Black Holes

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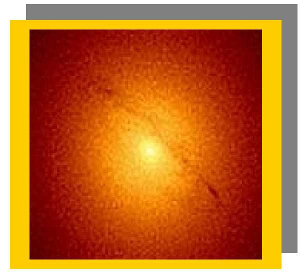

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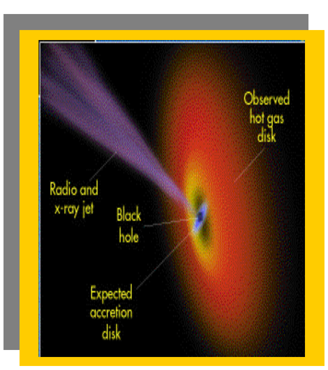
Galaxy, *showing evidence of black hole in center of galaxy*

When you launch a rock up into the air, it slows and is eventually pulled back down by gravity. If you launch it with more force, it starts off faster and goes higher before falling back to the Earth. If you continue throwing harder and harder, there will be a speed beyond which the rock escapes out of the Earth's gravity. That speed is called the **escape velocity** and has been recognized since Isaac Newton's time. Scientists have wondered, "What if something had gravity so strong that this escape velocity turned out to be at least the speed of light?" The answer is, "Then not even light shining straight up would escape." What we've worked out since then are a few things about what kind of object could have such strong gravity. The name we give it is a **black hole**.

Astronomers think that black holes are the remains of what sometimes happens when a star comes to the end of its lifetime. To understand a black hole, you must understand about gravity. In some ways, gravity is the same as any other form of energy, like light and sound. It gets weaker as you get further away from its source and stronger as you get closer to its source. Stars have a lot of **mass**, resulting in a lot of gravitational pull. But they also have a lot of outward pressure from their heat, which keeps them plumped-up like a balloon or a bubble under water. This determines their **volume** and their **density**.

The strength of an object's gravity is determined both by its mass and its density. Dense objects have strong gravitational pull near them. Most black holes probably have no more mass than do many stars. The force of their gravitational attraction is caused by their density. In fact, the extremely strong gravitational force near a black hole is so great that even light is pulled down into the black hole. This only occurs in their immediate vicinity, however, so one myth about black holes is false: they don't threaten to gobble up everything in the universe.

How dense are they? When a star runs out of fuel, the pressure that keeps it a nice, big ball is lost, and it collapses very quickly! Several things could happen next, depending on the details. One possibility is that the core of the dead star becomes so compact that its gravity overpowers the very structure of the matter that it is made of. Atoms, the cores of atoms (also known as **nuclei**), and even the particles that the nuclei are made of are crushed much like a stack of cardboard boxes in a trash compactor. The "stuff" of the soon-to-be black hole is crushed away into, essentially, "nothing." It becomes a singularity which at present, is beyond the ability of our science and math to fully describe. A singularity has mass, but takes up zero space; therefore it has infinite density! There is a simple example of a purely mathematical singularity (one that's just a non-physical idea). Get out a calculator, punch in any number, and then divide it by zero. Your calculator doesn't know what to make of the answer.



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If black holes are so black, how could we ever see one to know that they really exist? It's true that we can never see this singularity directly. No light can ever escape from a ball of some size around the singularity. At this **event horizon**, the escape velocity is greater than the speed of light, so even light can't come out. Atoms of gas and dust from space (or a conveniently located nearby star) experience more pull on their side nearest the black hole than they do on their farthest side. This is what's called a **tidal force**, as in the tides in the oceans of our Earth. The strength of gravity is increasing so fast as matter falls near a black hole that these tidal forces rip it apart. This, and the violent rubbing together of the torn-up pieces, makes the doomed gas and dust very hot. They emit a lot of energy that we can detect (**x-rays**, **gamma rays**), since they are not yet at the singularity. Astronomers have detected several good examples of this radiation, so they believe they have evidence that black holes really exist.