NEW COSMIC ERA BEGINS – REAL BLACK HOLE IMAGE REVEALED

1. ASTRONOMY

Astronomy (Greek) is a natural science that deals with the study objects positioned in the sky and its phenomena. It incorporates mathematics, physics, and chemistry to explain and analyse the origin of those objects and their evolution which include planets, moons, stars, nebulae, galaxies, comets and the phenomena also includes supernova explosions, gamma ray bursts, quasars, pulsars, and cosmic microwave background radiation. More generally, all phenomena that originate outside Earth's atmosphere are within the scope of the influence of astronomy. A related but distinct subject is physical cosmology, which is the study of the Universe as a whole.

Fig1. Astronomy - Mother of all sciences. Summer Milky way by Neeraj Ladia, SPACE Chennai

1.1 HISTORY

Astronomy is one of the oldest of the natural sciences. The early civilizations in recorded history, such as the Babylonians, Greeks, Indians, Egyptians, Nubians, Iranians, Chinese, Maya, and many ancient indigenous peoples of the Americas, performed methodical observations of the night sky. Historically, astronomy has included disciplines as diverse as astrometry, celestial navigation, observational astronomy, and the making of calendars, but professional astronomy is now often Considered to be synonymous with astrophysics.

Before tools such as the telescope were invented, early study of the stars was conducted using the naked eye. As civilizations developed, most notably in Mesopotamia, Greece, Persia, India, China, Egypt, and Central America, astronomical observatories were assembled and ideas on the nature of the Universe began to develop. Most early astronomy consisted of mapping the positions of the stars and planets, a science now referred to as astrometry. From these observations, early ideas about the motions of the planets were formed, and the nature of the Sun, Moon and the Earth in the Universe were explored philosophically. The Earth was believed to be the centre of the Universe with the Sun, the Moon and the stars rotating around it. This is known as the geocentric model of the Universe, or the Ptolemaic system, named after Ptolemy.

2. BLACK HOLES – A INTRODUCTION

A **black hole** is a region of space-time which exhibits such strong gravitational effects that nothing (i.e.) not even particles and electromagnetic radiation such as light could escape from inside it. The theory of general relativity by Albert Einstein predicts that a sufficiently compact mass can deformation of space-time to form a **black hole**. The boundary of the region from which no escape is possible is called the **event horizon**. A black hole acts like an ideal black body, as it reflects no light.

2.1 BLACK HOLE FORMATION

Black holes of stellar mass are expected to form when very massive stars collapse at the end of their life cycle. After a black hole has formed, it can continue to grow by absorbing mass from its surroundings. By absorbing other stars and merging with other black holes, supermassive black holes of millions of solar masses may form. There is general a general agreement that supermassive black holes exist in the centre of most galaxies.

2.2 BLACK HOLE IDENTIFICATION

Despite of its invisible interior region, the presence of a black hole can be inferred through its interaction with other matter and with electromagnetic radiation such as visible light. Matter that falls onto a black hole can form an external accretion disk heated by friction, forming some of the brightest objects in the universe. If there are other stars orbiting a black hole, their orbits can be used to determine the black hole's mass and location. Such observations can be used to exclude possible alternatives such as neutron stars. In this way, astronomers have identified numerous stellar black hole candidates in binary systems, and established that the radio source known as Sagittarius A*, at the core of the Milky Way galaxy, contains a supermassive black hole of about 4.3 million solar masses.

2.3 PROPERTIES AND STRUCTURE

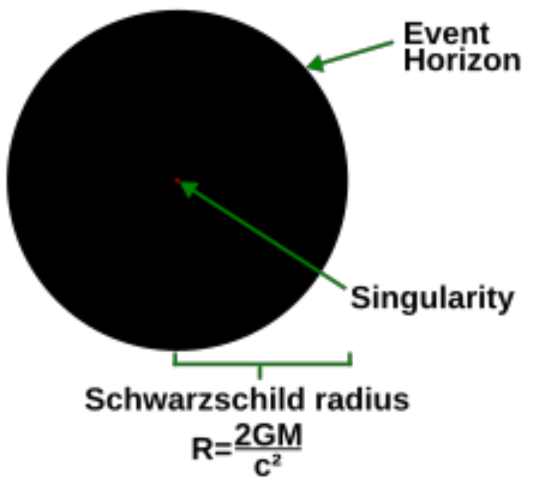

Fig 2. General model of a Black hole

Credits: Wikipedia, A simple illustration of a non-spinning black hole by author sandstorm de, 4th November 2018.

