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BLACK HOLE: A MYSTERY IN THE UNIVERSE

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Abstract : Black holes are enigmatic cosmic objects that continue to intrigue scientists and capture the imagination of the general public. This article provides an in-depth exploration of black holes, covering their formation, properties, and significance in the universe. We delve into the mechanisms behind black hole formation, including the gravitational collapse of massive stars and the mergers of compact stellar remnants. The properties of black holes, such as mass, spin, and electric charge, are discussed, along with the concept of the event horizon. We examine observational evidence for black holes, including the detection of accretion disks and the groundbreaking discovery of gravitational waves. Theoretical aspects, including Hawking radiation and its implications, are also explored. Furthermore, we highlight the role of black holes in galactic evolution, influencing star formation and triggering phenomena like quasars. The article concludes by addressing the remaining mysteries and future directions in black hole research, inviting further exploration of these fascinating cosmic entities.

***Index Terms* – Black Holes, Wormholes, Cosmology, Theory of Relativity.**

1. INTRODUCTION

HISTORICAL BACKGROUND

The term ‘black hole’ was first introduced by an American physicist J.A. Wheeler because everything, including the light wave and any electromagnetic wave, that went into its zone was not able to get out, and consequently, it appeared as black. In the 18th century, Laplace and Michell hypothesized for the first time that there exists an astronomical body with a massive mass that was able to cause an escape velocity greater than the speed of light in a vacuum for which no light was able to resist the strongest gravitational force generated by this celestial body to escape from it. The idea of a so massive body that even light could not escape was first introduced by John Michell in a letter written to Henry Cavendish in 1783, and in 1796, a mathematician Pierre-Simon Laplace promoted the same idea in the first and second editions of his book ‘Exposition du système du Monde’.

This hypothesis was supported by the corpuscular theory of light but not by the wave theory of light. On this account, the concept of a black hole was abandoned at that time. But some months after the publication of the General theory of relativity by the great Einstein in 1916, the black hole again became famous because the theory of general relativity predicted that a sufficiently huge and compact mass can deform space-time to form a black hole. In 1919, Eddington on the occasion of a total solar eclipse, measured the deflection of light by the sun coming from a remote star when light passed near the sun. He deduced that in place of the sun, a sufficiently massive celestial mass should have produced a great deflection of light that it could not able to pass by. The first modern solution of the general theory of relativity that would suggest a black hole was found by Karl Schwarzschild in 1916, although its interpretation as a region of space from which nothing can escape including light was first introduced by David Finkelstein in 1958. In 1916, Karl Schwarzschild calculated that the black hole should have possessed a huge mass because of its small radius (R=2×GM/C2, where G=Universal gravitational constant, M= Mass of the black hole, C= Speed of light in vacuum) and consequently to have an acceptable value of the radius, a very massive mass was necessary.

WHAT ARE BLACK HOLES?

Most people think that a black hole is a massive whirlpool in space, sucking in everything around it. But that is not the whole story. A black hole is a region in space where gravity is so strong that the escape velocity is faster than the speed of light. But what does it mean, exactly? Gravity is what keeps all the things on the earth, but it can be overcome anyway. If someone passes a coin up in the air, it will only go up little ways before the earth’s gravitational attraction slows down it and pulls it back to the earth. If the same is thrown a little harder, it goes faster and higher before coming back down. If someone could throw the coin hard enough with the velocity more than the escape velocity of the earth then the earth’s gravity could not slow it down enough to stop it. The coin would then escape from the earth. Thus, a black hole is a region in space with so much gravity that not even lights (the fastest thing around) can escape, hence the name. To an observer, it will just appear as a sphere of perfect lack. At the centre of a black hole is an object called a singularity, a point of zero size and infinite density. A black hole is an object for which nothing can have a high enough escape velocity to become free from it.

To reiterate, a black hole is a region in space where gravity is so incredibly strong that the escape velocity exceeds the speed of light. Escape velocity refers to the minimum velocity an object needs to overcome the gravitational pull of a celestial body and break free from its influence. On Earth, the escape velocity is approximately 11.2 kilometres per second (about 25,000 miles per hour). If an object attains a velocity greater than this, it can escape Earth's gravitational field. In the case of a black hole, the escape velocity surpasses the speed of light, which is the fastest speed at which information or any form of matter can travel. According to our current understanding of physics, nothing can exceed or even reach the speed of light. Therefore, if an object or particle ventures within the region known as the event horizon of a black hole, it is inevitably pulled towards the singularity, the central point of infinite density.

The singularity lies at the heart of a black hole and is a point of zero size and infinite density. It is a location where our understanding of physics reaches its limits, and our current theories fail to describe its nature accurately. The singularity represents a breakdown in the laws of physics as we know them, suggesting the need for a more comprehensive theory that unifies quantum mechanics and general relativity.

