The Enigmatic Cosmic Beasts

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1. Introduction

Think of a mass so densely compact as not to allow light to escape from it. Such a compact body is called a "Black Hole", and it is indeed very difficult to visualise it. These cosmic beasts are formed when stars above a certain mass die after running out of all their nuclear fuel. Black holes are extremely compact space objects that were once massive stars which collapsed inward due to the force of their own gravity. They pack vast mass into a pinpoint of space. Their intense gravity sucks in anything that passes too close, including light; they even distort time. As light waves hit the event horizon, they are thought to split into pairs of particles called 'quanta'; one falls into the black hole and one escapes as Hawking radiation. Incidentally, the name 'black hole' was invented by John Archibald Wheeler, and seems to have stuck because it was much catchier than the previous names. Before Wheeler came along, these objects were often referred to as 'frozen stars'.

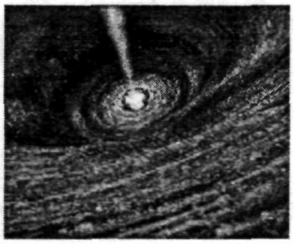

Fig1a. GRO J1655-40: Evidence for a Spinning Black Hole; Drawing Credit: A. Hobart, CXC

2. How a Black Hole is Formed?

Black holes are thought to form from stars or other massive objects if and when they collapse from their own gravity to form an object whose density is infinite: in other words, a singularity. During most of a star's lifetime, nuclear fusion in the core generates electromagnetic radiation including photons, the particles of light. This radiation exerts an outward pressure that exactly balances the inward pull of gravity caused by the star's mass. As the nuclear fuel is exhausted, the outward forces of radiation diminish, allowing the gravitation to compress the star inward. The contraction of the core causes its temperature to rise and allows remaining nuclear material to be used as fuel. The star is saved from further collapse — but only for a while. Eventually, all possible nuclear fuel is used up and the core collapses. How far it collapses, into what kind of object, and at what rate, is determined by the star's final mass and the remaining outward pressure that the burnt-up nuclear residue (largely iron) can muster. If the star is sufficiently massive or compressible, it may collapse to a black hole. If it is less massive or made of stiffer material, its fate is different; it may become a white dwarf or a neutron star.

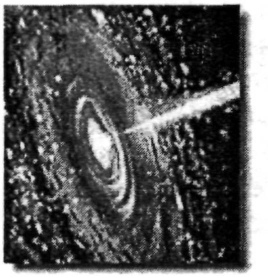

Fig.1b A black hole

3. The Singularity

At the center of a black hole lies the singularity, where matter is crushed to infinite density, the pull of gravity is infinitely strong, and spacetime has infinite curvature. Here it's no longer meaningful to speak of space and time, much less spacetime. Jumbled up at the singularity, space and time cease to exist as we know them.

4. Weight of a Black Hole

There is no limit in principle to how much or how little mass a black hole can have. A

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*3rd Year student of Computer Science & Technology typical mass for such a stellar black hole would be about 10 times the mass of the Sun, or about 10^{31} kilograms. Astronomers also suspect that many galaxies harbour extremely massive black holes at their centers. These are thought to weigh about a million times as much as the Sun, or 10^{36} kilograms. The more massive a black hole is, the more space it takes up. In fact, the Schwarzschild radius (which means the radius of the horizon) and the mass are directly proportional to one another: if one black hole weighs ten times as much as another, its radius is ten times as large. A black hole with a mass equal to that of the Sun would have a radius of 3 kilometers.

