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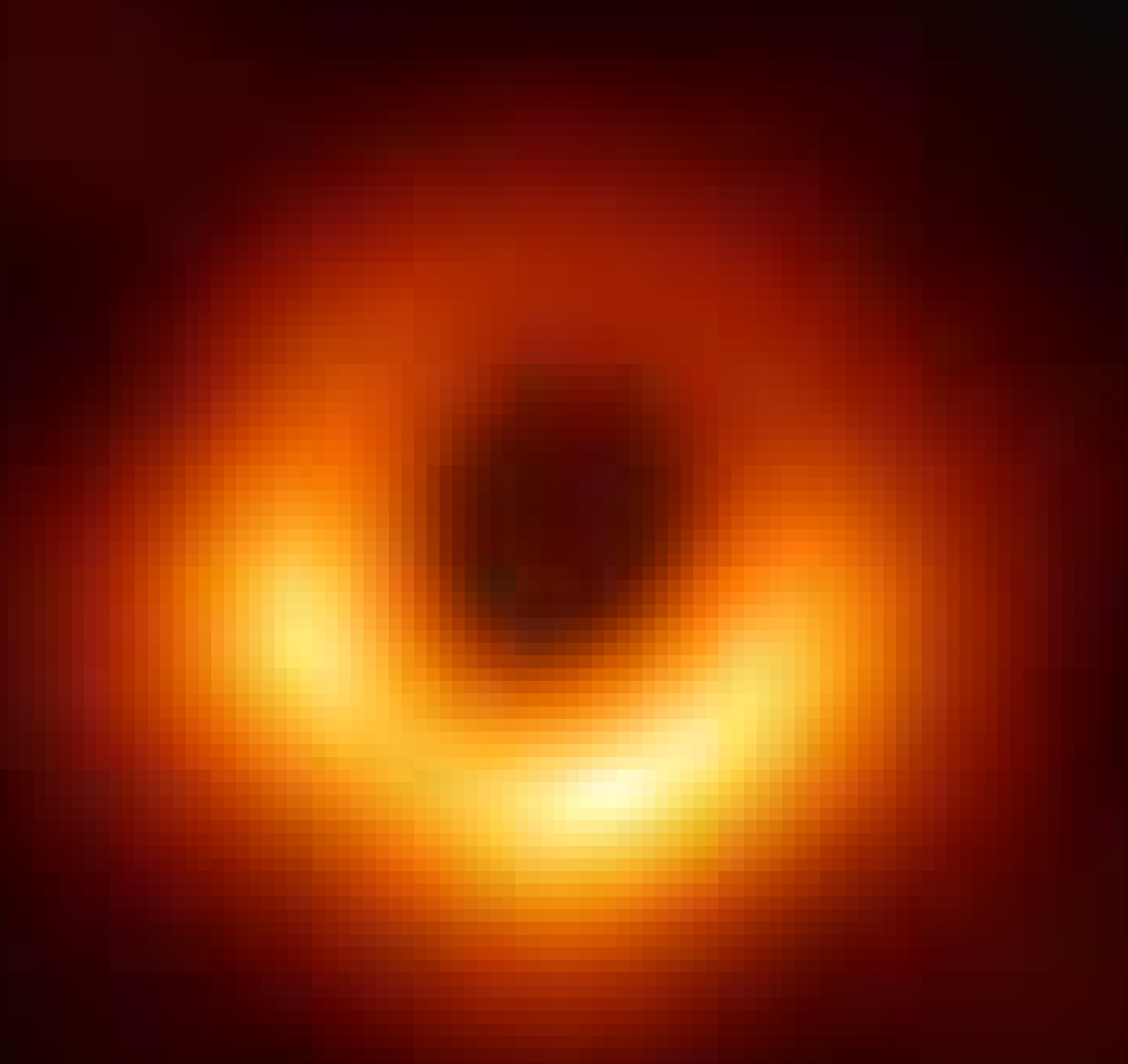

WHAT IS THE MOST FEASIBLE BLACK HOLE THEORY?

