Supernovae

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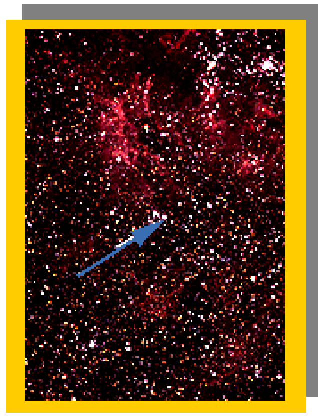
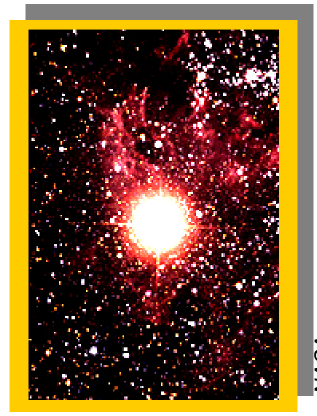


NASA

Supernova: Before the explosion



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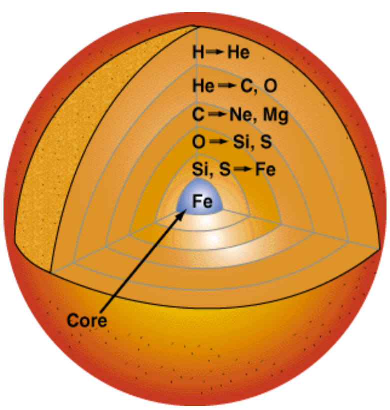
Supernova During explosion

A massive star (at least eight times as big as the sun) ends its life in a **supernova**, a spectacular explosion so powerful that it can outshine the entire galaxy the star was part of. Stars generate energy in their cores by **nuclear fusion**: four hydrogen **nuclei** fuse to create helium. Stars are so enormous (our sun has a mass almost a million times that of the Earth!) that the weight of a star's outer layer presses down on the core, raising the density of its gas to tens of times denser than iron, and the temperature to as much as 15 million °K. Under these conditions, the atoms are banging about quickly enough for fusion to take place. The energy generated by fusion results in radiation that travels out of the star. This energy heats the surrounding gas, causing it to expand, balancing the effect of gravity which tends to pull matter inward, keeping it from collapsing.

What happens when the star runs out of hydrogen fuel in its core? The nuclear fusion reactions slow down, energy generation stops, and there is nothing to counteract gravity. The outer layer of the star begins to collapse, compressing the core some more, raising its temperature and pressure until helium begins to fuse to form carbon. Energy generation begins again, stopping the collapse. However, the helium will also eventually run out, energy generation will stop again, and the star will start collapsing once more. At some point, even the carbon can start fusing, with the end result being oxygen.

This process continues through several cycles, forming increasingly heavier elements such as neon, magnesium, and silicon. It stops, however, with the formation of iron, such a heavy atom (typically its nucleus contains 26 protons and 30 neutrons) that it is impossible to generate more energy from it by fusion. With the end of nuclear fusion in the iron core, there is nothing to stop the collapse of the rest of the star. The star **implodes**, or collapses inward. The temperature of the gas inside the core, being compressed by the collapsing outer layer, can rise to 10 billion °K. Atoms are broken apart at these high temperatures resulting in a sea of loose **protons, neutrons,** and **electrons.**



McREL

Nuclear Reaction Layers in aging star

The densities and pressures are so high in the core that the free protons and electrons are forced together to form neutrons. The collapsing core soon consists of neutrons and expels **neutrinos**. For stars whose core is no more than three times the mass of our sun, the neutrons can be squeezed together only so much. At some point, the neutron core stops collapsing.

Even though the core has stopped collapsing, the rest of the star is still falling inward. Gas slams into the core, which can not grow any smaller. The outer layer of the star bounces off the core in an enormous explosion that sends gas flying outward into space. This is the supernova. What is left of the core is a **neutron star**. (For cores that are greater than three times the mass of our sun, nothing can stop the collapse, and a **black hole** is formed from the debris.) The supernova explosion is so powerful that elements heavier than iron, many important for life on earth, are formed from the debris. Some trace elements, like zinc and iodine, are essential in our diets. Others like nickel, copper, lead, gold, silver, and uranium have important uses in our society. All these elements and more could not have come into existence without a supernova.