5. How Can We See a Black Hole?

Though we cannot "see" a black hole itself (since not even light can escape the hole's gravitational field), we may see the hole's effects on nearby matter. For example, if gas from a nearby star were sucked towards the black hole, the intense gravitational energy would heat the gas to millions of degrees. The resulting X-ray emissions could point to the presence of the black hole. Or, if a massive black hole were surrounded by large amounts of orbiting material — gas, dust, even stars — their rapid motion close to the hole could be observable via shifts in the energy of the radiation they emit. To confirm that black holes actually exist, we'll need to be able to observe the gravitational waves they produce as they form or interact. If scientists could build gravitational wave detectors of sufficient sensitivity, they should be able to measure the vibrations in spacetime generated by black holes as they form from a collapsing star, when they ingest large amounts of matter, or if they interact, even collide with a second black hole or another massive object, such as a neutron star. Certain patterns of gravitational waves emitted would reveal the "smoking gun." So far, the wavelike disturbances in spacetime have eluded detection. In a relativistic universe, there should be no shortage of places in which to hunt for black holes.

6. Journey To a Black Hole

This section will describe a trip to the most compact star imaginable: a black hole. A black hole can be thought of as any star compressed so greatly that it not only has a photon sphere but also an event horizon. This is because, for one reason, any metre stick closer than the event horizon could not be seen by an observer outside the event horizon. A better way of visualizing radial distance is to picture orbiting the black hole at a fixed distance, measuring the circumference of the orbit, and dividing by 2 pi.

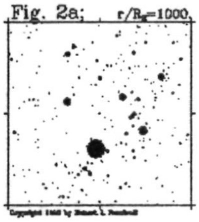


Fig. 2a; $r/R_s=1000$

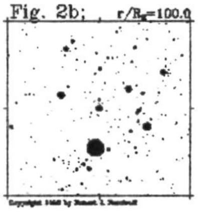


Fig. 2b; $r/R_s=100.0$

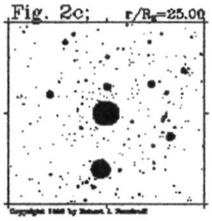


Fig. 2c; $r/R_s=25.00$

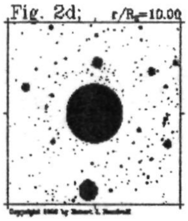


Fig. 2d; $r/R_s=10.00$

Fig. 2a shows the black hole from a distance of 1,000 R-S (4,200 km). From this distance the black hole and the stars behind it, appear very faint. Fig. 2b shows the black hole from a distance of 100 R–S (420 km). From this distance the viewer begins to notice that no light comes from a circular patch in the direction of the black hole. The only light that could possibly come to the viewer from this area would be from the black hole itself. The angular size of the filled black circle is the angular size of the photon sphere of the black hole mass. Fig. 2c shows the black hole from a distance of 25 R–S (105 km). Here the angular size of the black hole has increased and the secondary images, which are inside the first sky Einstein ring, are now quite clearly discernable. Fig. 2d shows the black hole from a distance of 10 R–S (42.0 km). Stars nearest to behind the black hole from the observer now have two bright images. The brightest star in the illustration (and the sky: Sirius) can be seen to have two bright images: the brightest primary image in the field of view on the lower left and a secondary image 180 degrees across the face of the black hole from it. Primary and secondary images can always be matched up by connecting them with a Great Circle (a line on these figures) through the center of the black hole. Sirius is not the only star to have two distinct images. Through sirius and the stars in the belt of Orion have been labelled in Fig. 2d. In fact, all bright stars visible in the field have two bright images. The first sky Einstein ring, shown in Fig. 2d, is an invisible circle centered on the black hole and dividing the first complete set of images from the second complete set of images. Each image in the first set is always brighter than the corresponding image in the second set. The second sky Einstein ring appears in the conglomeration of stellar images near the apparent photon sphere position, just outside the photon sphere.

