magnetic field disturbs it’s atmosphere and causes changes
- Sunspots, coronal holes, solar flares, and prominences are the most notable ones

Sunspots

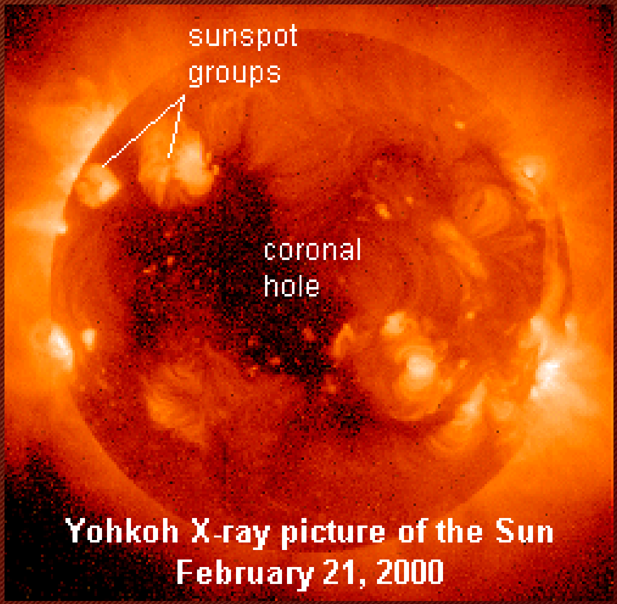


- a dark spot on the surface of the photosphere that typically lasts two months, occurs in pairs, and has a penumbra and an umbra
- Caused by a change in the magnetic field of the sun



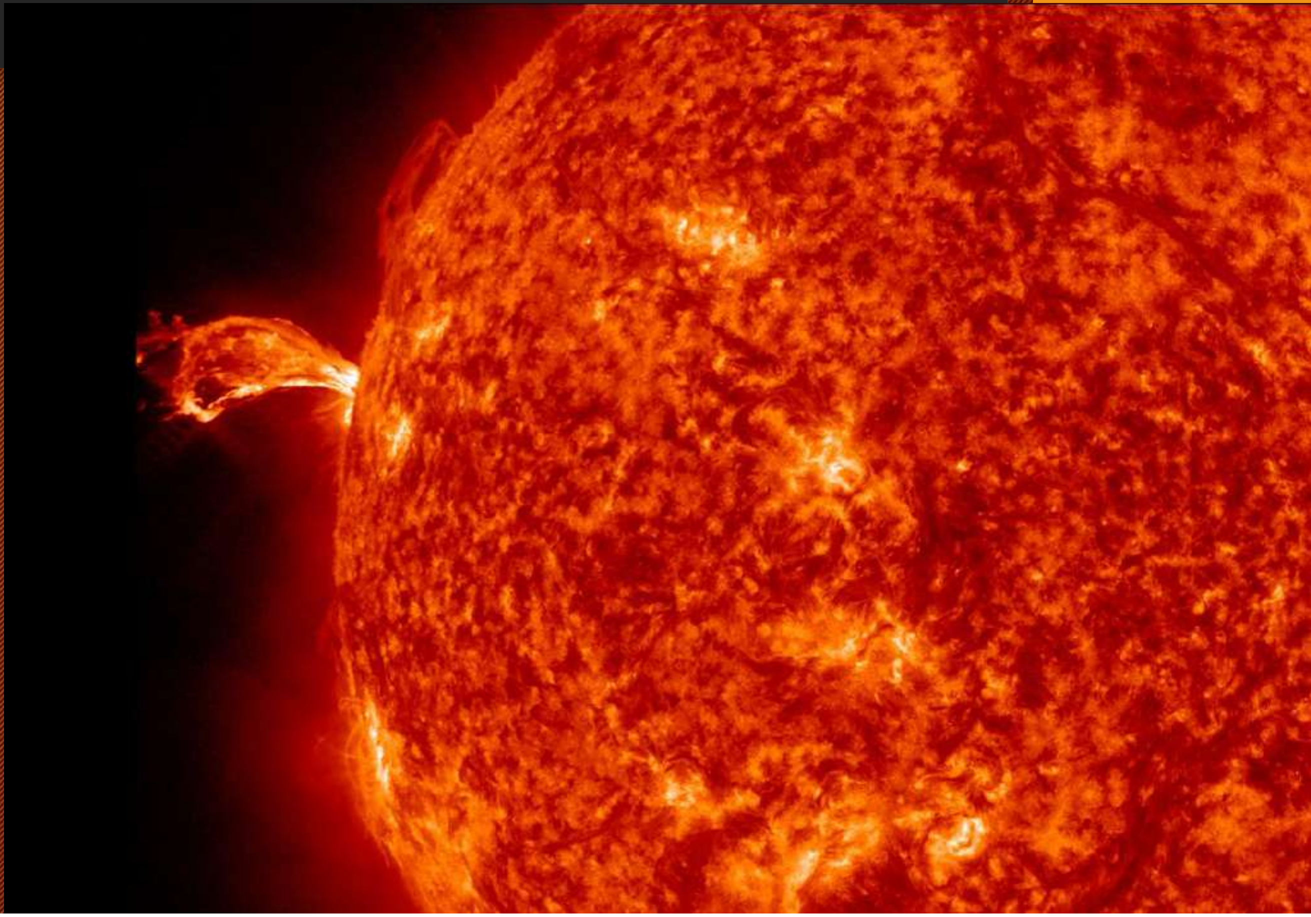
Coronal Holes

- often located over sunspot groups
- areas of low density in the gas of the corona
- main regions from which the particles that comprise the solar wind escape



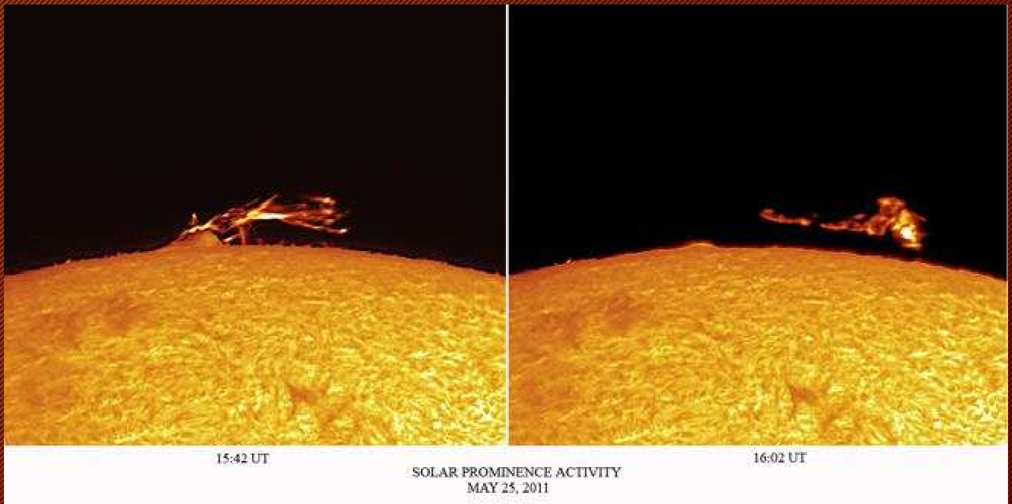
Solar Flares

- violent eruptions of particles and radiation from the surface of the Sun
- Highly active solar flares are associated with sunspots