Advancements in technology and observational techniques have allowed scientists to study black holes indirectly. The development of gravitational wave detectors, such as the Laser Interferometer Gravitational-Wave Observatory and by measuring tiny distortions in spacetime caused by these mergers, we can confirm the existence of black holes and study their properties. The study of black holes also presents intriguing theoretical aspects. One of the most remarkable theoretical predictions is the phenomenon of Hawking radiation, proposed by physicist Stephen Hawking. According to this theory, black holes are not entirely black but emit particles and energy over time, leading to their gradual evaporation. This discovery challenged long-held beliefs about black holes as eternal cosmic traps and raised profound questions about the conservation of information. Black holes play a crucial role in shaping the evolution of galaxies. Supermassive black holes, which reside at the centres of most galaxies, regulate the growth of galaxies through their interactions with surrounding matter. They influence the formation of stars, trigger powerful phenomena such as quasars, and play a significant role in galactic mergers and the redistribution of mass and energy.

However, despite significant progress in our understanding of black holes, many mysteries remain. The nature of the singularity at the heart of black holes, the resolution of the information paradox, and the existence of hypothetical structures such as wormholes are among the unresolved questions that continue to challenge scientists.

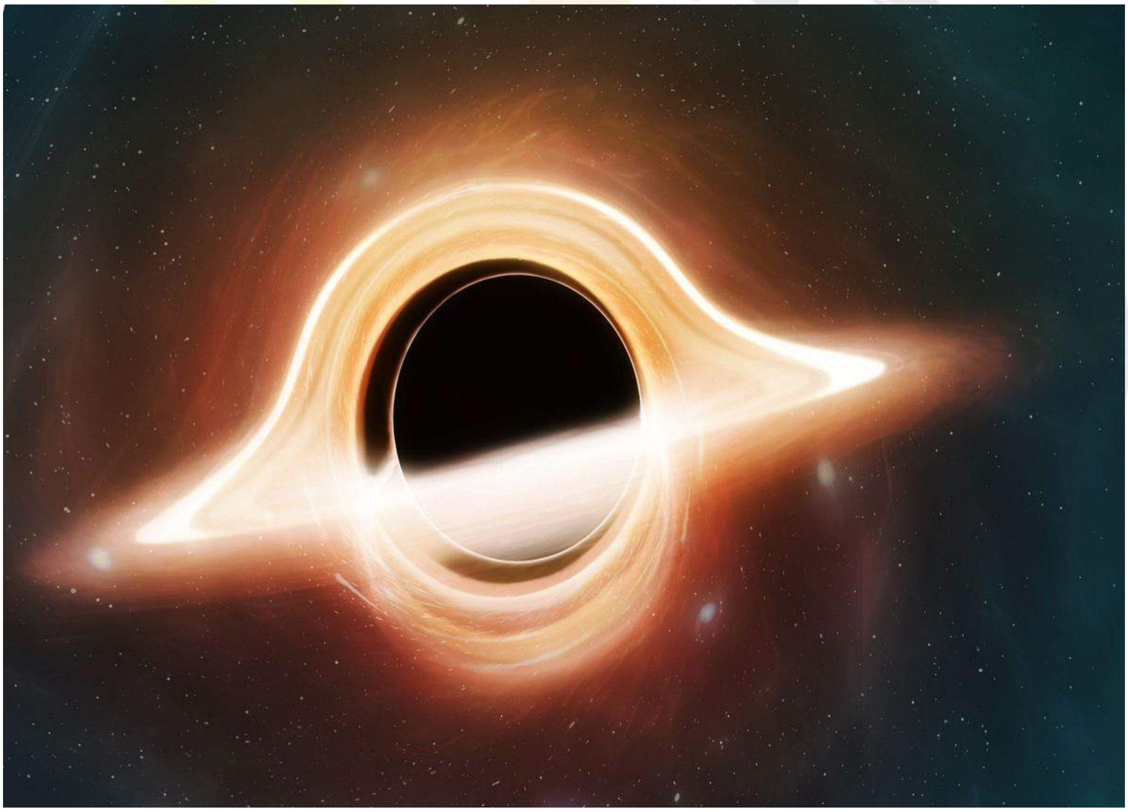

Fig 1: Image of the Black hole with Accretion disc and Hawking's Radiation

1.1 Different Types of Black Holes

Black holes come in different types based on their formation and properties.

Here are the main types of black holes:

1. Stellar Black Holes: Stellar black holes are formed when massive stars collapse under their own gravity after they exhaust their nuclear fuel. The gravitational collapse causes the star to implode, resulting in a highly dense core known as a black hole. Stellar black holes have a mass range of about a few times to tens of times that of our Sun. They are typically a few kilometres in size and have an extremely strong gravitational pull.

