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Black Holes

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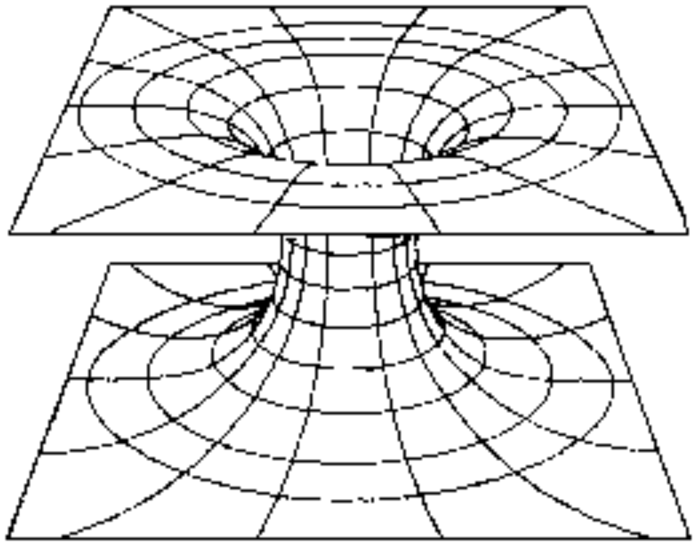
Gravity is the midwife and the undertaker of the stars. It gathers clumps of gas and dust from the interstellar clouds, compresses them and, if they are sufficiently massive, ignites thermonuclear reactions in their cores. Then, for millions or billions of years, they produce energy, heat and pressure which can balance the inward pull of gravity. The star is stable, like the Sun. When the star's energy sources are finally exhausted, however, gravity shrinks the star unhindered. Stars like the Sun contract to become white dwarfs -- a million times denser than water, and supported by quantum forces between electrons. If the mass of the collapsing star is more than 1.44 solar masses, gravity overwhelms the quantum forces, and the star collapses further to become a neutron star, millions of times denser than a white dwarf, and supported by quantum forces between neutrons. The energy released in this collapse blows away the outer layers of the star, producing a supernova. If the mass of the collapsing star is more than three solar masses, however, no force can prevent it from collapsing completely to become a black hole.

What is a black hole?



A black hole is a region of space in which the pull of gravity is so strong that nothing can escape. It is a "hole'' in the sense that things can fall into it, but not get out. It is "black'' in the sense that not even light can escape. Another way to say it, is that a black hole is an object for which the escape velocity (the velocity required to break free from an object) is greater than the speed of light -- the ultimate "speed limit'' in the universe.

In 1783, British amateur astronomer, Rev. John Mitchell, realized that Newton's laws of gravity and motion implied that the more massive an object, the greater the escape velocity. If you could somehow make something 500 times bigger than the Sun, but with the same density, he reasoned, even light couldn't move fast enough to escape from it and it would never be seen. But it took Einstein's general theory of relativity, the modern theory of gravity, for astronomers and physicists to understand the true nature and characteristics of black holes.

The boundary of a black hole is called the *event horizon*, because any event which takes place within is forever hidden to anyone watching from outside. Astronomer Karl Schwarzschild showed that the radius of the event horizon in kilometers is 3 times its mass expressed in units of solar masses; this radius is called the Schwarzschild radius. The event horizon is the one-way filter in the black hole: anything can enter, but nothing can leave.

A black hole is a very simple object: it has only three properties mass, spin and electrical charge. Because of the way in which black holes form, their electrical charge is probably zero, which makes them simpler yet. The form of the matter in a black hole is not known, partly because it is hidden from the outer universe, and partly because the matter would, in theory, continue to collapse until it had a radius of zero, a point mathematicians call a singularity, of infinite density -- something with which we have no experience here on Earth.

Black holes are theorized to come in three different sizes: small ("mini''), medium, and large ("supermassive''). There is good evidence that medium-sized black holes form as the corpses of massive stars which collapse at the end of their lives, and that supermassive black holes exist in the cores of many galaxies -- perhaps including our own.

Mini Black Holes

A black hole with a mass less than three solar masses would not form on its own; its gravity is too weak to cause it to completely collapse in on itself. Enormous outside pressure would be necessary to create a "mini-black hole.'' In 1971, astrophysicist Stephen Hawking theorized that, in the dense turbulence of the Big Bang from which the universe emerged, such enormous outside pressures existed and many mini-black holes formed. These would be as massive as mountains, but as small as the protons of which atoms are made. They would have another bizarre property: as a result of the laws of quantum mechanics which govern very small particles in the universe, they would spontaneously radiate energy and, after billions of years, eventually evaporate in a final violent explosion. Thus, mini-black holes may not be entirely "black" -- an intriguing possibility. No observational evidence of mini-black holes exists but, in principle, there could be such objects scattered throughout the universe, perhaps even near our solar system.

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