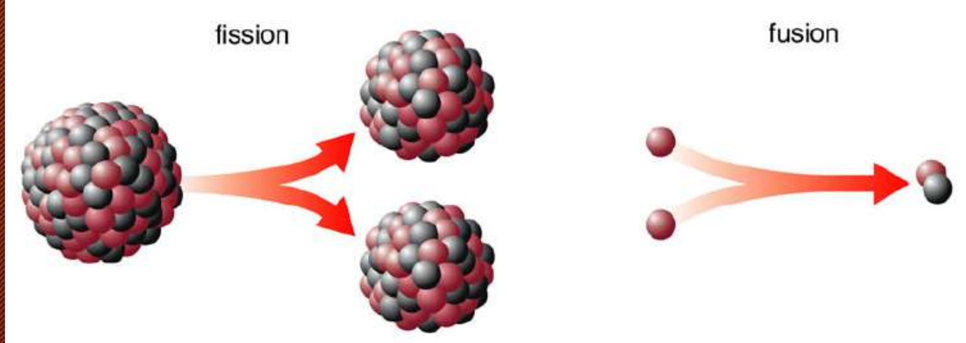
Solar Prominence (filament)

- arc of gas ejected from the chromosphere, or gas that condenses in the Sun's inner corona and rains back to the surface.
- Prominences can reach temperatures over 50,000 K and are associated with sunspots



The Sun's Interior

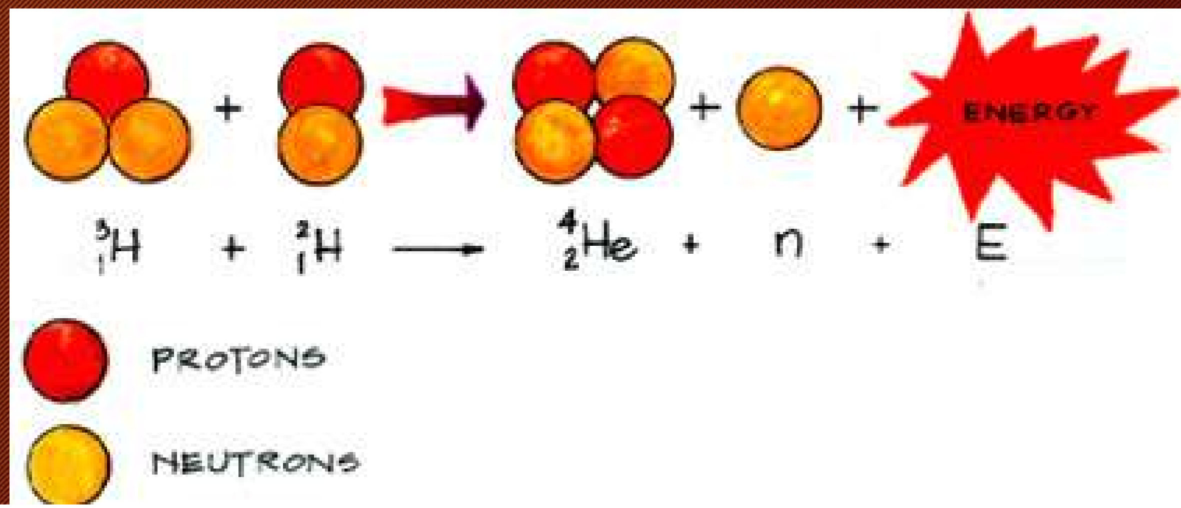
- Fusion is the combination of lightweight atomic nuclei into heavier nuclei, such as hydrogen fusing into helium.
- This is the opposite of the process of fission, which is the splitting of heavy atomic nuclei into smaller, lighter nuclei, like uranium into lead (nuclear energy)



The Sun's Energy

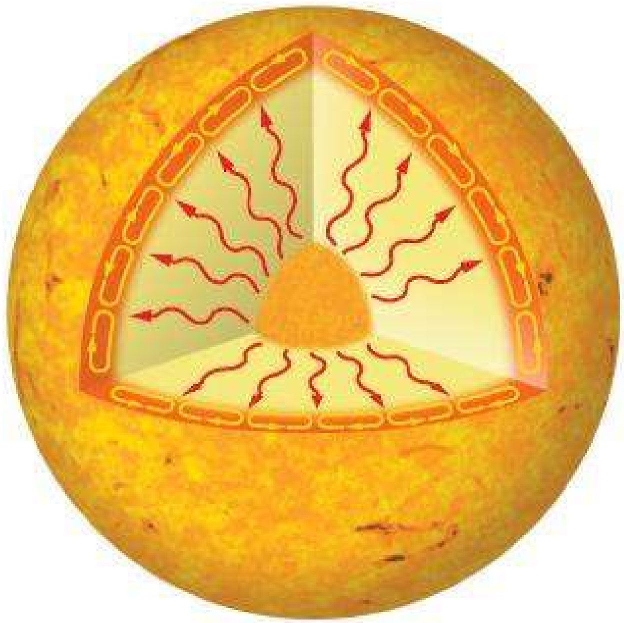
- In the core of the Sun, helium is a product of the process in which hydrogen nuclei fuse.
- The mass of the helium nucleus is less than the combined mass of the four hydrogen nuclei, which means that mass is lost during the process.

Albert Einstein's theory of relativity ($E=mc^2$)shows that mass and energy are equivalent, and that matter can be converted into energy and vice versa.