2. Intermediate-Mass Black Holes: Intermediate-mass black holes (IMBHs) have masses ranging from hundreds to thousands of times that of the Sun. Their formation is not yet fully understood, but they are thought to be created through the collision and merger of smaller black holes, or by the direct collapse of large gas clouds in the early universe. IMBHs are relatively rare and have been detected in the centres of some globular clusters and dwarf galaxies.

3. Supermassive Black Holes: Supermassive black holes (SMBHs) are the largest type of black holes, with masses ranging from millions to billions of times that of the Sun. They are found at the centres of most, if not all, massive galaxies, including our own Milky Way. The exact formation mechanisms of SMBHs are still being studied, but they are believed to grow over time by accreting vast amounts of matter from their surroundings, such as gas, dust, and even entire stars.

4. Primordial Black Holes: Primordial black holes are hypothetical black holes that are thought to have formed in the early universe, shortly after the Big Bang. They are different from the other types of black holes because they would have formed from extremely dense regions of matter in the early universe, rather than through the collapse of stars. Primordial black holes could have a wide range of masses, from microscopic to several times that of a star.

5. Miniature Black Holes: Miniature black holes are another hypothetical type of black hole. They are predicted by certain theories of physics, such as string theory, and are much smaller than stellar black holes. These black holes could have masses as small as a few grams or even less. However, their existence and observational evidence for them have not been confirmed.

CLASS OF BLACK HOLES	***Mass***	***Size***
Stellar Black Holes	~10 Solar Mass	~30km
Intermediate Black Holes	~10^3 Solar Mass	~10^3km ≈ R(Earth)
Supermassive Black Holes	~10^5 - 10^{10} Solar Mass	~0.001 - 400 AU
Primordial Black Holes	Varies (Hypothetical)	Varies (Hypothetical)
Miniature/Micro Black Holes	less than 1 gram	up to ~0.1 mm

Recently the Event Horizon Telescope (EHT) made a groundbreaking discovery in 2019 by capturing the first-ever direct image of a black hole. The black hole that was imaged is located at the centre of the galaxy Messier 87 (M87), and it is a supermassive black hole. The black hole in M87, known as M87* (pronounced M87-star), has a mass of about 6.5 billion times that of the Sun, making it one of the most massive black holes known to date. It resides about 55 million light-years away from Earth in the Virgo galaxy cluster.

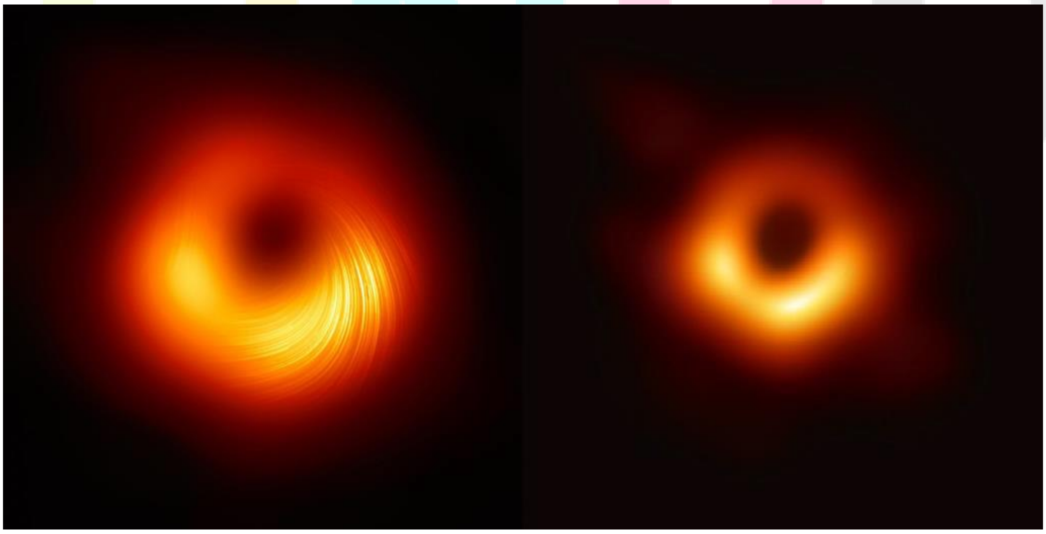

Fig 2: M87 Black hole image taken by Event-Horizon telescope in 2019

1.2 Formation of Black Holes

Naturally occurring black holes form when stars collapse into a single mass. Stars are very massive. Our nearest star, the sun, is roughly 1300000000 km wide and its weight is about 2×1030kg. Due to their enormous mass, they exert an extremely huge amount of gravitational force.