When an object falls into a black hole, any information about the shape of the object or distribution of charge on it is evenly distributed along the horizon of the black hole, and is lost to outside observers. The behaviour of the horizon in this situation is a dissipative system that is closely analogous to that of a conductive stretchy membrane with friction and electrical resistance . This is different from other field theories such as electromagnetism, which do not have any friction or resistivity at the microscopic level, because they are time-reversible. Because a black hole eventually achieves a stable state with only three parameters (i.e.) mass , electric charge and angular momentum, there is no way to avoid losing information about the initial conditions: the gravitational and electric fields of a black hole give very little information about what went in. The information that is lost includes every quantity that cannot be measured far away from the black hole horizon. This behaviour is so puzzling that it has been called the black hole information loss paradox.

**A black hole of a kind supposed to result from the complete gravitational collapse of an electrically neutral and non-rotating body, having a physical singularity at the centre to which in-falling matter inevitably proceeds and at which the curvature of space–time is infinite. A Schwarzschild radius is the radius of the boundary of a hole of this type.*

2.4 EVENT HORIZON

The defining feature of a black hole is the appearance of an event horizon which is a boundary in space-time through which matter and light can only pass inward towards the mass of the black hole. Nothing, not even light, can escape from inside the event horizon. The event horizon is referred to as such because if an event occurs within the boundary, information from that event cannot reach an outside observer, making it impossible to determine if such an event occurred.

At the centre of a black hole, as described by general relativity, may lie a gravitational singularity, a region where the space-time curvature becomes infinite. For a non-rotating black hole, this region takes the shape of a single point and for a rotating black hole, it is smeared out to form a ring singularity that lies in the plane of rotation. In both cases, the singular region has zero volume. It can also be shown that the singular region contains all the mass of the black hole solution. The singular region can thus be thought of as having infinite density.

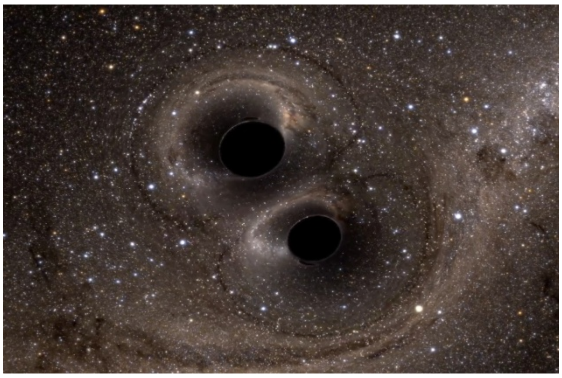

Fig 3. Merging of two black holes

Credits: Computer simulation of colliding black holes. Screenshot: LIGO Lab Caltech/MIT (YouTube)

2.5 GROWTH

Once a black hole has formed, it can continue to grow by absorbing additional matter. Any black hole will continually absorb gas and interstellar dust from its surroundings. This is the primary process through which supermassive black holes seem to have grown. A similar process has been suggested for the formation of intermediate-mass black holes found in globular clusters. Black holes can also merge with other objects such as stars or even other black holes. This is thought to have been important, especially in the early growth of supermassive black holes, which could have formed from the aggregation of many smaller objects. The process has also been proposed as the origin of some intermediate-mass black holes

2.6 EVAPORATION

In 1974, Hawking predicted that black holes are not entirely black but emit small amounts of thermal radiation at a temperature, this effect has become known as Hawking radiation. By applying quantum field theory to a static black hole background, he determined that a black hole should emit particles that display a perfect spectrum. If Hawking's theory of black hole radiation is correct, then black holes are expected to shrink and evaporate over time as they lose mass by the emission of photons and other particles. The temperature of this thermal spectrum (Hawking temperature) is proportional to the surface gravity of the black hole, which, for a Schwarzschild black hole, is inversely proportional to the mass. Hence, large black holes emit less radiation than small black holes

3. FIRST IMAGE OF A BLACK HOLE

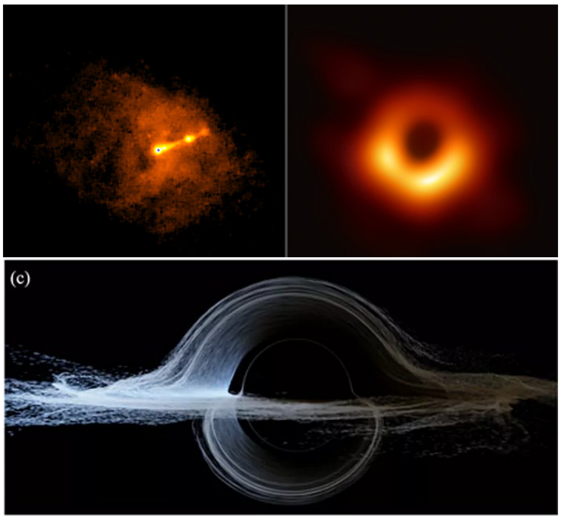

Fig 4. A) Chandra X-RAY B) EHT C)Simulation of a black hole from a paper by Thorne and colleagues

Credit: Credit: X-ray: NASA/CXC/Villanova University/J. Neilsen; Radio: Event Horizon Telescope Collaboration and the simulation of a black hole from a paper by Thorne and colleagues on the CG techniques used to develop Gargantua. (James et al. /Classical and Quantum Gravity)

A world-spanning network of telescopes called the Event Horizon Telescope zoomed in on the supermassive monster in the galaxy M87 to create this first-ever picture of a black hole in 2019.

