BLACK HOLES

American physicist John Archibald Wheeler first coined the term "black hole" in 1967. Before the adoption of the term by Wheeler, the objects now known as black holes were referred to as frozen stars, dark stars, or collapsed stars. Black holes come in all sizes. Stellar black holes are the result of massive stars dying. Supermassive black holes are believed to have been created during the early Universe. The exact mechanism by which they were created is under debate. Some scientists believe in the existence of mini-black holes that were created at the same time as the Universe. This type of black hole, they maintain, is the approximate size of an atom yet has the mass of a large mountain. No matter what the size of a black hole, they all share a common characteristic; not even light can escape their gravitational pull. Though black holes have probably been around since the Universe began, only recently have we begun to learn in-depth information about them. In the last few decades astronomers began to look at the Universe in the radio, infrared, ultraviolet, X-ray, and gamma-ray regions of the electromagnetic spectrum and have been able to gather much more black hole data.

STELLAR BLACK HOLES

Astronomers suspect that most black holes are produced when massive stars (at least 8-10 times the Sun's mass) reach the end of their lifecycle. Inside a star, gravity tries to pull matter closer together. While a star is glowing, it is consuming its fuel through a nuclear process known as fusion. It radiates not only light, but heat as well. The pressure of the heated gases pushing outward balances the force of gravity pulling inward. Once the star's nuclear fuel has been depleted, the star becomes unstable and the core implodes causing the outer shell to explode in a supernova. If the remnant core that remains after the supernova is less than 3 solar masses, gravity compresses the electrons and protons so that neutrons form. The pressure of neutrons in contact with each other counteracts the forces of gravity. This stable core, which is now composed almost entirely of neutrons, forms a neutron star. Neutron stars possess tremendous mass and consequently have a very powerful gravitational pull. If the remnant left after the supernova is greater than 3 times the Sun's mass, not even the neutron pressure can counteract gravity and the remaining material will continue to contract. The remnant collapses to the point of essentially zero volume (yet it has infinite density!). This creates a mathematical singularity. A singularity resides in the center of all black holes.

A spherical region known as the event horizon marks what scientists call the “boundary” of a black hole. It is given this name because information about events which occur inside this region can never reach us. The distance from the singularity to the event horizon is known as the Schwarzschild radius, after the German physicist who predicted the existence of a "magic sphere" around a very dense object. Inside the region, he theorized, gravity would be so powerful that nothing could escape from it, i.e., the gravitational pull would be so strong that the velocity necessary to escape the pull is unobtainable. A black hole has such an enormous concentration of mass in such a small volume that in order to escape from it, an object would have to be moving at a speed greater than the speed of light. At this time we know of nothing that can attain the necessary velocity.

Remember that a stellar black hole was once a star. Most stars have a companion star to which they are bound in a binary system. This nearby companion can be a source of material on which the black hole "feeds". Matter can be pulled off the companion in large swirling streams of hot gas that spiral toward the black hole as a fast moving incandescent whirlpool known as an accretion disk. As the matter in the disk falls closer to the black hole, it heats up and gives off radiation such as X-rays. By measuring the motion and radiation from an accretion disk, astronomers are able to infer the presence and mass of the black hole. When all of the material in the accretion disk has been consumed, the disk disappears and the black hole is virtually undetectable. Stars and planets at a safe distance from the black hole's event horizon will not be pulled in toward the black hole. They will instead orbit the black hole just as the planets orbit the Sun in our solar system. The gravitational force on stars and planets orbiting a black hole is the same as when the black hole was a normal star.

SUPERMASSIVE BLACK HOLES

Supermassive black holes have masses comparable to those of a typical galaxy. These masses range anywhere from 10 billion to 100 billion of our Suns. Supermassive black holes tend to be in the centers of galaxies, creating what are called Active Galactic Nuclei (AGNs). An AGN emits more energy than would be expected from a typical galactic nucleus. The answer as to why this is so lies in the presence of the supermassive black hole in the galactic center. In some AGN, the massive black hole and its accretion disk somehow produce outward-moving streams of particles that are projected away perpendicular to the disk. These streams are known as jets and have the power to accelerate electrons almost to the speed of light. This produces gamma-rays that can be detected by gamma-ray observatories. The most powerful AGNs in our Universe are called quasars. We have been able to detect quasars that reside 15 billion light-years away. Scientists believe that the study of quasars will provide information about the Universe during the time of early galaxy formation.