The distortions the viewer would see are shown in Figs. 2d - 2j. These figures depict viewing angles for relative angular positions of 0 degree, 5 degree, 10 degree, 90 degree, 180 degree, 270 degree, and 360 degree around the orbit. A complete orbit would encompass, of course, 360 degrees and so Fig. 2j is the same as Fig. 2d. Fig. 2e, showing a relative 5 degrees orbital angle compared to Fig. 2d, has several interesting differences with this figure. Stellar images nearest the first sky Einstein ring have shifted the most. These images represent stars that are closest to directly behind the black hole from the viewer. These images appear to move with the highest angular speeds. This is because a small angular step of the star from just to the left of behind the black hole from the observer to just to the right causes all of its images to move from one side of the Einstein ring to the other. Apparent angular speeds have no maximum limit. If one attributes a distance to the images they can even appear to exceed the speed of light. Stars approaching the nadir point below the black hole from the viewer (moving slowly) have images that appear to approach the Einstein ring and get very bright (moving rapidly), eventually receding from this Einstein ring and dimming. After a complete orbit with the viewer always facing the black hole, the distortions are depicted by Fig. 2j, which is the same as Fig. 2d.

Fig. 2e; r/R_s=10.00

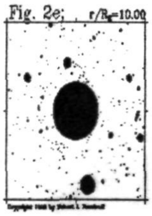


Fig. 2f; r/R_s=10.00

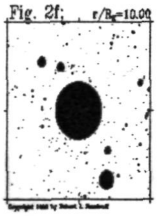


Fig. 2g; r/R_s=10.00

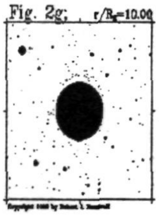


Fig. 2h; r/R_s=10.00

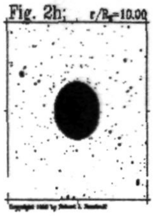


Fig. 2i; r/R_s=10.00

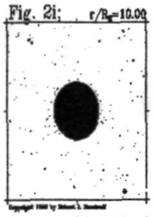


Fig. 2j; r/R_s=10.00

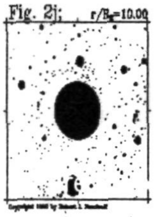


Fig. 2k; r/R_s=3.000

Fig. 2l; r/R_s=1.500

Fig. 2m; r/R_s=1.500

Fig. 2n; r/R_s=1.500

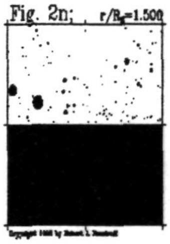


Fig. 2o; r/R_s=1.100

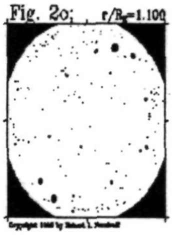


Fig. 2p; r/R_s=1.010

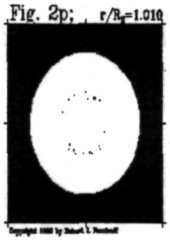


Fig. 2k shows the visible distortions from 3 R–S (12.6 km) at twice the distance of the photon sphere. Here the viewer is looking 45 degrees away from the black hole. Note the great number of clearly resolved secondary images visible near the black hole's limb. Fig. 2l shows the distortions from this distance: 1.5 R_S (6.3 km). The viewer looks north. The self Einstein ring where viewers could see the backs of their heads is the photon sphere horizon line dividing the light captured by the black hole from the light coming from the sky: it is a horizontal line across the middle of the figure. The first sky Einstein ring would be an invisible line about 2/9 of the way toward the top of the plot above the photon sphere. Those stellar images highly amplified above the Einstein ring are different than those that appear highly amplified just below the Einstein ring. The primary images just above the Einstein ring in one direction will have their secondary image appear just below the Einstein ring in the opposite direction. The viewer now starts along an orbit at the photon sphere, 1.5 R_S (6.3 km) from the black hole. The position of the first sky Einstein ring becomes more evident when comparing Figs. 2l, 2m, and 2n which have relative orbital angles of 5 degrees and 10 degrees. The viewer now descends and looks directly away from the black hole. Fig. 2o shows the distortions from 1.1 R_S (4.62 km). All of the sky images are now compressed into a hole in the direction opposite the black hole. Fig. 2p shows the distortions visible from 1.01 R_S (4.242 km) while looking directly away from the black hole. The black hole now encompasses almost the complete observer sky. The small hole at the top is what remains visible of the outside universe. In this hole there could appear, theoretically, an infinite number of complete images of the outside universe. The angular amplification A_angular of the vast majority of these images is, however, much less than unity: they are greatly deamplified. The outer radial limit of the dim ring marks the position of the second sky Einstein ring.