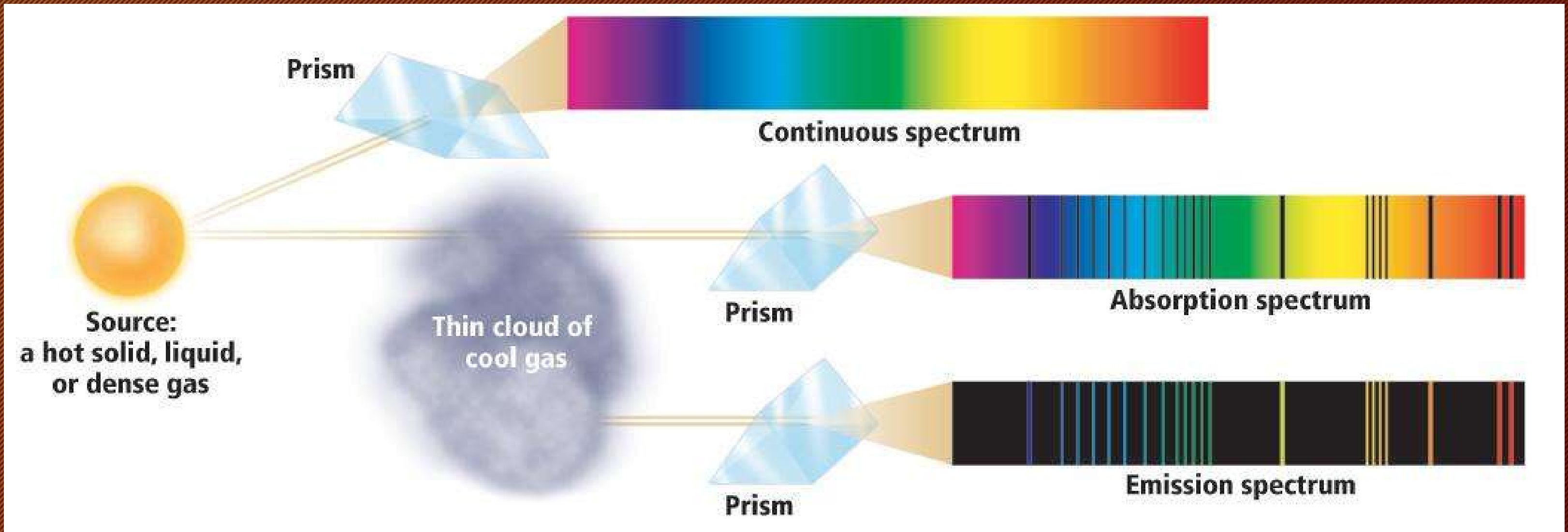
Energy Transport

•Energy in the Sun is transferred mostly by radiation from the core outward to about 86 percent of its radius. The outer layers transfer energy in convection currents.



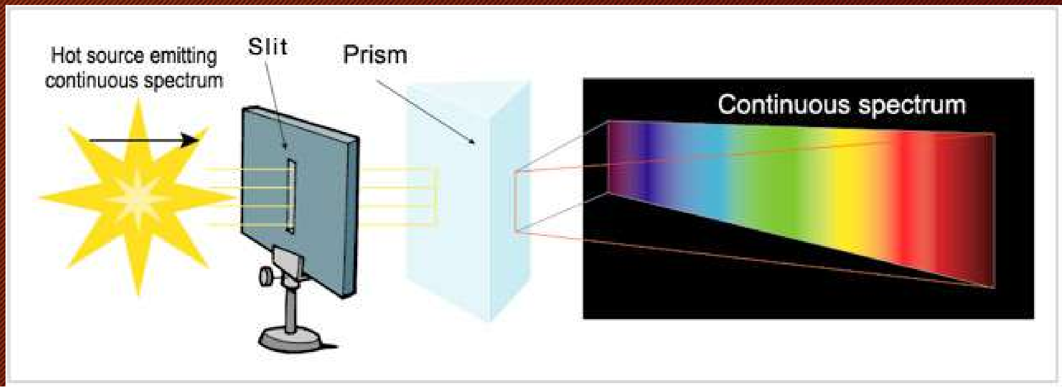
Spectra

- A spectrum (plural, spectra) is visible light arranged according to wavelengths. There are three types of spectra: continuous, emission, and absorption.

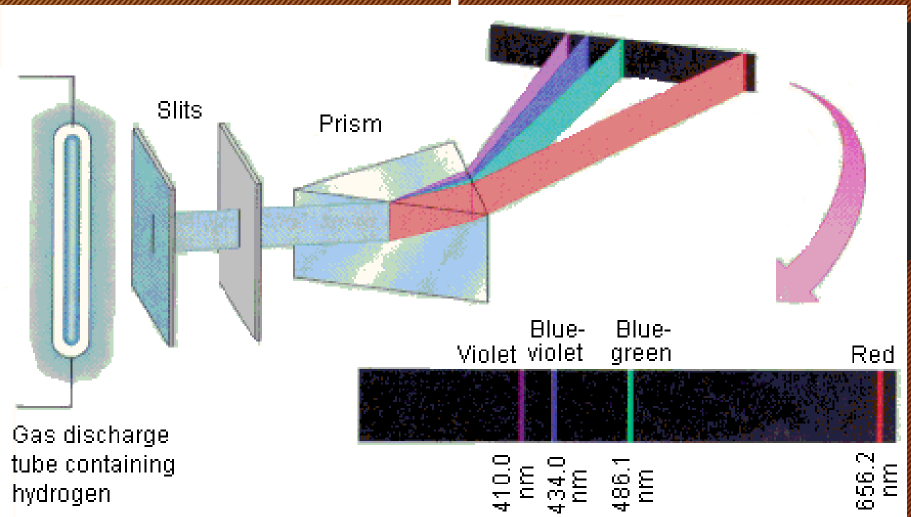


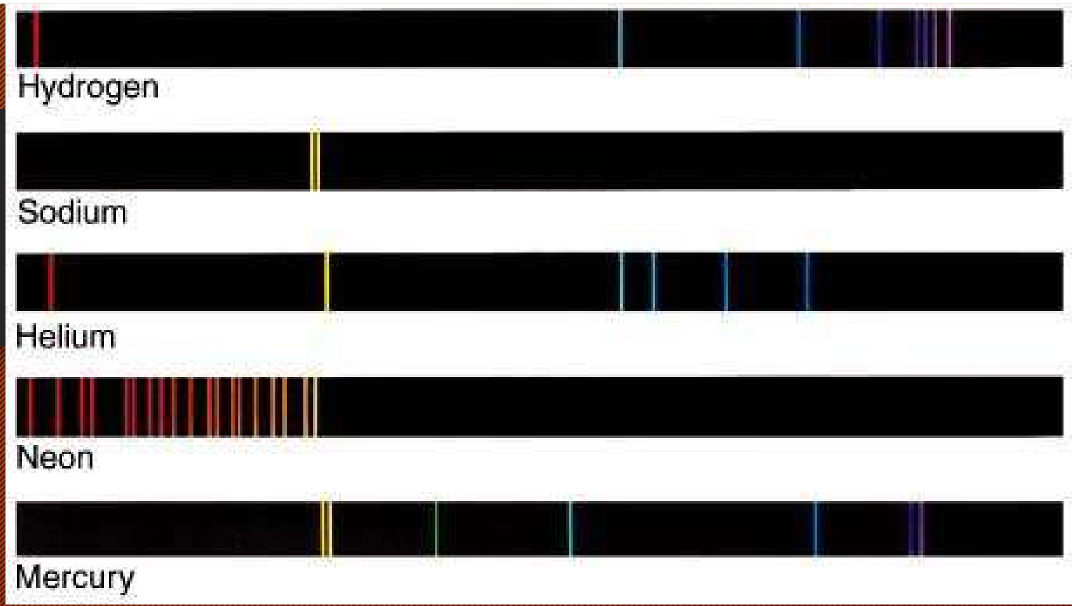
Continuous Spectra

- has no breaks in it, such as the one produced when light from an ordinary bulb is shined through a prism