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BLACK HOLE INTRODUCTION

Black holes are among the universe's most strange yet fascinating objects. They inexorably collapse to singularities surrounded by depths of space in which nothing can escape because they contain enormous amounts of mass in a very compact volume. If anything crosses the event horizon, it falls to the centre singularity, enlarging the black hole and increasing its mass. When anything comes too close to one, the black hole's forces will rip it apart. How objects get caught gravitating into the singularity is known, but what occurs beyond that remains a mystery.

WHAT IS A BLACK HOLE?

Throughout the depths of space, the presence of black holes has often been inferred by scientists. A black hole is a region, where the gravitational pull is so vigorous, that even light fails to escape its pull (1). Light's inevitable failure to escape a black hole's immense gravitational pull can be explained mathematically:

r = Schwarzschild Radius
M = Black Hole Mass
G = Newton’s Gravitational Constant
c = Speed of Light

$$r = \frac{2GM}{c^2}$$

Black holes exert a powerful influence on their surroundings. Their extreme gravitational field is inferred to be capable of distorting the fabric of space-time, causing nearby objects to move unpredictably. In addition, black holes are renowned for their intense gravitational pull that can cause other stars, planets, moons, and all other space objects to be drawn towards them (4). Consequently, a black hole’s presence can dramatically alter the structure of galaxies. Although their existence has been theorized for centuries, the first actual image of a black hole was captured in 2019. This image, taken from the Event Horizon Telescope, showed a bright ring of light surrounding a dark circle, indicating the presence of a powerful black hole (2).

CAN A BLACK HOLE BE SEEN?

A black hole cannot be seen, as gravity pulls all light to the middle of the black hole. Scientists infer the presence of black holes by assessing the stars and gasses around the black hole (2). When stars and black holes are close together, high energy light that cannot be viewed by humans is created. Thus, it is seen through special telescopes capable of detecting electromagnetic radiation. The presence of black holes can be detected through the study of their effects on nearby objects. For example, their intense gravity can cause stars to move unusually, hence revealing their presence (1).

TYPES OF BLACK HOLES

Scientists have compiled 3 categories of blackholes, all varying in mass. The least massive, stellar black holes, range from 10-20 solar masses. Supermassive black holes are approximately 100-1000 solar masses. Lastly, the most massive black holes consist of millions of solar masses (1).

HOW ARE BLACK HOLES FORMED

To form a black hole, a star must be remarkably massive. Even the sun in the solar system lacks the mass to form a black hole.

Stellar black holes, the most common, are formed when a large star collapses inward, forming an extremely dense object. Supermassive black holes are believed to have formed when its galaxy was created. The origin of intermediate black holes is still not known.

Near the end of the life of a black hole, the mass slowly evaporates, due to the intense gravity. The black hole decreases in size, and eventually sucks itself into the singularity.

WHAT HAPPENS TO MATTER WHEN IT ENTERS A BLACK HOLE?

When matter enters a black hole's event horizon (the space around the singularity where even light cannot escape), the matter is torn apart, stretched, and compressed into tiny subatomic particles that gravitate into the singularity. The mass engulfed by a black hole is directly proportional to the size of the event horizon of the black hole. When a black hole dies, the matter is shrunk to its smallest point, and with time, it evaporates in a flash of energy. This process, known as Hawking Radiation, can take at least 10^{100} years for a decent-sized black hole to evaporate.

