Concept of Black Hole

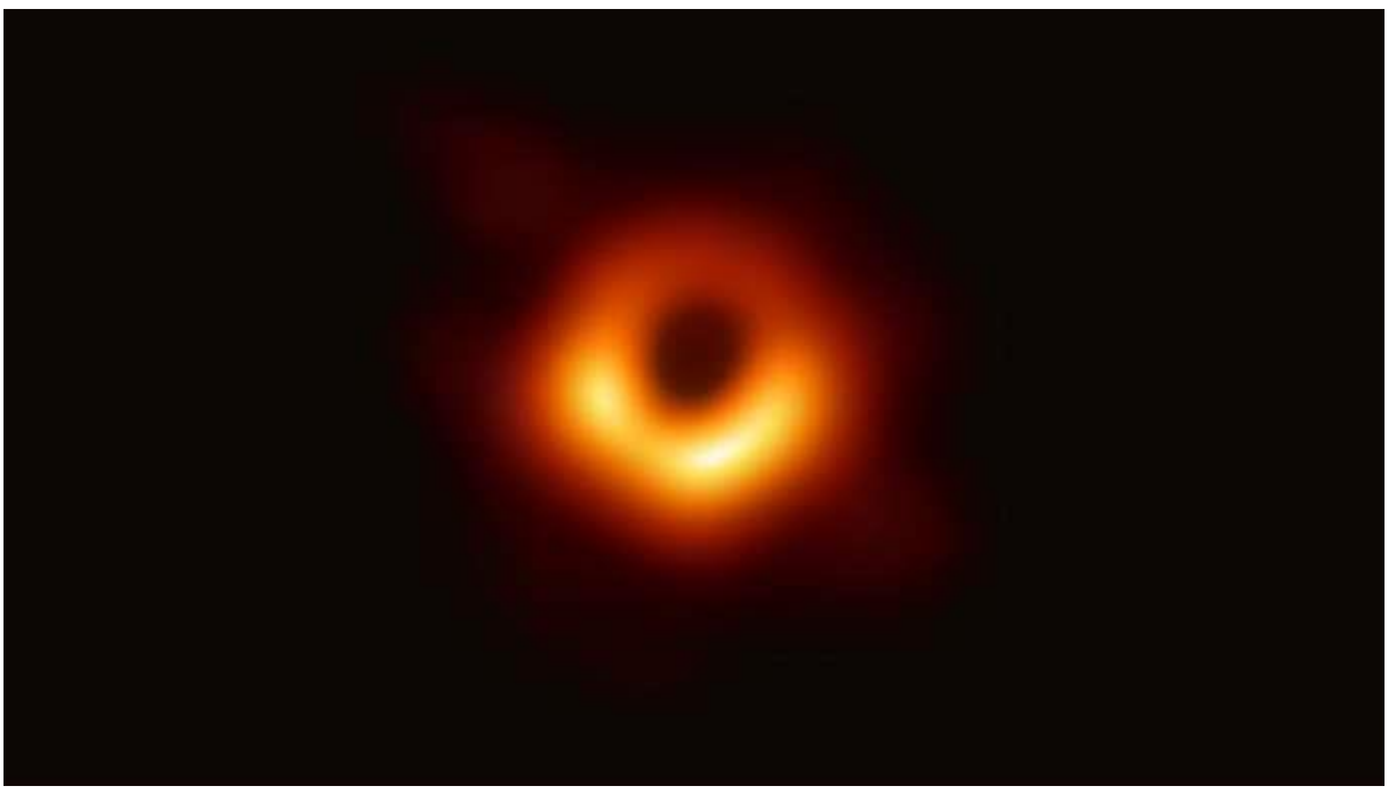
By

Dr.Vinod Kumar Singh

Associate Professor Physics K .S. Saket P G College Ayodhya

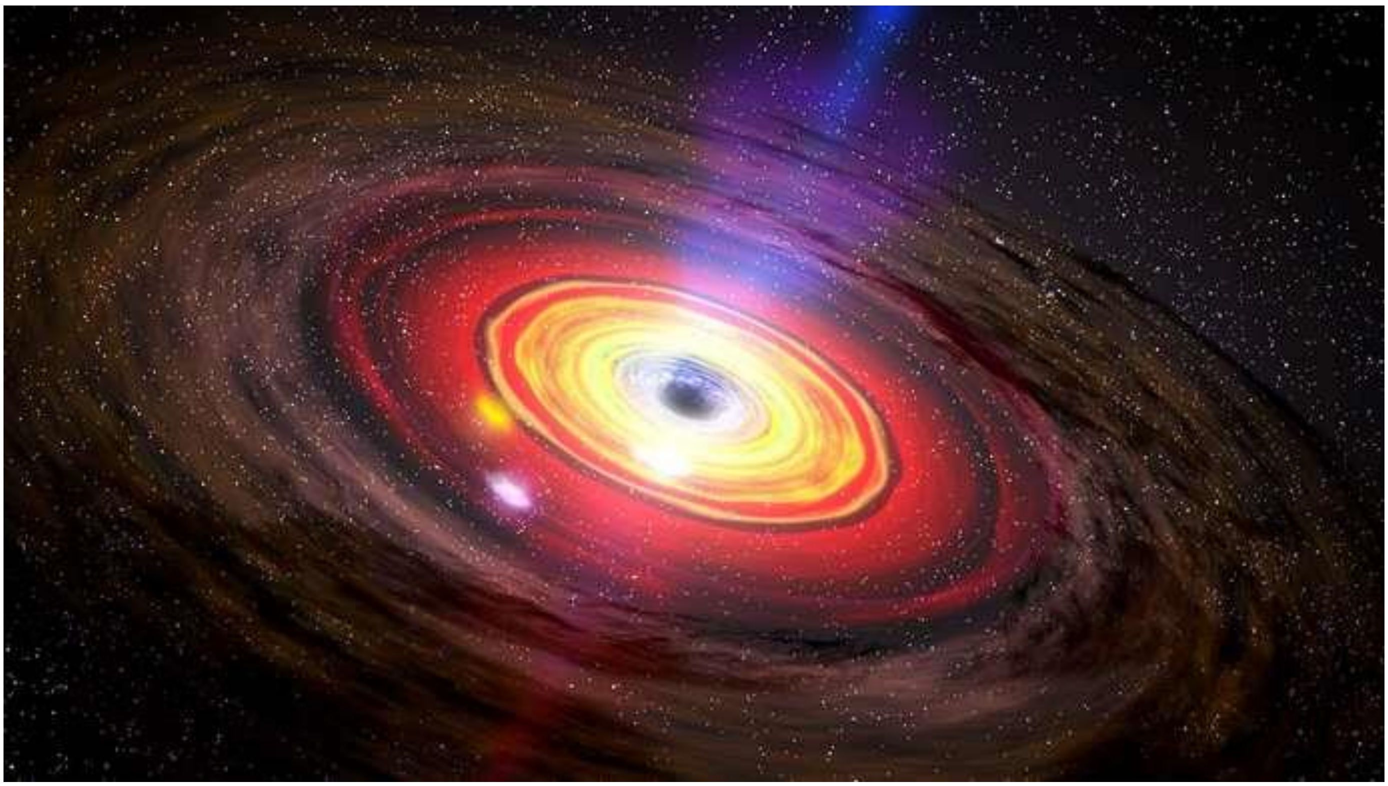
Email: vks423272@gmail.com

Black hole, cosmic body of extremely intense gravity from which nothing, not even light, can escape. A black hole can be formed by the death of a massive star. When such a star has exhausted the internal thermonuclear fuels in its core at the end of its life, the core becomes unstable and gravitationally collapses inward upon itself, and the star's outer layers are blown away. The crushing weight of constituent matter falling in from all sides compresses the dying star to a point of zero volume and infinite density called the singularity.



black hole in M87

Black hole at the centre of the massive galaxy M87, about 55 million light-years from Earth, as imaged by the Event Horizon Telescope (EHT). The black hole is 6.5 billion times more massive than the Sun. This image was the first direct visual evidence of a supermassive black hole and its shadow. The ring is brighter on one side because the black hole is rotating, and thus material on the side of the black hole turning toward Earth has its emission boosted by the Doppler effect. The shadow of the black hole is about five and a half times larger than the event horizon, the boundary marking the black hole's limits, where the escape velocity is equal to the speed of light.



black hole

Artist's rendering of matter swirling around a black hole.