1. Stellar Evolution: A massive star is initially in a state of equilibrium between the inward gravitational force and the outward pressure from nuclear fusion. The force of gravity is given by the expression:

$$F_{gravity} = G \times (mass_{star} \times mass_{particle})/r^2$$

where G = 6.67428×10-11 M.K.S. unit is the gravitational constant, $mass_{star}$ is the mass of the star, $mass_{particle}$ is the mass of a particle within the star, and r is the distance from the centre of the star.

2. Nuclear Fuel Depletion: As the star consumes its nuclear fuel, fusion reactions start to decline, resulting in a decrease in the outward pressure. The gravitational force, however, remains strong. This leads to the core collapsing under its gravity.

3. Core Collapse: The collapsing core experiences an increase in density and temperature due to the compression of matter. The force of gravity continues to dominate, causing the core to shrink further. The radius of the collapsing core, denoted as decreases over time.

4. Neutron Star or Black Hole Formation: If the mass of the collapsing core is below the Chandrasekhar limit, which is approximately 1.4 times the mass of the Sun (1.4 solar masses), electron degeneracy pressure can counteract gravity, leading to the formation of a stable neutron star. The radius of the neutron star is determined by the equation:

$$R_{ns} = [\{h^2/ (20\ \pi\ mass_{ns} \times c)\} \times \{3/ (4\ \pi\ G\ \rho_{ns})\}]^{1/3}$$

where h is Planck's constant, is the mass of a neutron, c is the speed of light, G is the gravitational constant, and ρ_{ns} is the average density of the neutron star. However, if the collapsing core's mass exceeds the Chandrasekhar limit, electron degeneracy pressure is unable to prevent further collapse, and a black hole form. The radius of a black hole, often referred to as the Schwarzschild radius, is given by the equation:

$$R_{schwarzschild} = (2 \times G \times mass_{blackhole})/c2$$

5. Singularity Formation: Within the event horizon (Schwarzschild radius) of the black hole, lies the singularity, a point of infinite density and zero volume. The energy required to form the singularity is immense and can be calculated using Einstein's mass-energy equivalence equation:

$$E = mass_{blackhole} \times c2$$

where E is the energy associated with the black hole formation, $mass_{blackhole}$ is the mass of the black hole, and c is the speed of light.

Now the question arises if Our Sun can end up being a Black Hole?

The answer is no because our Sun has a mass of about 1 solar mass, which is significantly lower than the TOV limit. Therefore, it does not possess the mass required to undergo gravitational collapse and become a black hole. Instead, the eventual fate of our Sun is to go through the stages of stellar evolution, culminating in the formation of a white dwarf.

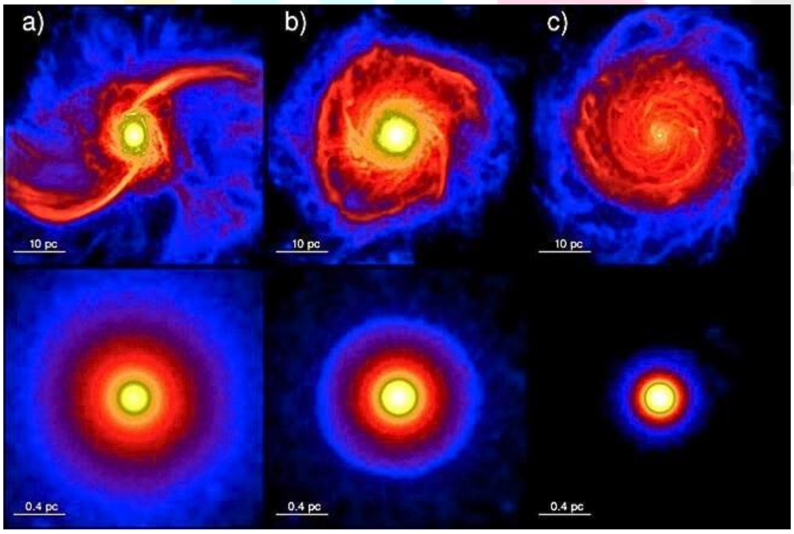

Fig 3: Formation of Supermassive Black Holes by colliding two Galaxies

1.3 Different Parts of a Black Hole

Black holes are extraordinary cosmic objects with distinct components that contribute to their unique nature. While our understanding of black holes is limited, we can identify several key parts or regions that play a role in their structure and behaviour. In this section, we will explore some of the different components of black holes.

1. Singularity: At the core of a black hole lies the singularity, a point of infinite density and zero volume. According to our current understanding, singularity is a region where the laws of physics, as we know them, break down. The concept of singularity arises from the mathematics of general relativity, but it is still a subject of active research and debate. The singularity is hidden beneath the event horizon and is inaccessible to direct observation.