HISTORY OF BLACK HOLES

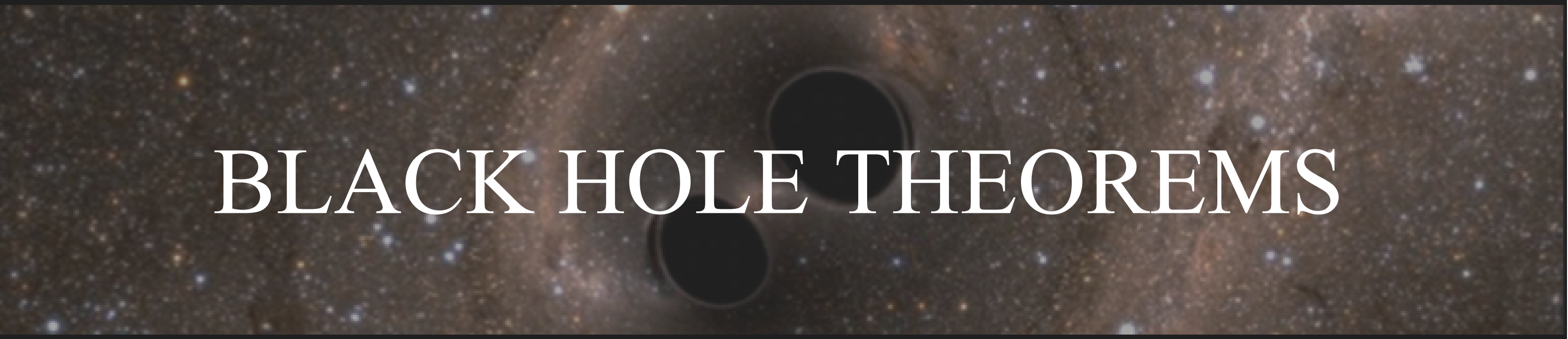
Black holes were initially proposed in the early 20th century when scientists such as Karl Schwarzschild and Albert Einstein began to develop the mathematical equations that described their properties. Schwarzschild provided the first exact solution to Einstein's field equations of general relativity, which described the characteristics of a non-rotating black hole. Einstein himself did not believe in the physical reality of black holes, but his theory of general relativity implied their existence.(3)

From the 1930s to 1970s, scientists such as Subrahmanyan Chandrasekhar and Stephen Hawking made significant strides in understanding the nature of black holes.

In the 1960s and 1970s, the first black hole candidates were observed, and in the 1990s, the first black hole was directly imaged, Cygnus X-1. The detection of X-ray emissions from Cygnus X-1 provided strong evidence for the existence of black holes (6).

In recent years, the study of black holes has advanced significantly with the development of new technologies and observational techniques. The Event Horizon Telescope Collaboration in 2019 published the first direct image of a black hole, located in the center of galaxy M87. This groundbreaking achievement, which was made possible by a global network of telescopes, provided direct evidence of the existence of black holes and revealed new details about their physical properties (6).

Black hole research continues to be an active area of study in astrophysics and theoretical physics, with ongoing efforts to understand their properties and behavior, and to detect and study black holes in different types of environments. Scientists are also working to detect gravitational waves, which are ripples in spacetime caused by the collision of black holes or other massive objects. The detection of gravitational waves will provide new insights into the dynamics of black holes and the nature of gravity.



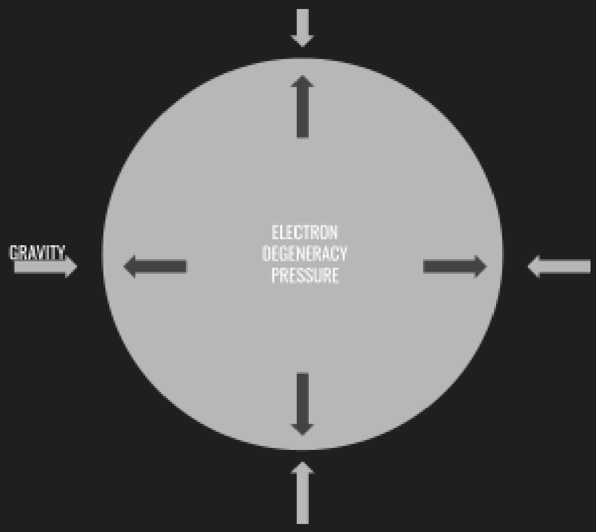
BLACK HOLE THEOREMS

For over 100 years, black holes have become a mathematical interest to theoretical physicists, and a downright mystery. Within that century many conclusions and scientific outbreaks have been made regarding black holes, which begs a question; What theory is the most feasible in the history of black hole revelations?

Some of the most notable black hole theories were made by the world's most renowned physicists in the world. These theories used conceptual explanations, theoretical learnings, and mathematical analysis hinting at the high chances of being correct.