7. Event horizon

The event horizon is thought to be the defining feature of a black hole, a point-of-no-return surrounding the hole inside which even light cannot escape the black hole's gravity. Imaging this would be a final step in the black hole's journey from curious theoretical oddity to cosmic reality. An event horizon is the theorized "one-way ticket" boundary around a black hole from which nothing, not even light, can escape. No object except for a black hole can have an event horizon, so evidence for its existence offers resounding proof of black holes in space. At the event horizon - the rim of a voracious black hole - dimensions as we know them disappear. To an observer on a spaceship, light and time appear to stand still. Applying the Einstein Field Equations to collapsing stars, German astrophysicist Kurt Schwarzschild deduced the critical radius for a given mass at which matter would collapse into an infinitely dense state known as a singularity. For a black hole whose mass equals 10 suns, this radius is about 30 kilometers or 19 miles, which translates into a critical circumference of 189 kilometers or 118 miles.

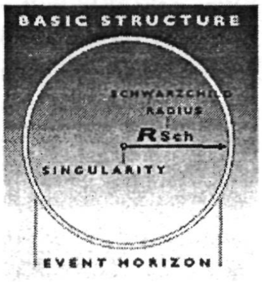
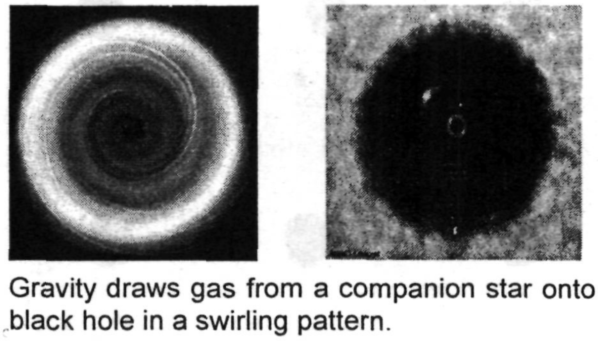


Fig3. Schwarzschild Black Hole

If you envision the simplest three-dimensional geometry for a black hole, that is a sphere (known as a Schwarzschild black hole), the black hole's surface is known as the event horizon. Behind this horizon, the inward pull of gravity is overwhelming and no information about the black hole's interior can escape to the outer universe.



Gravity draws gas from a companion star onto a black hole in a swirling pattern.

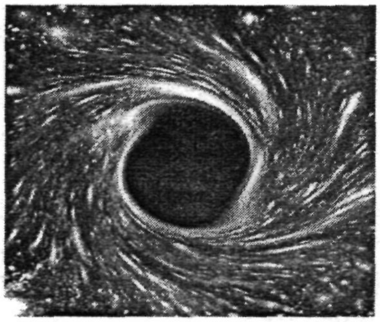


Fig5A blackhole

The simulation could create a mock version of elusive 'Hawking radiation'. These weak electromagnetic waves are thought to occur when light reaches the event horizon, but they are masked from us by other emissions. "We might even be able to see it with the naked eye," says astronomer Fulvio Melia of the University of Arizona in Tucson. The sum of the Universe's light equals a pale turquoise, it was revealed. Hawking radiation, too, "might have a particular tint", suggests Melia. "If it's true it's tremendously interesting," says cosmologist Bernard Carr of Queen Mary and Westfield College, London. Imitation event horizons may help us to understand the quantum effects of gravity, and resolve conflicts between general relativity (the theory of the biggest bodies in the Universe) and quantum theory (the rules governing its tiniest constituents). General relativity predicts that nothing can escape a black hole; quantum theory says that Hawking radiation does.