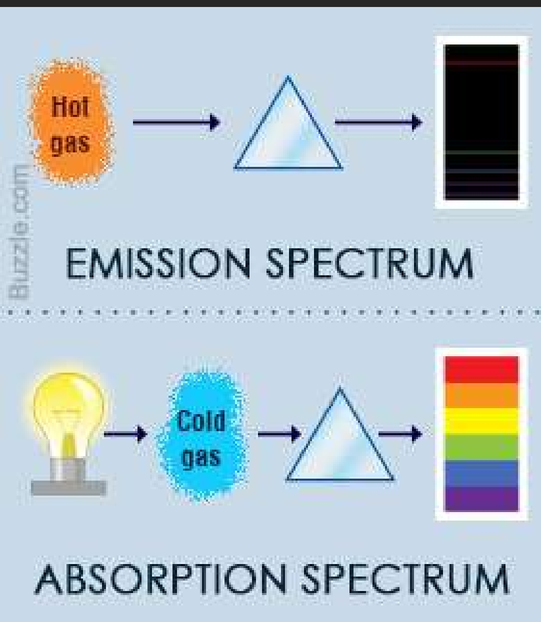
Emission Spectra

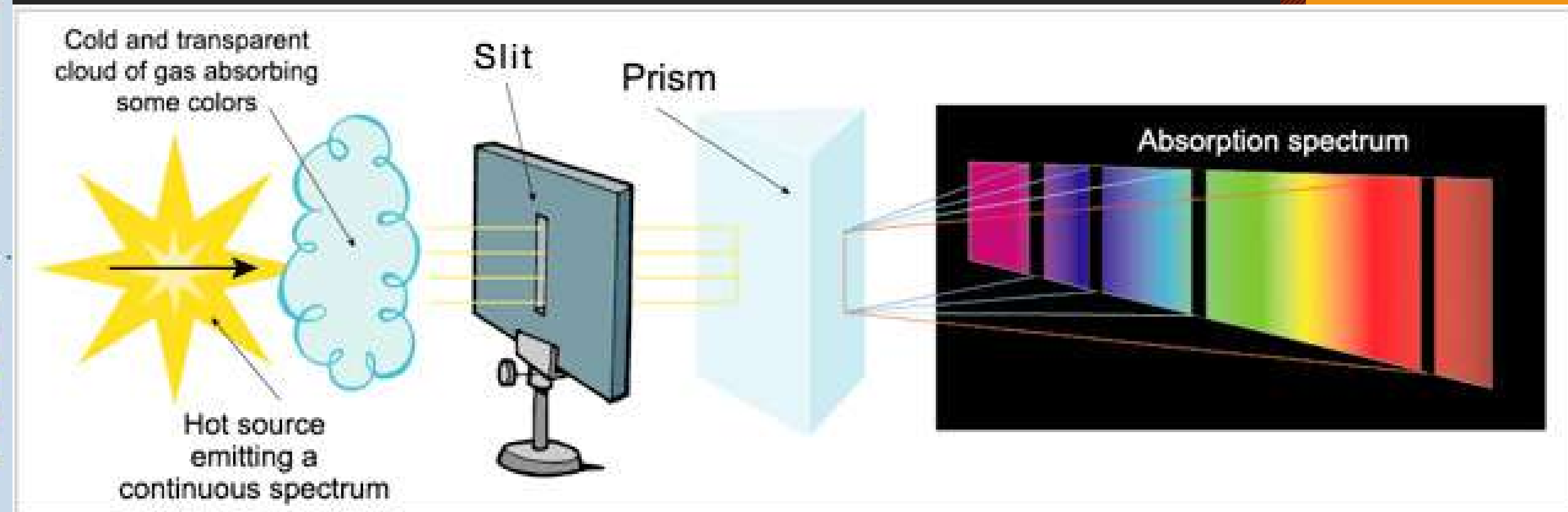




- from a noncompressed gas contains bright lines at certain wavelengths
- This is called an emission spectrum, and the lines are called emission lines.
- The wavelengths of the visible lines depend on the element being observed because each element has its own characteristic emission spectrum

Absorption Spectra

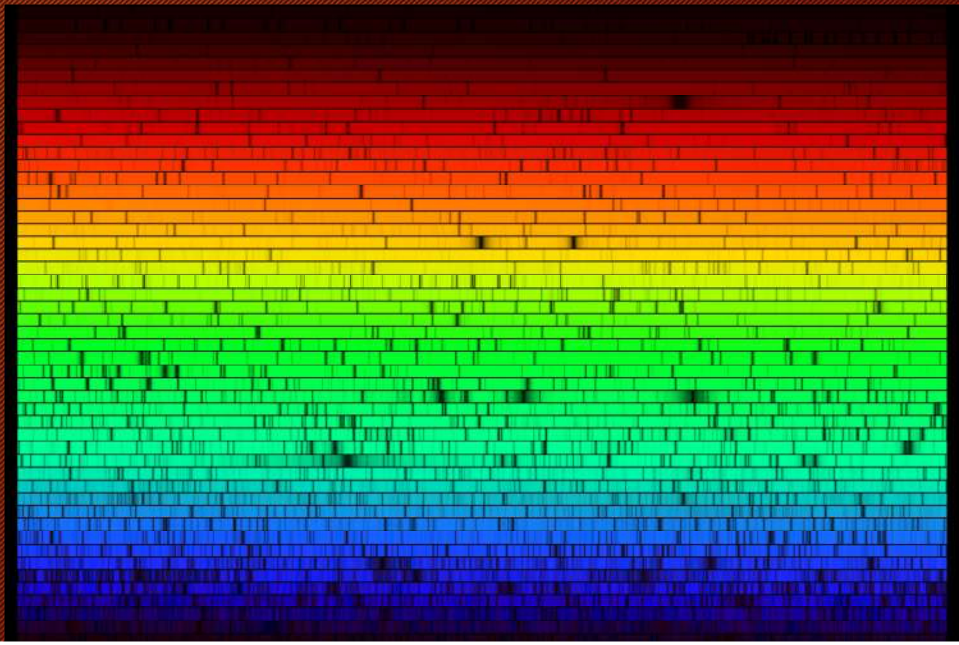




- A spectrum produced from the Sun's light shows a series of dark bands.
- These dark spectral lines are caused by different chemical elements that absorb light at specific wavelengths.
- This is called an absorption spectrum, and the lines are called absorption lines.

Solar composition

- Using the lines of the emission spectra like fingerprints, astronomers have identified the elements that compose the Sun. The Sun is composed primarily of hydrogen and helium with small amounts of other gases.