SUBRAHMANYAN CHANDRASEKHAR

Subrahmanyan Chandrasekhar - an Indian-born scientist most notable for developing a theory explaining the potential origin of black holes. Scientists before Chandrasekhar were confident that dead stars collapsed into white dwarfs (what stars like the sun become after it has consumed all of their hydrogen) Although the scientists were correct, they were partly wrong (7). At the age of 19 years, Chandrasekhar disproved the scientists during and before his time. According to the study of quantum mechanics, every atom of a white dwarf has a force that counteracts gravity. Using simple calculations like;



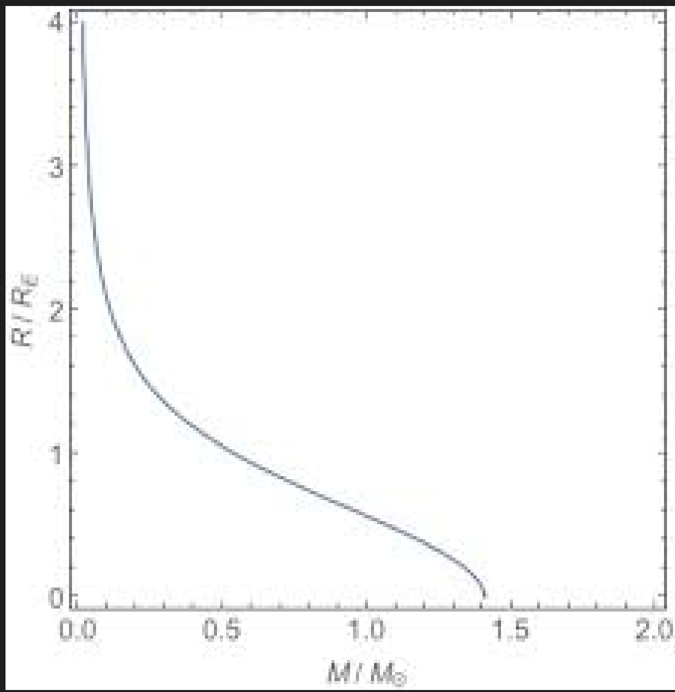
$$F=(Gm1m2)/r$$

(mass and force are proportional)

Chandrasekhar questioned the scientists, as he thought, if the star’s mass is immense, then the force must be incredibly overwhelmed.

$$F_g > F_{ed}$$ (electron deficiency pressure)

Years later Chandrasekhar theorized that when a star 1.4 times more massive than the sun runs out of fuel, the star collapses into a black hole. This was done by developing an equation for the maximum mass of a stable white star. The accepted value was 1.4 M (2.765 10^{30} kg), also known as the Chandrasekhar limit. The mathematical equations follow:



h = Planck's Constant
c = Speed of Light
G = Gravitational Constant
μ = Electron Molecular Weight
M = Mass of Hydrogen Atom

imit =

$$\mathbf{M}_{\text{limit}} = \frac{\omega^{0}\sqrt{3\Pi}}{2}\left(\frac{hc}{G}\right)^{\frac{2}{3}}\frac{1}{(\mu m)^{2}}$$

The primary force that counteracts gravity is electron degeneracy pressure, hence the force refusing to collapse is electron degeneracy pressure. For a stable white dwarf, the force of gravity in terms of the mass density must be equal to the electron degeneracy pressure.

Subrahmanyan Chandrasekhar's work was a historic discovery. His work was initially met with skepticism but is now widely accepted as the foundation for modern theories about the formation of black holes.

"This discovery is basic to much of modern astrophysics since it shows that stars much more massive than the Sun must either explode or form black holes" NASA mentions after naming their observatory the Chandrasekhar (4).