8. Einstein's theory

Einstein's general theory of relativity describes gravity as a curvature of spacetime caused by the presence of matter. If the curvature is fairly weak, Newton's laws of gravity can explain most of what is observed. The most compact objects imaginable are predicted by General Relativity to have such strong gravity that nothing, not even light, can escape their grip. Scientists today call such an object a black hole. Why black? Though the history of the term is interesting, the main reason is that no light can escape from inside a black hole: it has, in effect, disappeared from the visible universe. In fact, present theories of how the cosmos began rest in part on Einstein's work and predict the existence of both singularities and the black holes that contain them. Black holes are predictions of Einstein's theory of general relativity. The simplest static and spherically symmetric solution to Einstein's equations was found by Karl Schwarzschild in 1915. The Schwarzschild metric describes the curvature of spacetime in the vicinity of a nonrotating spherical mass. The Schwarzschild metric predicts that a gravitating object will collapse into a black hole if its radius is smaller than a characteristic distance called the Schwarzschild radius, which is proportionate to the object's mass. Below the Schwarzschild radius, space-time is so strongly curved that any light ray emitted in this region will travel towards the center of the system, regardless of the direction in which it is emitted. Because relativity forbids anything from traveling faster than light, anything below the Schwarzschild radius - including the gravitating object itself - will collapse into the center point, where a gravitational singularity forms. Because not even light can escape from within the Schwarzschild radius of a classical black holes it would truly appear black. More general black holes can be described by other solutions to Einstein's equations, such as the Kerr metric for a rotating black hole, which possesses a ring singularity.The generalization of the Schwarzschild radius is known as the event horizon.

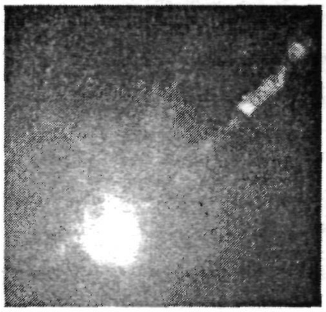


Fig. 6 Image of a super massive black hole in galaxy M87, taken by the Hubble Space Telescope

Black holes demonstrate some counter-intuitive properties of general relativity.

Black holes have only three measurable characteristics : mass, angular momentum and electric charge, and can be completely specified by these three parameters. The entropy of black holes is a fascinating subject, and an area of active research. In 1971, Hawking showed that the total event horizon area of any collection of classical black holes can never decrease. This sounds remarkably similar to the Second Law of Thermodynamics, with area playing the role of entropy. Therefore, Bekenstein proposed that the entropy of a black hole really is proportionate to its horizon area. In 1975, Hawking applied quantum field theory to a semi-classical curved spacetime and discovered that black holes can emit thermal radiation, known as Hawking radiation. This allowed him to calculate the entropy, which indeed was proportionate to the area, validating Bekenstein's hypothesis. It was later discovered that that black holes are maximum-entropy objects, meaning that the maximum entropy of a region of space is the entropy of the largest black hole that can fit into it. This led to the proposal of the holographic principle.

Partial solutions of the Einstein equations point to two possible outcomes:

i) A non-rotating, spherically symmetric black hole, first postulated by Schwarzschild.

ii) A rotating, spherical black hole, predicted in 1964 by the New Zealand mathematician Roy Kerr.