"We have seen what we thought was unseeable. We have seen and taken a picture of a black hole," Sheperd Doeleman, EHT Director and astrophysicist at the Harvard-Smithsonian Centre for Astrophysics in Cambridge, Mass., said April 10 in Washington, D.C., at one of seven concurrent news conferences. The results were also published in six papers in the *Astrophysical Journal Letters*.

Black holes are extremely camera shy. Luckily, there's a way to "see" a black hole without peering into the abyss itself. Telescopes can look instead for the silhouette* of a black hole's event horizon. That's what the Event Horizon Telescope, or EHT, did in April 2017, collecting data that has now yielded the first image of a supermassive black hole, the one inside the galaxy M87. * *The dark shape and outline of someone or something visible in restricted light against a brighter background.*

3.1 HOW DO THEY DID IT

Creating that first-ever portrait of a black hole is really challenging from Earth, as they appear very faint. The project of imaging M87's black hole required observatories across the globe working in tandem as one virtual Earth-sized radio dish with sharper vision than any single observatory could achieve on its own.

A black hole isn't an easy thing to photograph that even light can't escape their vicinity. By definition, they are invisible. So when the Event Horizon Telescope team released the first image of a black hole, what they really released was an image of the black hole's event horizon which is the minimum distance from the black hole's centre where gravity is still weak enough for light to escape and how they did it is nearly as impressive as the image itself. EHT scientists convinced researchers around the world to point their radio telescopes at a select group of black holes, then combined the observations to create one giant array the size of our planet.

3.2 IMAGING A MONSTER

Generally, the resolution of a telescope depends how small of a target it can see as comes down to its size. The larger the telescope, the more resolving power it has, and the smaller the details it can make out. Radio astronomers can get around this problem by linking together lots of smaller radio dishes into a single array, where they effectively act as one giant telescope. Each dish in the array collects light from a target object, like the glowing disk around a black hole, and converts the radio waves it receives into an electronic signal.

Fig 5.Taken by the Hubble Space Telescope, the image shows a jet of matter blasting from M87.

Credits: Hubble heritage team (aura/stsci), nasa

They then used a computer called a correlator to combine all the electronic signals from the various dishes into what's called an interference pattern. Finally, astronomers tapped a special kind of math (Fourier transforms for the curious) to decode that pattern, showing what the target would look like in the sky if our eyes could see in radio wavelengths.

With an array of radio telescopes, it's the distance between individual dishes, rather than the diameter of a single dish, that determines the array's resolving power. The farther apart two dishes are, the better the resolving power of that array. So, to really crank up the resolution, astronomers combine data from telescopes in entirely different locations, using precise atomic clocks and GPS systems to carefully time the observations and keep everything in sync. The EHT has taken that to a global scale to make a telescope as big as our entire planet. Radio telescopes in Arizona, Hawaii, Mexico, Chile, Spain, and even Antarctica all observed their black hole targets in tandem. With dishes spread as far as possible, the EHT aims for nothing less than the maximum resolution a radio array can get without leaving Earth. Thus the first image of a black hole is revealed.

3.3 EVENT HORIZON TELESCOPE

A network of eight radio telescopes around the world used radio waves to peer through the dust cloud and glimpse the edge of black hole and synchronized their observations of the black holes over 10 days in April, 2017.

Fig.6 Event Horizon Telescope

CREDITS:https://www.sciencenews.org/article/event-horizon-telescope-black-hole-picture

The individual telescopes involved are; ALMA, APEX, the IRAM 30-meter Telescope, the IRAM NOEMA Observatory, the James Clerk Maxwell Telescope (JCMT), the Large Millimetre Telescope (LMT), the Submillimetre Array (SMA), the Submillimetre Telescope (SMT), the South Pole Telescope (SPT), the Kitt Peak Telescope, and the Greenland Telescope (GLT).

3.4 CONCLUSION

Thus the image obtained by EHT is accordance with General theory of relativity by Albert Einstein developed in 1915, having earlier shown that gravity does influence light's motion.

4. REFERENCES

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5. TO READ MORE ON BLACK HOLES

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