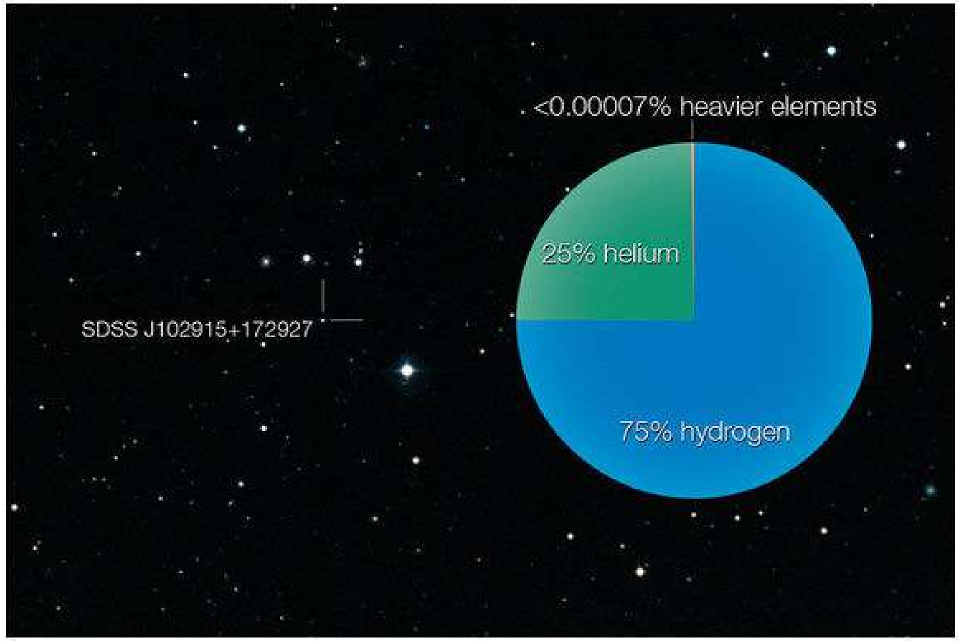


Basic Properties of Stars

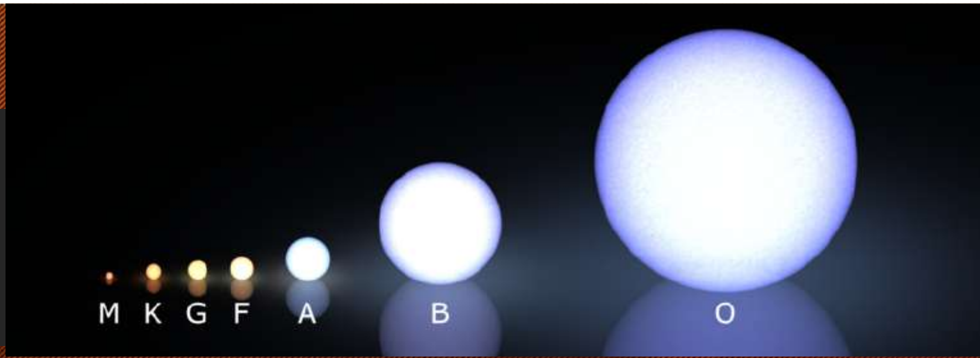
- Mass, Diameter, Luminosity, Composition
- These are all related
- Determines the spectral type of the star

Stellar Composition

- All stars, including the Sun, have very similar compositions, despite differences in their spectra. The differences in the appearance of their spectra are almost entirely a result of temperature differences.



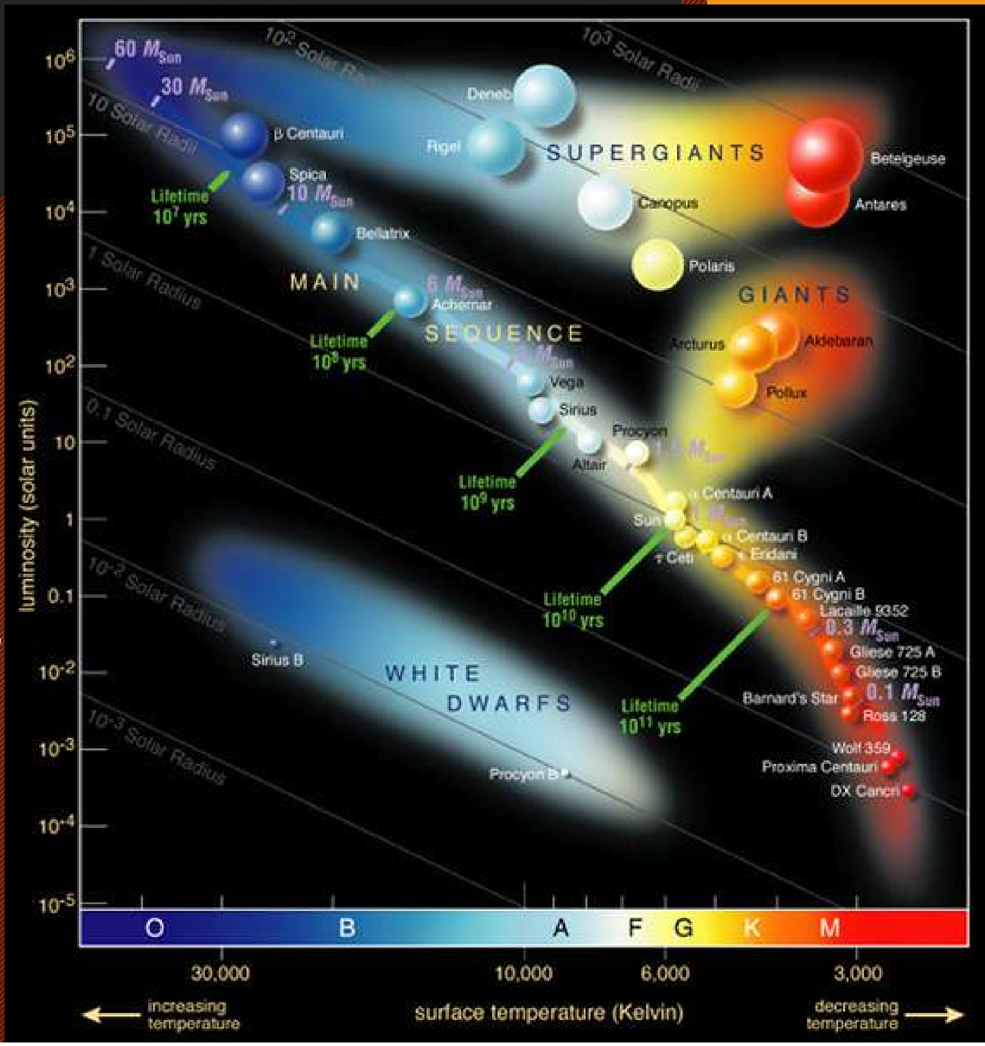
Classification of Stars



- Stars are assigned spectral types in the following order: O, B, A, F, G, K, and M. Each class is subdivided into more specific divisions with numbers from 0 to 9.
- originally based only on spectral lines, but astronomers later discovered that the classes also correspond to temperatures, with the O stars being the hottest and the M stars being the coolest. By examining a star's spectra, it is possible to estimate its temperature.
- Temperature is also related to luminosity. Typically, hotter stars put out more light than stars with lower temperatures.
- Because the temperature of a star is not affected by its distance, by measuring the temperature and luminosity, distance is known.