These two types of black holes have become known as Schwarzschild and Kerr black holes, respectively. Both types of black holes are "stationary" in that they do not change in time, unless they are disturbed in some way. As such, they are among the simplest objects known in General Relativity. They can be completely described in terms of just 2 numbers: their mass M and their angular momentum J. Theoretically, black holes may also possess electric charge, Q, but it would quickly attract enough charge of the opposite sign. The net result is that any "realistic" or astrophysical black hole would tend to exhibit zero charge. Both the Schwarzschild and Kerr black holes represent end states. Their formation may result from various processes, all of them quite complicated. When a "real" black hole forms from, say, the collapse of a very massive star, or when a black hole is disturbed by, say, another black hole spiraling into it, the resulting dynamics cause disturbances in spacetime that should lead to the generation of gravitational waves. By emitting gravitational waves, non-stationary black holes lose energy, eventually become stationary and cease to radiate in this manner. In other words, they "decay" into stationary black holes, namely holes that are perfectly spherical or whose rotation is perfectly uniform. According to Einstein's Theory of General Relativity, such objects cannot emit gravitational waves. Black hole has a singularity at the centre which is surrounded by an imaginary spherical wall known as its 'event horizon'. The black holes's gravitational pull is so intense that anything coming near the event horizon is sucked in straight towards the singularity. According to Prof. Parthasarathi Majumdar of Institute of Mathematical Sciences, Chennai, "there is nothing but pure gravity in the black hole. It has got no definitive structure and can be characterised by three parameters-gravitation, electric charge and angular momentum". Since black holes don't have any definitive structure, till 1970 they were thought to be ice-cold. In 1971 Stephen Hawking, Lucasian Professor of Mathematics, Cambridge University, U.K, discovered the laws concerning black holes and his discovery opened the floodgates of controversy, because the laws had a striking resemblance with classical thermodynamics.

9. Hawking's Laws

Hawking's first law states that acceleration of any particle at every point on the event horizon is the same.

It bears resemblance with temperature, which is constant everywhere for a system in equilibrium.

Hawking's second law states that the area of the event horizon never decreases classically.

It is similar to entropy or disorder which can never decrease as per the second law of thermodynamics.

Bekenstein, a researcher at Princeton, US, at that time, followed it up and declared that a black hole possesses a distinct entropy which equals the area of its event horizon. This sparked off a controversy because it contradicted both classical thermodynamics and Einstein's general theory of relativity.

Thermodynamics stipulates that any object with a temperature above zero in the Kelvin scale will radiate energy. This created a problem for theorists again, for, if nothing can get out of the event horizon how can a black hole radiate energy? In 1975, Stephen Hawking solved this problem through his famous theory in which he showed that black holes too can radiate. He showed that it was possible, as the intense curvature of space-time that is a black hole for it to give rise to electron-positron pairs just outside the event horizon. The positron goes into the black hole while the electron produces the thermal radiation. But a particle enters the black hole with its own entropy, thereby reducing the entropy of the earlier system. This again clearly contradicts classical thermodynamics. Bekenstein solved this problem by reformulating the second law of black hole: the area of the event horizon, together with the entropy of the outside Universe, can never decrease.

According to Heisenberg's uncertainty principle, a pillar of quantum theory, the so-called vacuum of space is not empty but rather foaming with virtual particles that flash into particles in particle-antiparticle pairs on borrowed energy and then meet and annihilate each other in a flash of energy that repays the debt of their energy.

If only one member of a pair fell into the black hole, though, its mate would be free to wander away. To a distant observer it would appear to be coming out of the black hole, and since the energy for its creation had been borrowed from the black hole's gravitational field and not paid back, the black hole would accordingly appear to shrink. As the black hole shrank, it would get hotter and radiate faster, according to Hawking's calculations, until it finally exploded. The mortality of a black hole was of little practical concern. A typical black hole would last 10^{64} years, trillions of times the age of the universe. Black holes are the prima donnas of Einstein's general theory of relativity, the idea explaining the force known as gravity as a warp in space-time caused by matter and energy. Hawking, citing classical physics, argued that an object with entropy had to have a temperature, and anything with a temperature – from a fevered brow to a star – must radiate heat and light with a characteristic spectrum. If a black hole could not radiate, it could have no temperature, and thus have no entropy. But that was before gravity, which shapes the cosmos, met quantity theory, the paradoxical rules that describe the behaviour of matter and forces within it.

