BLACK HOLES: THE OTHER SIDE OF INFINITY

Deep in the middle of our Milky Way galaxy lies an object made famous by science fiction—a supermassive black hole. Scientists have long speculated about the existence of black holes. German astronomer Karl Schwarzschild theorized that black holes form when massive stars collapse. The resulting gravity from this collapse would be so strong that the matter would become more and more dense. The gravity would eventually become so strong that nothing, not even radiation moving at the speed of light, could escape. Schwarzschild's theories were predicted by Einstein and then borne out mathematically in 1939 by American astrophysicists Robert Oppenheimer and Hartland Snyder.

WHAT EXACTLY IS A BLACK HOLE?

First, it's not really a hole! A black hole is an extremely massive concentration of matter, created when the largest stars collapse at the end of their lives. Astronomers theorize that a point with infinite density—called a singularity—lies at the center of black holes.

SO WHY IS IT CALLED A HOLE?

Albert Einstein's 1915 General Theory of Relativity deals largely with the effects of gravity, and in essence predicts the existence of black holes and singularities. Einstein hypothesized that gravity is a direct result of mass distorting space. He argued that space behaves like an invisible fabric with an elastic quality. Celestial bodies interact with this "fabric" of space-time, appearing to create depressions termed "gravity wells" and drawing nearby objects into orbit around them. Based on this principle, the more massive a body is in space, the deeper the gravity well it will create. Therefore, an object with enormous mass but infinitely small size would create a bottomless pit—a black hole.

CAN A BLACK HOLE SUCK US IN?

A black hole is not like a vacuum, sucking in everything nearby—though it is often compared to one. It is better compared to the relentless force of a waterfall, harder to resist the closer you approach. A black hole's gravity is so strong that anything passing close to it is affected by its strong gravitational attraction. Astronomers theorize that because of this very strong gravity, strange things happen near black holes. They believe that time slows down, and space becomes infinitely warped. The laws of physics, as we know them, would cease to exist.

WHAT IS SCIENCE FICTION VS. SCIENCE FACT?

Einstein's theories infer that tubes, or tunnels, might exist within the strange world of black holes. First named EinsteinRosen bridges, and later called wormholes, these invisible passageways predicted connections between different regions of space-time. We now know that these wormholes are too unstable to exist, but even if they did, wormholes could not support human "time travel" as science fiction writers would imagine it. The enormous gravity associated with black holes and wormholes

would rip apart any matter that came near it. So black holes can't be used for time travel the way they are in movies.

WHAT DOES A BLACK HOLE LOOK LIKE?

Because of their nature, black holes cannot be seen. Black holes do not have a physical surface. Instead, they begin at a central point of singularity and continue out to a spherical boundary. The event horizon is the "dividing line," beyond which anything that crosses cannot escape. Outside the event horizon, material falling into the black hole collects into a band of hot gas and dust called an accretion disk. Narrow jets of gas shoot out from the accretion disk, emitting detectable radiation. The physical size of black holes is measured with a special unit called the Schwarzschild radius. This radius is defined to be the distance from the point of singularity to the event horizon. The larger the Schwarzschild radius, the more massive the black hole.

IF WE CAN'T SEE THEM, HOW DO WE KNOW THEY'RE OUT THERE?

Black holes—by definition—cannot be seen directly. The only way to find a black hole is to look for its effects on other objects in space around it. Observation of gas jets, radiation, rapidly orbiting objects, and other methods are used to indirectly detect the locations of black holes. Astronomers have observed evidence this way for dozens of black holes in our own galaxy. Scientists who study black holes focus on how other bodies are affected in the space around them. The first approach to locating black holes involved observing binary star systems. In these systems, two stars orbit each other, moving in generally predictable ways because of the gravitational attraction between the stars. Scientists knew that if they saw a single star moving as if there were a massive object nearby, but with no other star in evidence, then its invisible companion could be a black hole. Scientists also realized that if the invisible object in a binary system was a black hole, there would be huge gravitational force associated with it. The gas from the visible star—or any nearby gas and dust—would spiral at very high speeds around the black hole before disappearing into it. This action would create enormous heat and X-ray radiation, which could be detected through observations. In the 1970s, scientists took great interest in gamma-ray bursts as a way to detect black holes. One hypothesis suggested that a binary system consisting of a normal star and a black hole creates gamma-ray bursts when the black hole finally consumes all of its companion star's material. Another widely-accepted theory suggests that gamma rays are released when black holes or neutron stars collide. Gamma-ray bursts are probably also released when a giant star collapses and a black hole is formed

ARE ALL BLACK HOLES THE SAME?

A stellar mass black hole forms when a star at least eight times the mass of our Sun explodes at the end if its life in a blaze of glory called a supernova. While the outer layers shoot outward, the inner parts known as the core collapse down … and down … and down. The core's mass is collapsed enough to that it becomes a black hole, so dense that not even light can escape its gravity. Scientists estimate there are probably tens of millions of stellar mass black holes, just in our own galaxy. Another type of black holes is highlighted in Black Holes: The Other Side of Infinity: a supermassive black hole. These huge black holes form at the cores of galaxies, where they grow larger and larger, feeding on the gas

and dust at the center. We know our own Milky Way galaxy has a supermassive black hole—sometimes called Sagittario—several millions of times the mass of our own Sun. Scientists theorize that all large galaxies have a central supermassive black hole, and that the central black hole and the evolution of the galaxy are intrinsically tied together in ways scientists are still discovering. Even though they are large, supermassive black holes still can't be seen directly. In order to measure the mass of these supermassive black holes, scientists observe the speeds at which matter orbits them. Using this data, they can deduce how massive the central object must be to produce the velocities observed. In recent years, scientists have intensified their study of the cores of other galaxies, and their efforts have revealed central black holes potentially in excess of 1.2 billion solar masses.