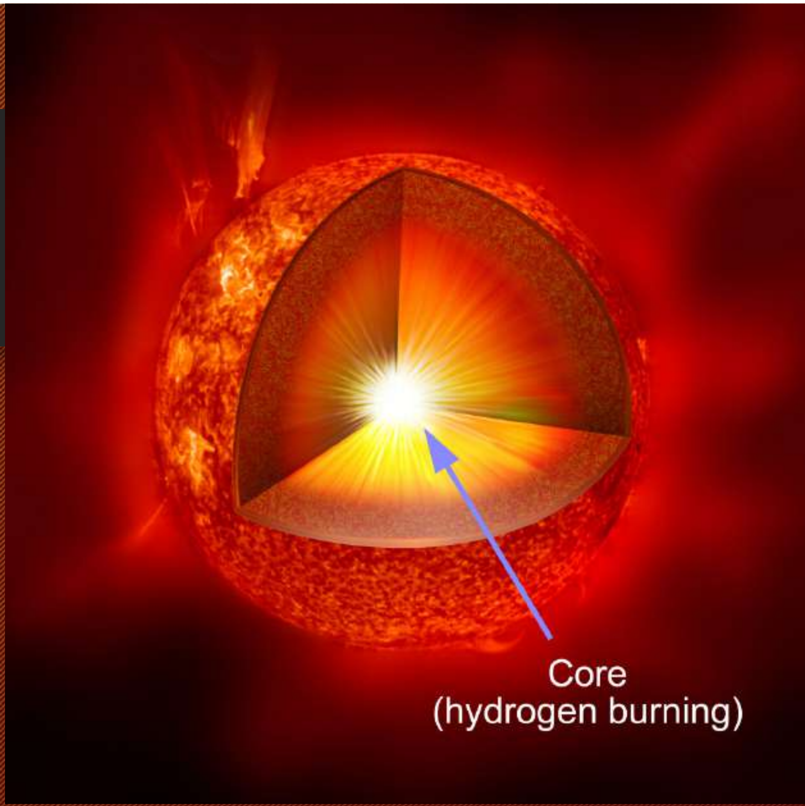
H-R Diagram

- A Hertzsprung-Russell diagram (H-R diagram) is a graph that relates stellar characteristics— class, mass, temperature, magnitude, diameter, and luminosity.
- Luminosity is plotted on the vertical axis and temperature or spectral type is plotted on the horizontal axis.
- Most stars occupy the region in the diagram called the main sequence



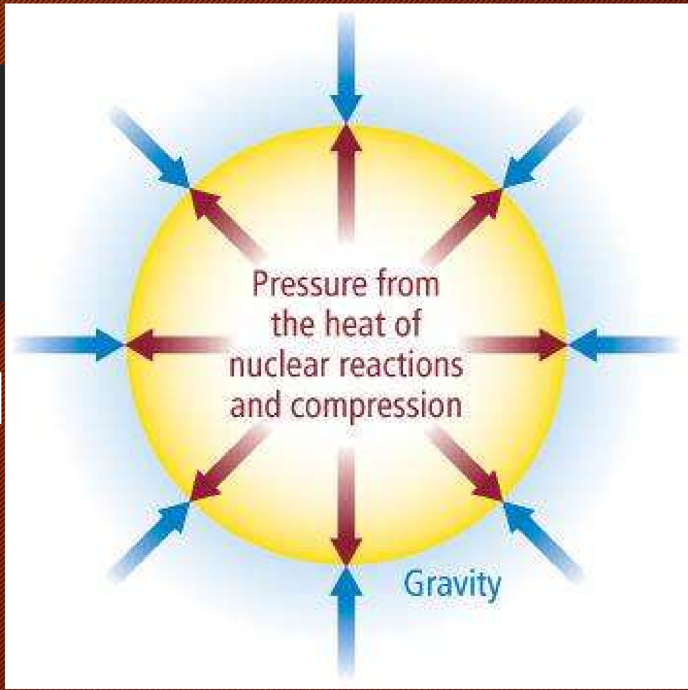
Main Sequence Stars

- While stars are in the main sequence, they are fusing hydrogen in their cores. As stars evolve off the main sequence, they begin to fuse helium in their cores and burn hydrogen around the core edges.
- A star's mass determines almost all its other properties, including its main-sequence lifetime. The more massive a star is, the higher its central temperature and the more rapidly it burns its hydrogen fuel.



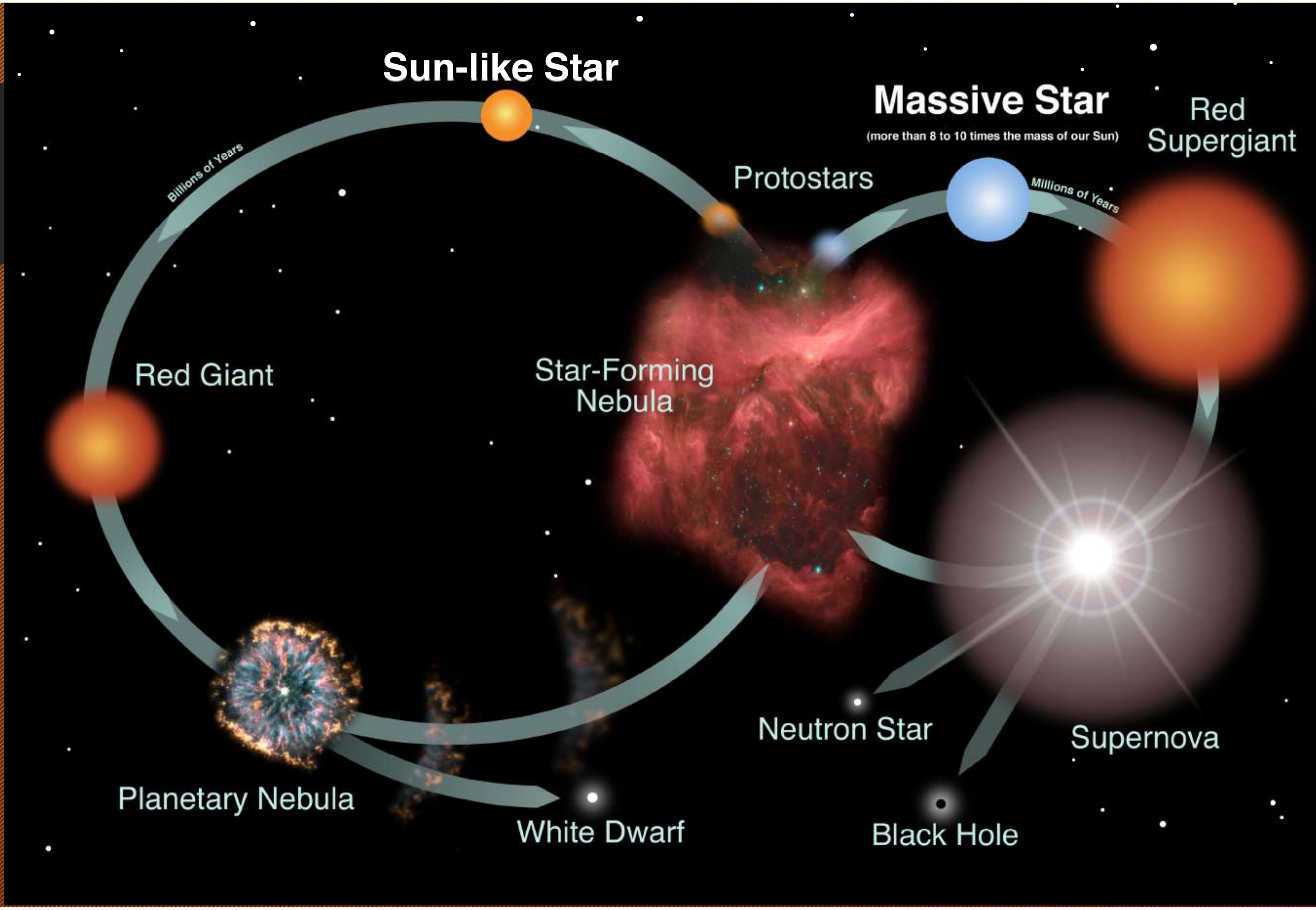
A star's balance

- The more massive a star is, the greater the gravity pressing inward, and the hotter and more dense the star must be inside to balance its own gravity.
- The balance between gravity squeezing inward and outward pressure is maintained by heat due to nuclear reactions and compression.
- This balance, governed by the mass of the star, is called hydrostatic equilibrium, and it must hold for any stable star.