A few years back an Indian-born scientist, Abhay Ashtekar, working at Pennsylvania State University, US, used ideas of quantum gravitation to show that the space-time structure outside the event horizon manifests itself like a fishing net. This redefines black hole entropy as the area of the event horizon plus "something else." This extra factor is still being worked out through mathematical calculations.

10. String Theory and Black Hole

In order to enumerate the possible ways of arranging the contents of black hole, physicists needed a theory of what was inside. By the mid-1990s they had one, the string theory, which potrays the forces and particles of Nature, including those responsible for gravity, as tiny vibrating strings. In this theory, the black hole is a tangled variety of strings and multidimensional membranes known as 'D-branes'. In a virtuoso calculation in 1995, Strominger and Cumrun Vafa, also of Harvard, untangled the innards of a so-called "extremal" black hole, in which electrical charges just balanced gravity. Such a hole would stop evaporating and thus would appear static, allowing the researchers to count its quantum states. They calculated the entropy of a black hole was its area divided by four – just as Hawking and Bekenstein said it would be. The result was a huge triumph for string theory. Perhaps the most mysterious and far-reaching consequence of the exploding black hole is the idea that the Universe can be compared to a hologram, in which information for a three-dimensional image can be stored on a flat surface, like an image on a bank card.

11. Huge Black Hole in Milky Way

On the 26 October last year, a tiny patch of darkness in the constellation Sagittarius flashed a brief pulse of X-rays into space, providing compelling evidence that slap-bang in the middle of our Galaxy is one of the weirdest objects known to astronomers: a supermassive black hole. The length and location of the X-ray pulse make it a strong evidence of a black hole at the heart of our Galaxy. The flare was released when something, a comet perhaps, was sucked violently into a black hole, says Frederick Baganoff at the Massachussets Institute of Technology. His team spotted it using the orbiting Chandra X-ray observatory. Astronomers already know that the centre of our Galaxy - a region called Sagittarius A* - weighs about 2.6 million times more than our Sun. According to the astrophysics rule book, general relativity, such a vast mass squeezed into an area so small can mean only one thing: "This has to be a black hole," says Baganoff.

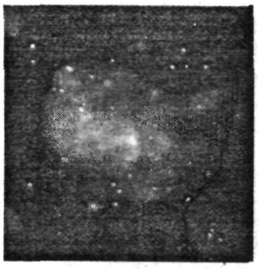


Fig. 7 Hole in one: Sagittarius scores with flare.

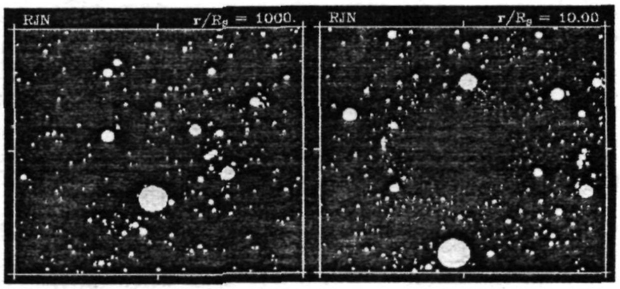


Fig. 8 Too Close to a Black Hole

In Fig. 8, there is a normal star field containing the constellation Orion on the left. Notice the three stars of nearly equal brightness that make up Orion's Belt. On the right is the same star field but this time with a black hole superposed in the center of the frame. The black hole has such strong gravity that light is noticeably bent towards it - causing some very unusual visual distortion. In the distorted frame, every star in the normal frame has at least two bright images - one on each side of the black hole. In fact, near the black hole, you can see the whole sky - light from every direction is bent around and comes back to you. Black holes are thought to be the densest state of matter, and there is indirect evidence for their presence in stellar binary systems and the centers of globular clusters, galaxies, and quasars.