2. Event Horizon: The event horizon is the boundary of a black hole, marking the point of no return. It is the region beyond which nothing, including light, can escape the gravitational pull of the black hole. Once an object crosses the event horizon, it is inevitably drawn toward the singularity. From an external observer's perspective, the event horizon appears as a spherical surface surrounding the black hole.

3. Accretion Disk: Around many black holes, particularly stellar black holes, and supermassive black holes, there can be an accretion disk. An accretion disk forms when matter, such as gas and dust, is drawn toward the black hole due to its immense gravitational pull. As the matter spirals inward, it gains energy and emits various forms of electromagnetic radiation, including X-rays and radio waves. The accretion disk can provide valuable information about the mass and activity of the black hole.

4. Photon Sphere: The photon sphere is an intriguing region surrounding a black hole. It is the orbit where photons (particles of light) can maintain a stable circular path due to the strong gravitational field. Photons that pass close to the photon sphere can be significantly affected by the black hole's gravity, causing their paths to bend or even become trapped in unstable orbits. This phenomenon contributes to the distorted appearance of light near a black hole.

5. Ergo-sphere: The ergo-sphere is a region just outside the event horizon of a rotating black hole. In this region, spacetime is dragged along with the black hole's rotation, creating a region where objects can gain energy and momentum from the black hole's rotation. The ergo-sphere plays a role in phenomena such as the extraction of energy from a spinning black hole through the Penrose process.

6. Jet: In certain cases, black holes can generate powerful jets of high-energy particles. These jets extend outward from the vicinity of the black hole, traveling at close to the speed of light. The exact mechanisms that drive jet formation are still under investigation, but they are thought to involve magnetic fields and the accretion of matter onto the black hole. These jets can have a significant impact on their surrounding environments and can be observed across the electromagnetic spectrum.

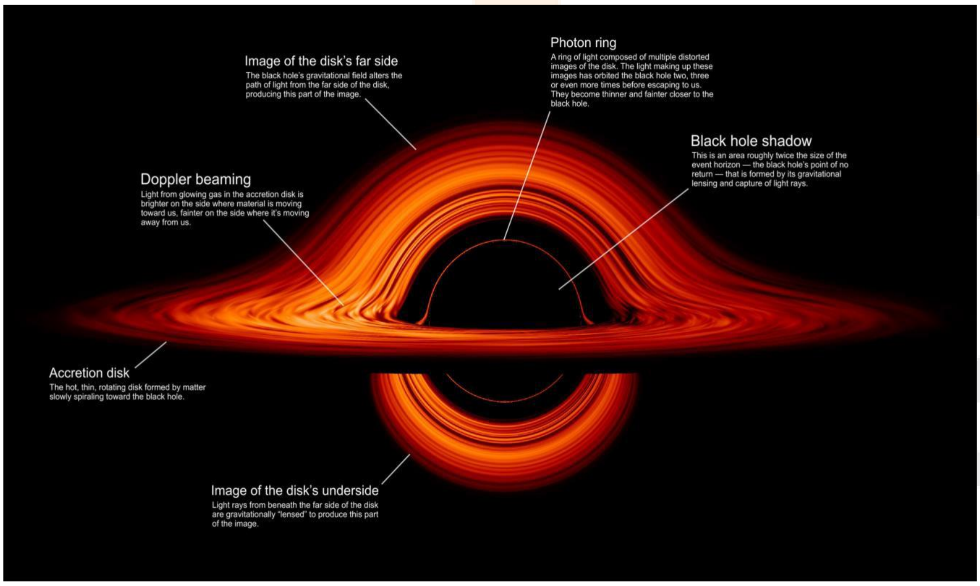

Fig 4: Parts of Black Holes

1.4 Can a Black Hole Suck Us?

The concept of a black hole "sucking" or "pulling" objects into it is a common way to describe the strong gravitational attraction near a black hole. However, it's important to understand the scientific explanation behind it. Black holes have an extremely powerful gravitational field due to their immense mass. According to Einstein's general theory of relativity, the curvature of spacetime around a massive object like a black hole causes other objects to follow curved paths when in the vicinity of the black hole. When an object, such as a planet or a spaceship, approaches a black hole, it experiences a gravitational force that becomes increasingly stronger as it gets closer to the black hole. This force is described by Newton's law of universal gravitation:

$$F_{gravity} = (G \times mass_{blackhole} \times mass_{object}) / r^2$$

where is the gravitational force, G is the gravitational constant, $\text{mass}_{\text{blackhole}}$ is the mass of the black hole, $\text{mass}_{\text{object}}$ is the mass of the object, and r is the distance between the object and the black hole. If an object gets too close to a black hole, there is a specific point called the event horizon beyond which, according to our current understanding, it cannot escape. The event horizon represents the boundary beyond which the gravitational pull of the black hole is so strong that not even light can escape from it. However, it's important to note that black holes don't actively "suck" or "pull" objects towards them like a vacuum cleaner. Instead, objects near a black hole follow their natural paths in spacetime, which can result in them falling into the black hole if they cross the event horizon.

