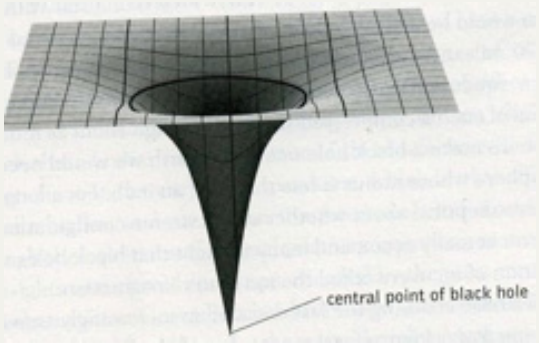
Cornell University Professor Saul Teukolsky studies black holes and neutron stars. Neutron stars, like black holes, are extremely dense objects that are formed after a large star dies. They are not quite as massive or as small as black holes, however (a neutron star is not a singularity). Teukolsky's research group is currently writing software (computer code) that will allow supercomputers to simulate black holes and neutron stars. This simulation will allow astrophysicists to "experiment" with black holes, since keeping a black hole in a laboratory would obviously not be practical!

Much of current astrophysics research centers around searching for what are called "gravitational waves." Have you ever heard of "space-time?" Space-time, as the name suggests, is the combination of space and time into one entity. Einstein predicted that gravity works by bending space-time—in other words, heavy objects create dents in the "fabric" of space-time.

Einstein also predicted that gravity causes ripples in space-time (gravitational waves) that travel through space and transport energy. Scientists think that the best way to discover these gravitational waves is to study black holes, especially binary systems of two black holes that orbit each other, since incredibly massive objects would create very powerful gravitational waves.



Black Holes bend spacetime so much that they create a bottomless pit (Image by UniverseReview).

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Peering into a black hole...

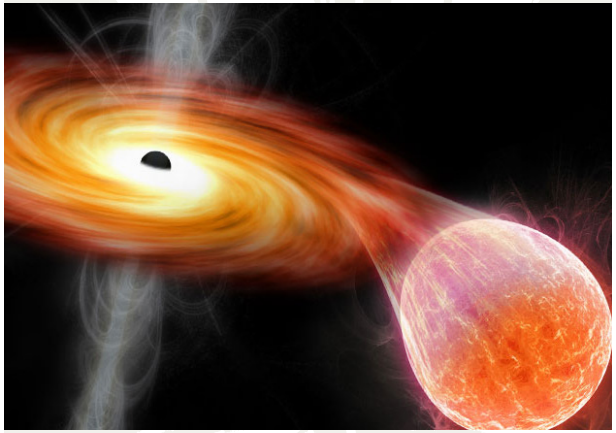


Image credit: Markus Hammonds, Discovery.com

...don't fall in!

HELPING TO FURTHER

PUBLIC UNDERSTANDING

OF PHYSICS CONCEPTS

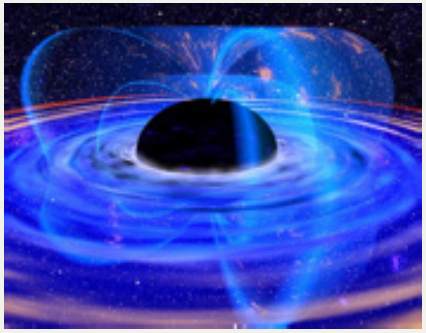
Black Holes!

Have you ever seen a black hole? Of course not! They are invisible! Black holes are formed when a very massive star dies in a huge supernova explosion and then collapses into a small, dense core. Black holes are so incredibly massive that nothing can escape from their gravity—not even light. Because no light can come out of them, they appear completely dark and invisible. They are also very small, because all of a black hole's mass is pulled in towards its center due to its powerful gravity. In other words, black holes effectively squish themselves. As a result, a black hole is an extremely small point with a humongous amount of mass. This is called a "singularity."

But why can't light escape from a black hole? You have seen again and again that no matter how hard you throw a ball into the air it will always come back to the ground due to the earth's gravity. But what if you wanted to go to the moon for your summer vacation? It turns out there is a minimum speed required to escape from the earth. If you were able to throw a ball at that minimum speed or greater, it would continue to fly into the air until it left the earth. This minimum speed is called the "escape velocity." The more massive the planet or object is, the greater the escape velocity required to overcome its gravity. For example, the escape velocity for the Sun is much greater than that for the earth.

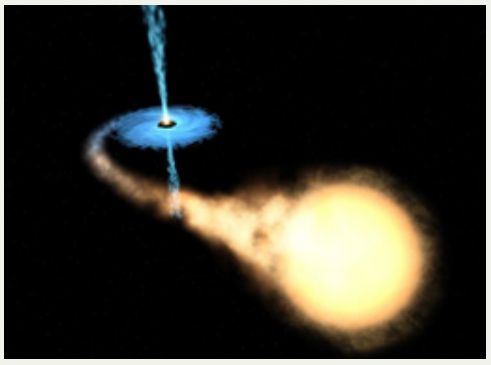
What happens when the escape velocity is greater than or equal to the speed of light (approximately 3 x 108 meters per second)? Then nothing, not even light, can escape from the object, and the body must be so incredibly massive that it is a black hole. Remember that Einstein showed that nothing can ever go faster than the speed of light.

The "event horizon" is an imaginary sphere drawn around a black hole that marks the distance from the black hole at which the escape velocity is equal to the speed of light. If an object travels into and through the event horizon, it cannot escape, and it is no longer visible to observers outside the event horizon.



Artst's depiction of a black hole accumulating matter around it in an "accretion disk." (Image: NASA).

Since black holes are invisible, you may be wondering how scientists even know they exist. Even though we can't see them, we can observe the effects of their intense gravity on nearby stars. There are many binary systems in which a star orbits a black hole. The star's gases are gradually sucked in by the black hole's gravity. The gases swirl around the black hole, forming what is called an "accretion disk." Because of the black hole's strong gravity, these gases become incredibly hot and send out very powerful X-rays. Scientists search for these X-rays to find black holes. Also, the companion star will appear teardrop shaped, because it is being pulled into the black hole from its side.



Gas from a companion star is sucked into a black hole, forming an "accretion disc." (Image: NASA).

So what would happen to you if you were sucked into a black hole? Well, nobody really knows, but I wouldn't recommend it! If we assume that the ordinary laws of physics continue to work behind the event horizon, we can predict some very strange things! Of course, in our world, you can move around in space by exerting effort. If you want to leave a room, you use the energy from your food to move your leg muscles and walk out. On the other hand, you have no control over your "motion" through time. Time continues to move forward whether you like it or not! But this may actually be reversed in a black hole! A person falling into a black hole cannot change his or her direction of motion. He/she will always continue to fall towards the singularity. With effort, however, the person could potentially change his/her "position" in time. In other words, black holes might actually be time machines!

The Milky Way galaxy (Image by Nick Risinger).

Scientists continue to learn more about these mysterious objects, since so much about them is still unknown. Did you know that there is a super-massive black hole at the center of our galaxy? In fact, there are black holes at the centers of almost every galaxy scientists have observed! The black hole at the center of the Milky Way may have become so incredibly massive because of collisions between galaxies. As galaxies collide, their central black holes combine, and a new, larger galaxy is formed. Our Milky Way home may actually be the result of many collisions between smaller galaxies!