

Question

How does a star become a supernova or a black hole? How does the star decide which one to turn into?

Answer

Stars are sustained by the nuclear fusion reactions taking place in their cores. For stars on the main sequence, such as our own Sun, this mostly involves combining hydrogen to form helium. The energy that these reactions produce is enough to support their mass against its own gravity.

As a star runs out of fuel it can expand and will begin to form heavier elements such as carbon and iron (most of the matter in our solar system comes from extra-solar sources). Once it finally exhausts all of its fuel it will begin to collapse. It is here that the stars begin to undergo different fates.

Our own sun will collapse until it becomes a white dwarf, at this point the Pauli exclusion principle keeps the electrons in the star far enough apart to resist further collapse - this energy is called 'electron degeneracy'.

Stars greater than 1.4 times the mass of the Sun (called the Chandrasekhar limit after the Indian physicist who discovered it on his way to England) will tend to explode in a supernova casting off much of their mass. A small central core will remain and like smaller stars this will collapse only this time electron degeneracy will not be enough to support the star's mass against its gravitational collapse and it will continue to shrink until it becomes a tiny, but hugely massive, neutron star held together by neutron degeneracy.

If neutron degeneracy is not enough to resist the star's collapse it will continue to shrink until the matter is all compressed into an infinitely small, infinitely dense point called a singularity. This is the centre of a black hole.

Answer 2

The life span of a star and its final state are determined by the mass of the star. All stars, as far as we know, are under two basic forces, that of gravity and that of the internal pressure formed by the fusion of hydrogen into helium. Gravity acts as an energy source that creates tremendous heat and pressure inside a star and begins the fusion process that produces the massive amounts of heat and energy that make the star shine and tries to push the gases away from the star until the balance is found.

When most of the hydrogen is fused into helium, fusion stops and gravity again takes over. The star starts to collapse without the energy from fusion. What happens next in the life of a star is dependent on its mass. For a low mass star (smaller than our sun) gravity is not strong enough to start fusion again and the burnt-out cinder becomes a brown dwarf and eventually a cold, dead body in space.

For stars near sun's mass, the gravitational force is great enough to squeeze the center and make it hot enough for the star to start fusing helium into other light elements. This renewal of energy causes the star to swell into a red-giant and shed some of the outer layers into space as a planetary nebula. When our sun turns into a red giant (in about 5 billion years), the orbit of Mars will be inside the sun. After the star finishes fusing everything that it can, gravity again takes over and starts squeezing the atoms tighter and tighter until the repulsive forces of the electron shells around the atoms balances the force of gravity and the star comes to equilibrium as a white dwarf with a great density (1

teaspoon would weigh several tons). This star will eventually cool down and drift through space as a cold, burned out cinder.

Stars greater than two and a half times the mass of the sun, their fate is even more exotic. The force of gravity is great enough to produce iron in the center of the star from fusion. Iron is the heaviest substance that a star can make in its life because heavier elements require more energy to fuse together than they release, so the star collapses. For massive stars, this collapse is so violent that it causes a huge, catastrophic explosion known as a supernova. It is in these explosions that all elements heavier than iron are produced. It has been said that we are made of stardust. Supernovas are so bright that close ones have been seen even during the day during the middle ages. The final fate of the star after a supernova depends on the amount of mass left in the core after the explosion. Some of the stars are still massive enough to overcome the electrical repulsion of the electron shells and smash the electrons into the nucleus of the atoms thereby cancelling out the positive charge of the protons until the force of gravity is balanced by the force of the neutrons pressing against each other and a neutron star is formed. The material from this star weighs even more than the material from a white dwarf. If a star is even more massive than the one that forms a neutron star, it goes through the same process of creating a supernova, but the force of gravity is so great because of the amount of mass involved, that the neutrons cannot halt the collapse of the star which continues to be squeezed into a smaller and smaller space until the gravity of the star is able to trap light inside of what is known as the 'event horizon' which creates a black hole. To give you an idea of the density of a black hole, if we wanted to compress the earth enough to create a black hole, all of the earth's mass would have to fit in the palm of your hand, and would tear your body apart and draw you into it thereby adding more mass to the hole.

Black holes are detected by finding the ones that are close to other stars and watching for the radiation (mostly x-rays) given off by matter falling into it before the event horizon is crossed. Check out the Chandra X-Ray Telescope site for x-ray pictures of possible black holes.

The key to the puzzle is gravity which is determined by mass. There may be other mechanisms for forming a black hole, but this is the general stellar process for the formation of these objects.