Black Holes

What would happen if you were to travel to a black hole? Your body would be stretched, flattened, and eventually pulled apart. What is a black hole? What is known about black holes?

A black hole is one of the possible final stages in the evolution of a star. When fusion reactions stop in the core of a star that is at least 20 times more massive than the Sun, the core collapses forever, compacting matter into an increasingly smaller volume. The infinitely small, but infinitely dense, object that remains is called a singularity. The force of gravity is so immense in the region around the singularity that nothing, not even light, can escape it. This region is called a black hole.

Nothing Can Escape In 1917, German mathematician Karl Schwarzschild verified, mathematically, that black holes could exist. Schwarzschild used solutions to Einstein's theory of general relativity to describe the properties of black holes. He derived an expression for a radius, called the Schwarzschild radius, within which neither light nor matter escapes the force of gravity of the singularity. The Schwarzschild radius is represented by the following equation:

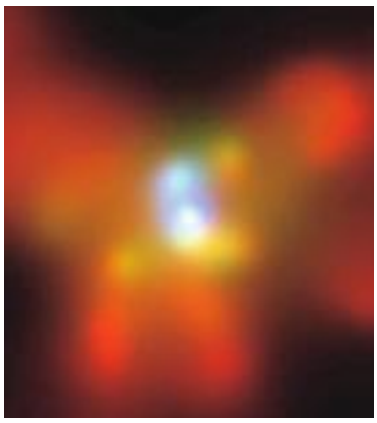
$$R_s = \frac{2GM}{c^2}$$

In this equation, G is Newton's universal gravitational constant, M is the mass of the black hole, and c is the speed of light. The edge of the sphere defined by the Schwarzschild radius is called the event horizon. At the event horizon, the escape velocity equals the speed of light. Because nothing travels faster than the speed of light, objects that cross the event horizon can never escape.

Indirect and Direct Evidence Black holes have three physical properties that can theoretically be measured—mass, angular momentum, and electric charge. A black hole's mass can be determined by the gravitational field it generates. Mass is calculated by using a modified form of Kepler's third law of planetary motion. Studies using NASA's *Rossi X-ray Timing Explorer* have shown that black holes spin just as stars and planets do. A black hole spins because it retains the angular momentum of the star that formed it. Even though a black hole's electric charge has not been measured, scientists hypothesize that a black hole may become charged when an excess of one type of electric charge falls into it. Super-heated gases in a black hole emit X rays, which can be detected by X-ray telescopes, such as the space-based *Chandra X-ray Observatory*.

Although not everything is known about black holes, there is direct and indirect evidence of their existence. Continued research and special missions will provide a better understanding of black holes.

***Hubble* visible image of galaxy NGC 6240.**



***Chandra* X-ray image of two black holes (blue) in NGC 6240.**

Going Further

Solve The escape velocity of an object leaving the event horizon can be represented by the following equation:

$$v = \sqrt{\frac{2GM}{R_s}}$$

In this equation, G is Newton's universal gravitational constant, M is the mass of the black hole, and R_s is the radius of the black hole. Show that the escape velocity equals the speed of light.

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