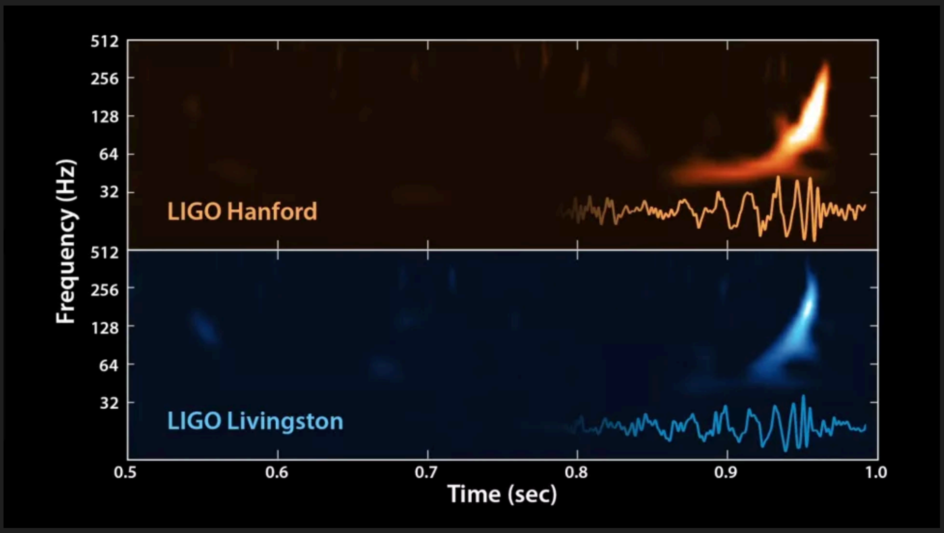
Although Chandrasekhar's discovery presented the origin of black holes and the evolution of stars, his research merely scratched the surface of the knowledge of black holes. The talk about black holes appearing from stars was a prominent discussion, but it was never proven until Chandrasekhar.

Henceforth, Chandrasekhar developed and proved a theory that changed the way scientists perceived stars, however, his discovery lacked the depth seen in other theories. His theory was a realization and a mathematical equation that delivered one big answer regarding black holes. Although Chandrasekhar's discovery was one of high value, some theorists went deeper.

ALBERT EINSTEIN

One who acquired more depth than Chandrasekhar in terms of black hole theories was Albert Einstein. In his most notable work, general relativity, Einstein predicted that there would be spots in space where particles and light can't escape, evidently describing a black hole.

Einstein also predicted outlandish events that were purely theoretical. For instance, he predicted that when 2 large black holes collide, they create ripples in space-time, known as gravitational waves. Almost 100 years later, Einstein's theory was proven correct when LIGO (Laser Interferometer Gravitational Wave Observatory) announced it had detected gravitational waves for the first time ever (5).



As black holes come closer together, the frequency of the gravitational waves increase (LIGO)

Einstein's work on black holes continues to inform the understanding of the universe today. His theories provided the groundwork for the further study of black holes, and his work inspired others to explore and uncover the mysteries of these puzzling objects.

However, Einstein lacked the completion of mathematical analysis to unequivocally prove the existence of black holes and the effects of collided black holes. When Einstein published the general theory of relativity in 1915, his speculations regarding black holes were purely theoretical. He later took the daunting task of mathematically proving it, utilizing tensor calculus, only able to approximate the equation. (9)

Despite directly declaring the existence of black holes through his research in the general theory of relativity, and also theorizing gravitational waves in colliding black holes. Einstein was doubtful that they existed. (10)

He also argued against the theory of the formation of black holes from stars, which would later be proven to be accurate. In fact, in 1939, Einstein published a paper proclaiming, "star collapsing would spin faster and faster, spinning at the speed of light with infinite energy well before the point where it is about to collapse into a Schwarzchild singularity or black hole.". This has been proven false, as collapsing stars cannot be stable. (9)

Henceforth, Einstein has been certified as the father of black holes through his general theory of relativity. However, he has pleaded inaccuracies in his theories and was not able to mathematically prove his black hole theorems, thereby declaring his black hole theories below the greatest.

THE MOST FEASIBLE THEORY

STEPHEN HAWKING

Black holes are one of the most mysterious and fascinating objects in the universe. Many physicists have sought to explain their nature. Stephen Hawking is one of the most prominent names in the field of black hole research, having made significant contributions to the study of their properties. He proposed the area theorem, which describes the law of all black holes, as well as proposing that black holes emit radiation. Today, physicists continue to study black holes and make discoveries about their properties.