Details of the structure of a black hole are calculated from Albert Einstein's general theory of relativity. The singularity constitutes the centre of a black hole and is hidden by the object's "surface," the event horizon. Inside the event horizon the escape velocity (i.e., the velocity required for matter to escape from the gravitational field of a cosmic object) exceeds the speed of light, so that not even rays of light can escape into space. The radius of the event horizon is called the Schwarzschild radius, after the German astronomer Karl Schwarzschild, who in 1916 predicted the existence of collapsed stellar bodies that emit no radiation. The size of the Schwarzschild radius is proportional to the mass of the collapsing star. For a black hole with a mass 10 times as great as that of the Sun, the radius would be 30 km (18.6 miles).

Only the most massive stars—those of more than three solar masses—become black holes at the end of their lives. Stars with a smaller amount of mass evolve into less compressed bodies, either white dwarfs or neutron stars.

Black holes usually cannot be observed directly on account of both their small size and the fact that they emit no light. They can be "observed," however, by the effects of their enormous gravitational fields on nearby matter. For example, if a black hole is a member of a binary star system, matter flowing into it from its companion becomes intensely heated and then radiates X-rays copiously before entering the event horizon of the black hole and disappearing forever. One of the component stars of the binary X-ray system Cygnus X-1 is a black hole. Discovered in 1971 in the constellation Cygnus, this binary consists of a blue supergiant and an invisible companion 14.8 times the mass of the Sun that revolve about one another in a period of 5.6 days.

Some black holes apparently have nonstellar origins. Various astronomers have speculated that large volumes of interstellar gas collect and collapse into supermassive black holes at the centres of quasars and galaxies. A mass of gas falling rapidly into a black hole is estimated to give off more than 100 times as much energy as is released by the identical amount of mass through nuclear fusion. Accordingly, the collapse of millions or billions of solar masses of interstellar gas under gravitational force into a large black hole would account for the enormous energy output of quasars and certain galactic systems.

dust disk around black hole in NGC 4261

Hubble Space Telescope image of an 800-light-year-wide spiral-shaped disk of dust fueling a massive black hole in the centre of galaxy NGC 4261, located 100 million light-years away in the direction of the constellation Virgo.

One such supermassive black hole, Sagittarius A*, exists at the centre of the Milky Way Galaxy. Observations of stars orbiting the position of Sagittarius A* demonstrate the presence of a black hole with a mass equivalent to more than 4,000,000 Suns. (For these observations, American astronomer Andrea Ghez and German astronomer Reinhard Genzel were awarded the 2020 Nobel Prize for Physics.) Supermassive black holes have been detected in other galaxies as well. In 2017 the Event Horizon Telescope obtained an image of the supermassive black hole at the centre of the M87 galaxy. That black hole has a mass equal to six and a half billion Suns but is only 38 billion km (24 billion miles) across. It was the first black hole to be imaged directly. The existence of even larger black holes, each with a mass equal to 10 billion Suns, can be inferred from the energetic effects on gas swirling at extremely high velocities around the centre of NGC 3842 and NGC 4889, galaxies near the Milky Way.

The existence of another kind of nonstellar black hole was proposed by the British astrophysicist Stephen Hawking. According to Hawking's theory, numerous tiny primordial black holes, possibly with a mass equal to or less than that of an asteroid, might have been created during the big bang, a state of extremely high temperatures and density in which the universe originated 13.8 billion years ago. These so-called mini black holes, like the more massive variety, lose mass over time through Hawking radiation and disappear. If certain theories of the universe that require extra dimensions are correct, the Large Hadron Collider could produce significant numbers of mini black holes.

Supermassive black holes — the birth of giants

Small black holes populate the universe, but their cousins, supermassive black holes, dominate. These enormous black holes are millions or even billions of times as massive as the sun, but are about the same size in diameter. Such black holes are thought to lie at the center of pretty much every galaxy, including the Milky Way.

Scientists aren't certain how such large black holes spawn. Once these giants have formed, they gather mass from the dust and gas around them, material that is plentiful in the center of galaxies, allowing them to grow to even more enormous sizes.

Supermassive black holes may be the result of hundreds or thousands of tiny black holes that merge together. Large gas clouds could also be responsible, collapsing together and rapidly accreting mass. A third option is the collapse of a stellar cluster, a group of stars all falling together. Fourth, supermassive black holes could arise from large clusters of dark matter. This is a substance that we can observe through its gravitational effect on other objects; however, we don't know what dark matter is composed of because it does not emit light and cannot be directly observed.