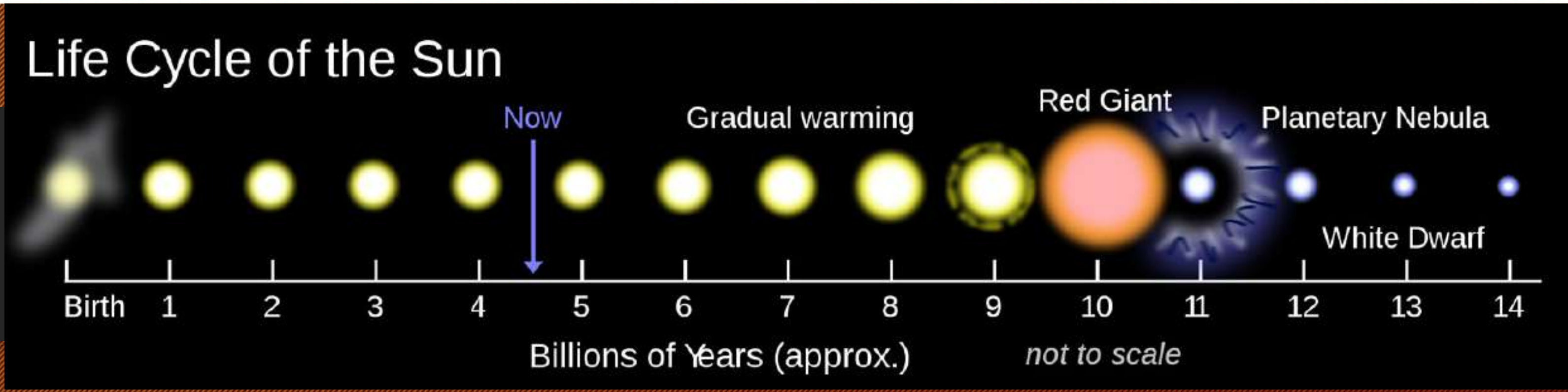
Stellar evolution

- Eventually, when its nuclear fuel runs out, a star's internal structure and mechanism for producing pressure must change to counteract gravity. The changes a star undergoes during its evolution begin with its formation.



Sun-like Star
Massive Star
(more than 8 to 10 times the mass of our Sun)
Red Supergiant
Billions of Years
Millions of Years
Protostars
Red Giant
Star-Forming Nebula
Neutron Star
Supernova
Planetary Nebula
White Dwarf
Black Hole

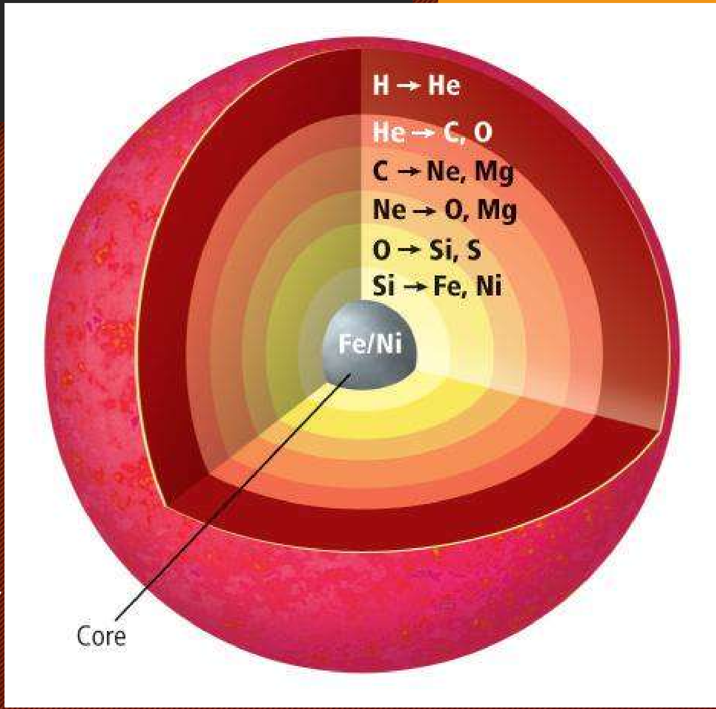
Sun-like star



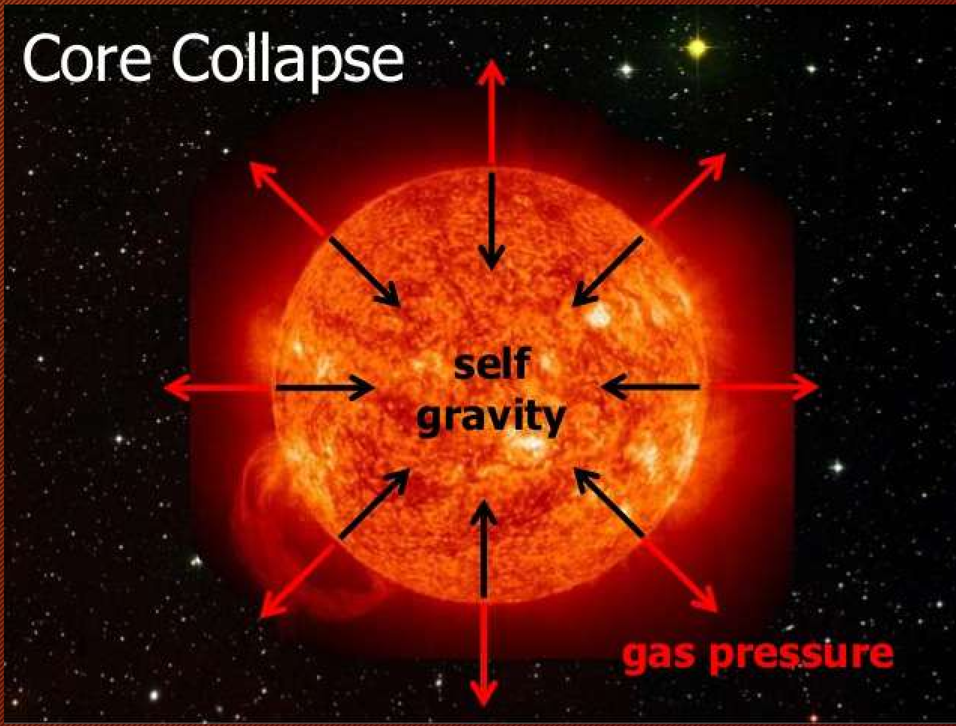
- Protostar forms, then equilibrium is achieved
- Continues as regular star until all the H in it's core is He, H is only fusing in a thin layer around the core
- The energy produced by this layer causes the outer layers of the star to expand and cool (red giant)
- As Carbon begins to form in the star, the outer layers expand more and form a gassy bubble (planetary nebula)
- In the center is the core, a white hot small star about the size of Earth (White Dwarf)
- Eventually, it will 'burn out' and become a black dwarf

Massive stars

- A massive star undergoes many more reaction phases and thus produces a rich stew of many elements in its interior. The star becomes a red giant several times as it expands following the end of each reaction stage.
- As more shells are formed by the fusion of different elements in a massive star, the star expands to a larger size and becomes a supergiant. These stars are the source of heavier elements in the universe.