For objects like planets or spaceships, the gravitational force from a black hole becomes increasingly stronger as they get closer, making it difficult for them to escape if they pass the event horizon. This is why we often describe objects falling into a black hole as being "pulled" or "sucked in." It's worth noting that the extreme conditions near black holes can have powerful tidal forces, which can stretch and deform objects that come close. These tidal forces can be highly destructive, tearing apart objects before they cross the event horizon.

1.5 What happen when We fall into a Black Hole?

If someone were to fall into a black hole, the experience would be quite different depending on their position relative to the event horizon. Let's explore the hypothetical scenario of an observer falling into a black hole:

1. Approaching the Event Horizon: As an observer falls towards a black hole, they would experience the increasing gravitational pull. Time dilation would occur, meaning that time would appear to pass more slowly for the falling observer compared to an observer far away from the black hole. This effect becomes more pronounced as the observer approaches the event horizon.

2. Crossing the Event Horizon: Once the observer crosses the event horizon, a point of no return, they would be unable to escape the black hole's gravitational pull. From an external observer's perspective, the falling observer would appear to freeze at the event horizon due to the extreme time dilation. However, from the perspective of the falling observer, they would continue their journey toward the black hole's singularity.

3. Spaghettification: As the falling observer moves further inward, they would experience an effect known as spaghettification. The tidal forces near the black hole are incredibly strong, causing a significant difference in the gravitational pull between their head and feet. This immense stretching force would elongate the observer into a thin, elongated shape resembling spaghetti. It is a result of the extreme gravitational gradient near the black hole.

4. Approaching the Singularity: As the falling observer continues to move closer to the black hole's singularity, the gravitational forces become infinitely strong. According to our current understanding, at the singularity, spacetime curvature becomes infinitely severe, and the laws of physics, as we currently understand them, break down. The observer's ultimate fate would be to become part of the singularity, where their matter would be crushed to infinite density.

It's essential to note that the above description is based on our current understanding of general relativity. However, the true nature of what happens inside a black hole, particularly at the singularity, is not yet fully understood. Resolving the behavior of singularities is an active area of research and requires a theory that unifies general relativity with quantum mechanics.

1.6 Effect of Relativity in Black Hole?

There is a common misconception that time doesn't exist in black holes. However, it's important to clarify the concept and understand the role of time in the context of black holes. In the vicinity of a black hole, the intense gravitational field causes significant distortions in the fabric of spacetime. According to general relativity, these distortions affect the flow of time itself, leading to what is known as time dilation. Time dilation refers to the phenomenon where the passage of time is experienced differently depending on the strength of the gravitational field.

As an observer approaches a black hole, they would experience time dilation compared to an observer further away from the black hole. This means that time would appear to pass more slowly for the observer closer to the black hole than for the observer further away. This effect becomes more pronounced as the observer gets closer to the event horizon. However, it's essential to note that time does indeed exist inside a black hole, but our understanding of it becomes uncertain near the singularity. According to our current understanding, singularity is a point of infinite density at the center of a black hole, where the laws of physics, including our understanding of time, break down. Therefore, our conventional concept of time may not be applicable at the singularity.

It's also worth mentioning that from an outside observer's perspective, it would take an infinite amount of time for an object to reach the event horizon of a black hole. This is due to time dilation and the fact that the gravitational pull near the event horizon slows down the flow of time for the falling object. However, for the object itself, time would continue to pass as it falls toward the singularity.

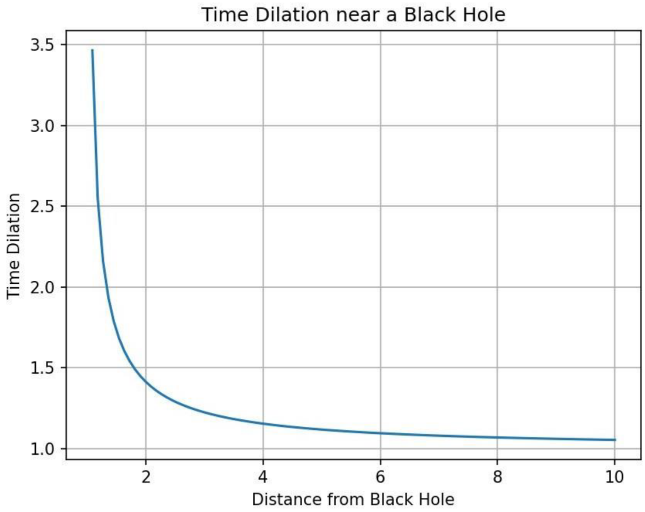

Fig 5: Graphical representation of the dilation of time as an observer approaches the event horizon