HAWKING AREA THEOREM

In 1971 Hawking proclaimed a central law that all black holes must obey. The law states that the total area of their event horizons should never shrink (11). 50 years later, Hawking's theorem has been proved by researchers and scientists at MIT and Caltech's Advanced Laser Interferometer Gravitational-Wave Observatory. The MIT and Caltech researchers used the first gravitational wave signal from 2015 (the same one to prove Einstein's black hole collision theory), and analyzed the horizon area before and after the collision. If Hawking's theorem holds, then the horizon area of the new black hole should not be smaller than the total horizon of its parent black holes. The researchers found that the new black hole did not decrease after the collision. Not only did Hawking prove his theory conceptually, but also mathematically, and was later observably confirmed.

Hawking's area theorem provided fundamental insights regarding black hole mechanics. His theorem allowed for momentous steps towards uncovering the true nature of black holes.

After noticing a similarity in the area theorem and the law of thermodynamics, it suggested that black holes could emit heat. Black holes are known to refuse the escape of energy or radiation. In 1974, Hawking concluded that when quantum mechanical effects are taken into account, a black hole can reduce its surface area over time by emitting radiation. This incredible discovery was coined as "Hawking Radiation".

HAWKING RADIATION

The thermal radiation known as "Hawking radiation" is thought to be produced by black holes on their own. This radiation was first proposed by Stephen Hawking in 1974. It is created when quantum vacuum fluctuations, which are the fluctuations of the empty space-time, are gradually converted into pairs of particles (photons, neutrinos, and some massive particles(13)). One of these particles escapes at infinity and the other is imprisoned within the black hole horizon. As the trapped particle is lost inside the black hole, the black hole loses energy. This energy loss is in the form of radiation, which reduces the mass of black holes and, hence, also evaporates the black hole. This process is known as the hawking radiation and it's a fundamental concept in understanding the properties of black holes (12).

Hawking also explored whether black holes have a temperature, and found that they do, using knowledge from the Hawking Radiation theory. He discovered that the temperatures in a black hole is extremely low.

Due to the "fuzziness" of quantum particles, the event horizon of a black hole cannot completely contain all the energy. Hawking radiation allows energy to escape a black hole's force of gravity. As a result, Hawking discovered that mass and energy black holes release are inversely proportional. Subsequently, Black holes have incredibly low temperatures due to the limited quantity of energy that exists.

Hawkings mathematically supported his theory of radiation by calculating for the black hole temperature, which would later be crowned his most notable equation.

T = Black Hole Temperature
H = Planck's Constant
c = Speed of Light
K = Bolzmann Constant
M = Black Hole Mass

$$T = \frac{hc^3}{8\Pi GkM}$$

THE INFORMATION PARADOX

The Hawking Radiation theory offered a subsequent theoretical response. If a black hole can evaporate and perish, then so can the information regarding what fell into it. This contradicts fundamental laws of physics, as information can never be destroyed, and physics can't be mathematically reversed. Hawking's daunting statement was poked at by many scientists for nearly half a century until scientists developed the no-hair theorem, which refers to the lack of visible characteristics that distinguish black holes. However, it is believed that black holes do have "hair", or characteristics that carry information regarding their history and origin.

Hawking's discovery of the area theorem and Hawking radiation were two cohesive theorems that described certain conditions. Hawking's energy theorem ascertains a black hole when more energy is being added (a black hole is absorbing additional mass). Hawking's radiation only applies to a black hole when energy is being lost (a black hole is not absorbing additional mass).

CONCLUSION

Stephen Hawking’s work on black holes was a pivotal moment in black hole research. He discovered the most notable black hole theorem in the history of black hole research. Hawking radiation and the Hawking area theorem aided in providing fundamental insights into black hole mechanics. He also solved whether a black hole has a temperature mathematically, aiding in understanding the conditions of a black hole. The information paradox bestows a significant question to all scientists to understand the fate of information from a black hole after it has collapsed, which was later solved, making Hawking partially responsible for the solutions.

Henceforth, it is clear that Stephen Hawking's work on black holes has exceeded even Einstein and Chandrasekhar. Stephen Hawking explored more than just one thought of black holes, but rather diversified his research, allowing for a more informative and deep theory. Although Einstein is the father of black holes, and Chandrasekhar explained the origin of many black holes, Hawking discovered theories and answered questions imperceptible to every scientist. Mathematical and conceptual evidence for every theory, as well as confidence and consistency with his findings, solidifies his theorem as the most feasible theory in the history of black holes.

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