# The Life Cycle of a Star

We know that the first or (primordial) stars were created from lumps and clumps of material in the newly formed and expanding universe. Other stars are formed in a similar way. Gravity compresses clouds of dust and gas in space so much that they begin to glow, eventually becoming what we call stars.

Stars continue to change throughout their lives, much as humans change throughout theirs. Exactly what happens to a star during its life depends on how large it is to begin with, but all stars, regardless of size go through the same first few stages of their lives. These stages are summarized below.

**Nebula**-a nebula is simply a cloud of dust and gas in space. The dust and gases get compressed by the force of gravity and their density slowly increases.

**Protostar-** This is the next stage in the life of a star. Eventually gravity compresses the nebula so much that it begins to get warm . Whenever you increase the pressure on something, it begins to get warm, this is a universal constant, it ALWAYS happens. When the nebula gets squeezed so much that it starts to radiate or glow, it enters the Protostar stage of its life. A Protostar is simply a nebula which has started to glow.

**Main Sequence Stage-** The main sequence star is often called the "adult" form of a star. As gravity continues to compress the Protostar, individual Hydrogen atoms are fused to each other in a process called *Thermonuclear Fusion of Hydrogen*. When four atoms of hydrogen are fused in this manner, they form a new type of atom called *helium*. In the process of this new atom being formed, a little bit of the hydrogen matter is actually converted to pure energy. Einstein's famous equation: $E=mc^2$ describes how much energy is produced from this reaction. since at one point you multiply by the speed of light, the amount of energy produced by even a small amount of matter is great indeed. When Thermonuclear Fusion of Hydrogen begins, the remainder of the Protostar is burned away. All that remains is the new Main Sequence Star. This is an extremely stable form of a star. Our yellow, Main Sequence Star uses about 4 million tons of Hydrogen each second. Even at this incredible rate, there's enough Hydrogen there to make this reaction last about another 5 billion years. (It's already been going for about 5 billion years) A main sequence star can be just about any color of the rainbow:

Red, Orange, Yellow, Green, or Blue/White. Red main sequence stars are relatively cool, (only about 1000 degrees Celsius at the surface), and consume their fuel relatively slowly. Blue/White main sequence stars are very hot (around 100,000 degrees Celsius at the surface), and thus consume their fuel at a much faster rate. Red main sequence stars are also not very dense, while the Blue/White stars are extremely dense. Most of the stars that you can see in the sky at night are Blue/White stars. There are plenty of the other types of stars out there, but most are too far away, or just too dim, to be seen with the naked eye.

**Red Giant Stars-** Eventually, all good things must come to an end. Such is the case with a main sequence star's supply of hydrogen atoms. When he last of this fuel has been consumed, the nuclear "fire" within the star is extinguished. Since the life of a star is characterized by the continuing struggle between two forces, the force of gravity which seeks to crush the star ever smaller, and the force of the fusion-reactin, which seeks to make the star expand ever larger, gravity eventually wins the contest. What occurs next is termed Gravitational Collapse. Gravity, now unopposed, crushes and squeezes the star into an ever-smaller package. As this occurs, great heat is built up in the stars core. Red giant stars produce energy by a process called Thermonuclear Fusion of Helium. As this process produces much heat, the star expands, and the outer layers cool. The outer layers of these huge stars are only about 1000 degrees Celsius in temperature, and are therefore red in color. Since the star has expanded so much in size, it is termed a "giant" or sometimes a "supergiant".

The next step is determined by the original size of the main sequence star. There are three possibilities, the star may be about he same size as our sun, about 3 times larger, or 5 or more times large than our sun. We will now examine how each of these types of stars completes its life cycle.

Sun-Sized Stars-

Stars about the size of our sun go through the same first four stages as does any other star. They begin their lives as a nebula, then become a Protostar, eventually becoming a main sequence star and finally a red giant. When the red giant runs out of helium fuel, the thermonuclear fusion of Helium stops, and the star experiences gravitational collapse. Great pressures build up in the star, but this pressure is not enough to trigger another fusion-reaction.

Eventually, the outer layers of the red giant star simply fade away, or dissipate, leaving only the hot, dense core behind.

**White Dwarf Stage-** The hot and dense core of a star is called a white dwarf. This type of star is only about the size of the Earth, but has the gravitational strength of a huge, million-mile-in-diameter star. This enormous gravitational forces compresses the material of the white dwarf into a very compact package. One teaspoon of white dwarf material has been estimated to weigh one ton! A white dwarf is also very hot, having a temperature of about 100,000 degrees Celsius. It is interesting to note that the white dwarf isn't actually producing any energy, it is like a piece of hot metal, slowly losing its heat to surrounding space. Eventually, the white dwarf loses the last of its heat energy to the environment and becomes a.....

**Black Dwarf Stage-** A black dwarf is a white dwarf which has cooled off. It is no longer glowing because it is no longer hot. A black dwarf isn't actually black in color, it is referred to as black because it is no longer radiating any heat.

**Stars twice as big as our sun:**

These stars go through the same first stages in their lives as all other stars go through. When the red giant star uses the last of its helium fuel, thermonuclear fusion of helium stops and the star experiences gravitational collapse. Gravity causes the core to experience a great buildup of pressure which translates to heat. This heat causes the star to experience a phenomenon known as a:

**Supernova-** a supernova is an explosion which rips a star apart near the end of its life. When the supernova occurs, the star is destroyed, with only the dense core remaining. Gravity continues to compress this core until the atoms themselves are crushed. Still, the gravitational collapse continues. Finally, only the electrically neutral parts of the atoms, the neutrons, remain. You end up with a star composed entirely of neutrons.

**Neutron Star-** A neutron star is an extremely small and dense star that is composed entirely of neutrons. The average neutron star is only a mile or two in diameter, and is so dense that a teaspoonful of material would weigh

as much as a mountain! (40 tons or more!) Because of their powerful gravitational fields, neutron stars allow light to escape only at their poles. Since neutron stars also spin rapidly, these stars appear to flash on and off! (Like a lighthouse). These stars have also been named Pulsars due to their flashing appearance.

**Stars five times larger than our sun (and larger)-**

Stars of this size go through the same steps as do the other stars in the early years of their lives. When the red giant runs out of helium fuel, gravitational collapse occurs. In this instance, not even the neutrons are able to bring a halt to the collapse, since gravity is so strong. The remains of this star continue to get crushed by gravity more and more and more...until it disappears from sight! This stage in the life of a star is called:

**The Black Hole-** A black hole is a star with gravity so strong that even light is unable to escape. All light touching the black hole is trapped in its immense gravitational field. To an outside observer, the star simply blinks out of sight (as the light waves are trapped). Black holes are the subject of intense scientific study today, and our understanding of this phenomenon grows daily.