1.7 Black Holes aren't so Black!

The image of the M87 Black Hole revealed a bright, luminous ring surrounding a dark central region, known as the black hole's shadow. This ring-like structure is an accretion disk, a region of swirling hot gas and dust that forms as matter is pulled into the gravitational well of the black hole.

Black holes derive their name from the fact that their gravitational pull is so strong that nothing, including light, can escape their gravitational grasp once it crosses the event horizon. This absence of visible light gives the impression of "blackness." However, black holes interact with their surroundings through various processes, making them far from truly "black." One significant aspect is the emission of radiation known as Hawking radiation. Proposed by physicist Stephen Hawking, this theory suggests that black holes can emit particles and energy over time. According to quantum mechanics, particle-antiparticle pairs continuously pop into existence and annihilate each other near the event horizon. Occasionally, due to quantum fluctuations, one of the particles may escape while the other falls into the black hole, resulting in a net loss of mass and energy. This process gradually depletes the black hole's mass, causing it to "evaporate" over an extremely long timescale. Hawking radiation implies that black holes aren't entirely devoid of radiation and that they possess a finite temperature. However, due to their immense mass, the radiation from black holes is exceedingly weak and difficult to detect. Additionally, matter falling into a black hole forms an "accretion disk" around it. As matter spirals inward, it undergoes tremendous friction and heats up, emitting various forms of electromagnetic radiation, such as X-rays and gamma rays. These emissions can be exceptionally bright and observable, allowing us to indirectly study black holes through the radiation they generate.

Another intriguing concept related to black holes not being entirely black is the phenomenon of jets. In certain cases, black holes can produce powerful jets of high-energy particles that shoot out from their vicinity at speeds close to that of light. These jets are thought to originate from the strong magnetic fields and the intense gravitational forces near the black hole. They can extend over vast distances and release substantial amounts of energy, influencing their surrounding environments.

1.8 Observational Evidence

Observational evidence for the existence and properties of black holes has been accumulating over the years, supporting theoretical predictions and providing substantial confirmation of their existence. Here are some key observational pieces of evidence:

1. Stellar Motion: In binary star systems, where two stars orbit around each other, astronomers have observed companion stars moving in highly elliptical orbits or exhibiting unusual velocity variations. These observations suggest the presence of an invisible, massive object exerting gravitational influence. The most plausible explanation for such behavior is the presence of a black hole.

2. Accretion Disks and X-ray Emission: Accretion disks, formed when matter falls into a black hole, emit intense radiation, particularly in the X- ray part of the electromagnetic spectrum. X-ray telescopes, such as NASA's Chandra X-ray Observatory, have detected intense X-ray emissions from regions where black holes are believed to exist. These emissions are consistent with theoretical predictions for matter heating up and releasing energy as it falls into a black hole, supporting the presence of these objects.

3. Gravitational Waves: The direct detection of gravitational waves has provided compelling evidence for the existence of black holes. Gravitational waves are ripples in spacetime caused by the acceleration of massive objects. In 2015, the Laser Interferometer Gravitational-Wave Observatory (LIGO) made the groundbreaking detection of gravitational waves generated by the merger of two black holes. Since then, numerous black hole mergers have been detected, providing strong empirical evidence for the existence of black holes.

4. Strong Gravitational Lensing: Black holes can act as gravitational lenses, bending and distorting light passing near them. This effect, known as gravitational lensing, has been observed and studied extensively. Astronomers have observed light from distant galaxies or quasars being magnified, distorted, or even forming multiple images due to the gravitational influence of black holes in the foreground. These observations confirm the presence of massive, compact objects consistent with the predictions of black hole theory.

5. Event Horizon Telescope: In April 2019, the Event Horizon Telescope (EHT) collaboration released the first-ever image of a black hole. By synchronizing multiple radio telescopes around the world, the EHT captured an image of the supermassive black hole at the center of the galaxy M87.

2. WHITE HOLES HYPOTHESIS

White holes are hypothetical astronomical objects that are the reverse of black holes. While black holes have intense gravitational pull from which nothing can escape, white holes are theorized to have an outward flow of matter and energy without anything being able to enter them.