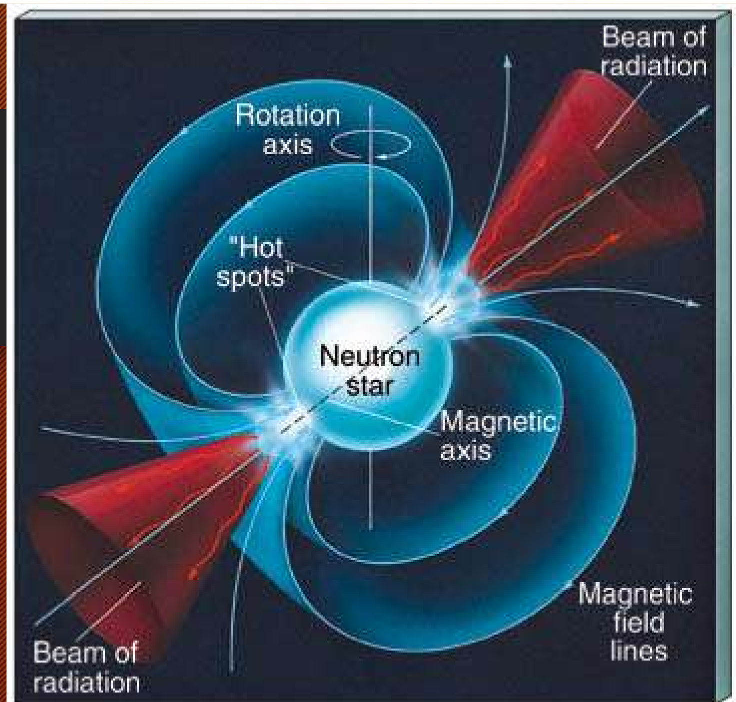


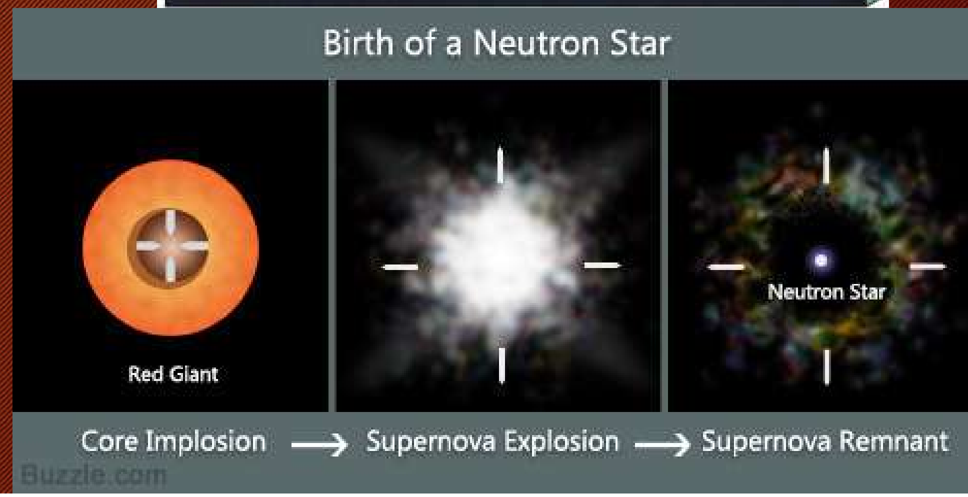
- A star that begins with a mass between about 8 and 20 times the Sun's mass will end up with a core that is too massive to be supported by electron pressure. Once reactions in the core of the star have created iron, no further energy-producing reactions can occur, and the core of the star violently collapses in on itself.



Option One – Neutron Stars

- When the outer layers of a star collapse into the core, the central mass of neutrons creates a pressure that causes this mass to explode outward as a supernova, leaving a neutron star
- A neutron star is a collapsed, dense core of a star that forms quickly while its outer layers are falling inward. It contains mostly neutrons.
- A pulsar is a spinning neutron star that exhibits a pulsing pattern.





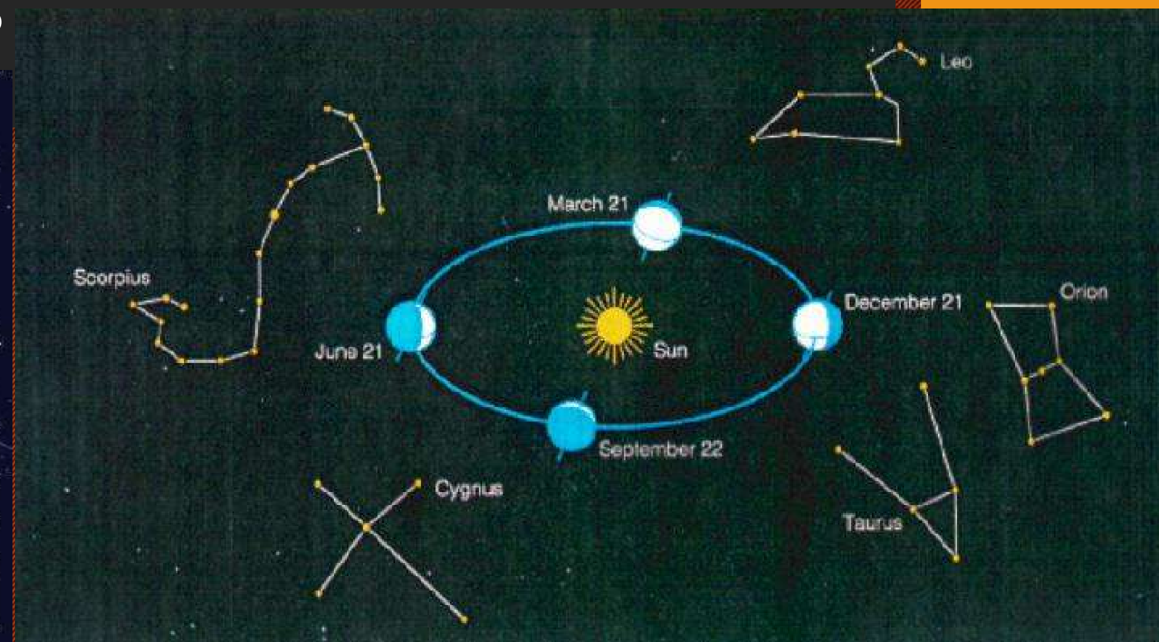
Option Two – Black Holes

- A star that begins with more than 20 times the Sun's mass will be too massive to form a neutron star. The resistance of neutrons to being squeezed is not great enough to stop the collapse. The core of the star continues to collapse, compacting matter into a smaller volume
- A black hole is a small, extremely dense remnant of a star whose gravity is so immense that not even light can escape its gravity field

Groups of Stars

- As seen from Earth – Constellations
- Some constellations are visible throughout the year, depending on the observer's location.
- Constellations that appear to rotate around one of the poles are called circumpolar constellations. Ursa Major, also known as the Big Dipper, is a circumpolar constellation for the northern hemisphere

Seasonal Constellations



- Unlike circumpolar constellations, the other constellations can be seen only at certain times of the year because of Earth’s changing position in its orbit around the Sun