Intermediate black holes — stuck in the middle

Scientists once thought that black holes came in only small and large sizes, but recent research has revealed the possibility that midsize, or intermediate, black holes (IMBHs) could exist. Such bodies could form when stars in a cluster collide in a chain reaction. Several of these IMBHs forming in the same region could then eventually fall together in the center of a galaxy and create a supermassive black hole.

In 2014, astronomers found what appeared to be an intermediate-mass black hole in the arm of a spiral galaxy.

"Astronomers have been looking very hard for these medium-sized black holes," study co-author Tim Roberts, of the University of Durham in the United Kingdom, said in a statement. "There have been hints that they exist, but IMBHs have been acting like a long-lost relative that isn't interested in being found."

Newer research, from 2018, suggested that these IMBHs may exist in the heart of dwarf galaxies (or very small galaxies). Observations of 10 such galaxies (five of which were previously unknown to science before this latest survey) revealed X-ray activity — common in black holes — suggesting the presence of black holes of from 36,000 to 316,000 solar masses. The information came from the Sloan Digital Sky Survey, which examines about 1 million galaxies and can detect the kind of light often observed coming from black holes that are picking up nearby debris.

What do black holes look like?

Black holes have three "layers": the outer and inner event horizon, and the singularity.

The event horizon of a black hole is the boundary around the mouth of the black hole, past which light cannot escape. Once a particle crosses the event horizon, it cannot leave. Gravity is constant across the event horizon.

The inner region of a black hole, where the object's mass lies, is known as its singularity, the single point in space-time where the mass of the black hole is concentrated.

Scientists can't see black holes the way they can see stars and other objects in space. Instead, astronomers must rely on detecting the radiation black holes emit as dust and gas are drawn into the dense creatures. But supermassive black holes, lying in the center of a galaxy, may become shrouded by the thick dust and gas around them, which can block the telltale emissions.

Sometimes, as matter is drawn toward a black hole, it ricochets off the event horizon and is hurled outward, rather than being tugged into the maw. Bright jets of material traveling at near-relativistic speeds are created. Although the black hole remains unseen, these powerful jets can be viewed from great distances.

The Event Horizon Telescope's image of a black hole in M87 (released in 2019) was an extraordinary effort, requiring two years of research even after the images were taken. That's because the collaboration of telescopes, which stretches across many observatories worldwide, produces an astounding amount of data that is too large to transfer by internet.

With time, researchers expect to image other black holes and build up a repository of what the objects look like. The next target is likely Sagittarius A*, which is the black hole in the center of our own Milky Way galaxy. Sagittarius A* is intriguing because it is quieter than expected, which may be due to magnetic fields smothering its activity, a 2019 study reported. Another study that year showed that a cool gas halo surrounds Sagittarius A*, which gives unprecedented insight into what the environment around a black hole looks like.

Shining light on binary black holes

In 2015, astronomers using the Laser Interferometer Gravitational-Wave Observatory (LIGO) detected gravitational waves from merging stellar black holes.

"We have further confirmation of the existence of stellar-mass black holes that are larger than 20 solar masses — these are objects we didn't know existed before LIGO detected them," David Shoemaker, the spokesperson for the LIGO Scientific Collaboration (LSC), said in a statement. LIGO's observations also provide insights about the direction a black hole spins. As two black holes spiral around one another, they can spin in the same direction or in the opposite direction.

There are two theories on how binary black holes form. The first suggests that the two black holes in a binary form at about the same time, from two stars that were born together and died explosively at about the same time. The companion stars would have had the same spin orientation as one another, so the two black holes left behind would as well.

Under the second model, black holes in a stellar cluster sink to the center of the cluster and pair up. These companions would have random spin orientations compared to one another. LIGO's observations of companion black holes with different spin orientations provide stronger evidence for this formation theory.

"We're starting to gather real statistics on binary black hole systems," said LIGO scientist Keita Kawabe of Caltech, who is based at the LIGO Hanford Observatory. "That's interesting because some models of black hole binary formation are somewhat favored over the others even now, and in the future, we can further narrow this down."