1. Theoretical Concept: The concept of white holes emerged from the mathematical solutions of Einstein's field equations in general relativity. These equations describe the curvature of spacetime due to the presence of mass and energy. While black holes represent regions where spacetime is highly curved inward, white holes represent regions where spacetime is curved outward.

2. One-Way Flow: According to theoretical models, matter and energy can only flow outward from a white hole, and nothing can enter or cross its event horizon. This is the reverse of black holes, where matter and energy can only enter and not escape the event horizon.

3. Violation of the Second Law of Thermodynamics: The existence of white holes is often considered to conflict with the second law of thermodynamics, which states that the total entropy of a closed system tends to increase over time. Since white holes are associated with a continuous flow of matter and energy outward, they would theoretically have to decrease entropy, contrary to the expected increase in entropy over time.

4. Stability and Formation: White holes are considered highly unstable and unlikely to form through natural processes. The same gravitational collapse mechanisms that lead to the formation of black holes are expected to be reversed for white holes. However, it's important to note that there is currently no observational evidence to support the existence of white holes.

5. Connection to Wormholes: Some theories suggest a possible connection between white holes and wormholes, hypothetical tunnels in spacetime that could potentially connect distant regions or even different universes. It has been theorized that a white hole could serve as one end of a traversable wormhole, allowing matter and energy to pass through.

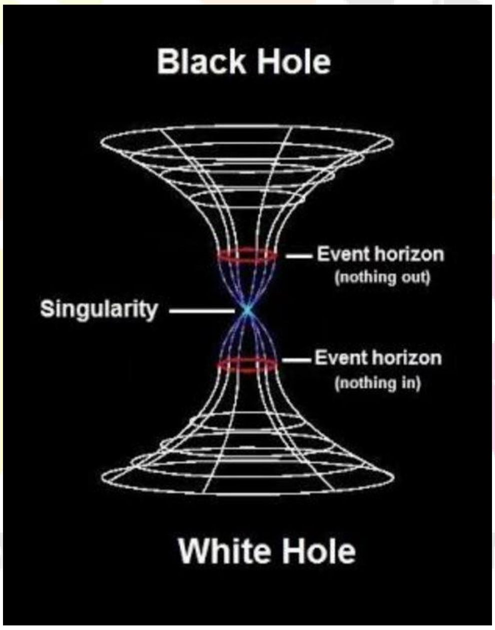

Fig 6: Hypothetical Structure of Black Hole and White Hole

3. ETERNALLY COLLAPSING OBJECT

The concept of an "eternally collapsing object" is associated with the work of Indian physicist and philosopher Abhay Ashtekar, who developed a theoretical model known as the "Ashtekar wormhole" or the "Ashtekar black hole." This model explores the possibility of a connection between black holes and a cyclic cosmological scenario. Ashtekar's model incorporates elements of loop quantum gravity, a quantum theory of gravity that seeks to unify general relativity and quantum mechanics. In this framework, spacetime is quantized at the smallest scales, leading to discrete structures and a departure from the continuous geometry of classical spacetime. According to Ashtekar's model, instead of a traditional singularity at the core of a black hole, there exists a highly curved region where the geometry of spacetime changes dramatically. This region is often referred to as a "quantum bounce" or "quantum bridge." It is believed to connect the interior of the black hole to a new expanding phase of the universe, forming a wormhole-like structure.

The term "eternally collapsing object" is used to describe this model because, from an external perspective, the black hole appears to be in a state of continuous collapse due to its event horizon continually moving inward. However, within the framework of Ashtekar's model, the collapse is halted and replaced by a quantum bounce at the center, leading to a new expanding phase. It suggests the possibility of a cyclic universe, where the collapse and subsequent expansion of black holes give rise to a series of interconnected universes or cosmological cycles. While Ashtekar's model provides an alternative framework for understanding black holes and their relationship to the wider cosmos, it's crucial to recognize that the model is not yet confirmed by empirical evidence.

4. CONCLUSION

Considering all the previous discussions, it can be argued that black holes are like celestial monsters in the universe. Black holes could be a serious concern for mankind to survive on this beautiful earth though the probability of occurrence of an incident that we all are sucked by a black hole is very small. So, there is no need to fear too much for getting spaghettified soon. Now a day, many scientists are working in this field. Many scientists have given their opinion and explanations about the black hole. But these views are different. This is creating an uncertain situation to be known explicitly about the black hole. There is no independent concrete theory or assumption to interpret this phenomenon-black hole. This research can be very useful for all of us in fighting against this astronomical monster. But still, there are lots to discover or investigate about the black holes. Many quality researches on black holes are to be continued to find out many interesting things about black holes. Falling into a black hole would be the last thing that we ever can do, but for scientists, black holes are just the beginning step of our explorations in space, time, and everything in between.

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