12. The Holy Grail

The Milky Way's black hole has been

described as the 'Holy Grail' of astrophysics. Its edge, the event horizon, "separates our Universe from another world", says Melia. "Some say that when you cross the event horizon, time becomes space and space becomes time." Although Baganoff's observation is extremely convincing, "nature could be fooling us", Melia warns. "It has been cruel to astronomers in the past." The likelihood is vanishingly small, but the X-rays could have come from something behind or in front of Sagittarius A*, Baganoff admits. Baganoff's team used Chandra to stare into the heart of darkness for 14 hours.

13. Conclusion

Recent observations have raised the stakes for ideas like holography and black hole information. The results suggest that the expansion of the Universe is accelerating. If it goes on, astronomers say, distant galaxies will eventually be moving fast that we will not be able to see them anymore. Living in such a Universe is like being surrounded by a horizon, over which information is forever disappearing. And since this horizon has a finite size, physicists say, there is a limit to the amount of complexity and information our Universe can hold, ultimately dooming life. Physicists admit that they do not know how to practice physics or string theory in such a space, called the de Sitter space after the Dutch astronomer, Willem de Sitter, who first solved Einstein's equation to find such a space. "De Sitter space is a new frontier," said Strominger , who hopes that the techniques and the attention that were devoted to black holes in the last decade will enable physicists to make headway in understanding a Universe that may actually represent the human condition.

Timeline of black hole physics

- 1784 - John Michell discusses classical bodies which have escape velocities greater than the speed of light
- 1795 - Pierre Laplace discusses classical bodies which have escape velocities greater than the speed of light
- 1916 - Karl Schwarzschild solves the Einstein vacuum field equations for uncharged spherically symmetric systems
- 1918 - H. Reissner and G. Nordström solve the Einstein-Maxwell field equations for charged spherically symmetric systems
- 1923 - George Birkhoff proves that the Schwarzschild spacetime geometry is the unique spherically symmetric solution of the Einstein vacuum field equations
- 1939 - Robert Oppenheimer and Hartland Snyder calculate the gravitational collapse of a pressure-free homogeneous fluid sphere and find that it cuts itself off from communication with the rest of the universe
- 1963 - Roy Kerr solves the Einstein vacuum field equations for uncharged rotating systems
- 1964 - Roger Penrose proves that an imploding star will necessarily produce a singularity once it has formed an event horizon
- 1965 - Ezra Newman, E. Couch, K. Chinnapared, A. Exton, A. Prakash, and Robert Torrence solve the Einstein-Maxwell field equations for charged rotating systems
- 1968 - Brandon Carter uses Hamilton-Jacobi theory to derive first-order equations of motion for a charged particle moving in the external fields of a Kerr-Newman black hole
- 1969 - Roger Penrose discusses the Penrose process for the extraction of the spin energy from a Kerr black hole

- 1969 - Roger Penrose proposes the cosmic censorship hypothesis
- 1971 - Identification of Cygnus X-1/HDE 226868 as a binary black hole candidate system
- 1972 - Stephen Hawking proves that the area of a classical black hole's event horizon cannot decrease
- 1972 - James Bardeen, Brandon Carter, and Stephen Hawking propose four laws of black hole mechanics in analogy with the laws of thermodynamics
- 1972 - Jacob Bekenstein suggests that black holes have an entropy proportional to their surface area due to information loss effects
- 1974 - Stephen Hawking applies quantum field theory to black hole spacetimes and shows that black holes will radiate particles with a blackbody spectrum which can cause black hole evaporation
- 1989 - Identification of GS2023+338/V404 Cygni as a binary black hole candidate system
- 2002 - Astronomers present evidence for the hypothesis that Sagittarius A* is a supermassive black hole at the centre of the Milky Way galaxy
- 2002 - NASA's Chandra X-ray Observatory identifies double galactic black holes system in merging galaxies NGC 6240.

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> *"The only way to discover the limits of the possible is to go beyond them into the impossible"*
>
> \- Arthur C. Clarke