The First Sight of Black Holes using the Event Horizon Telescope

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Abstract

Black holes were predicted long ago by scientists like Albert Einstein and Karl Schwarzschild. However, they had never been seen until recently: In 2009, the Event Horizon Telescope was launched. It is a telescope array that consists of a global network of 12 radio telescopes. It was built to observe two supermassive black holes which are Sagittarius A and Messier 87 (M87). On April 10, 2019, the Event Horizon Telescope Collaboration announced taking the first direct image of a black hole. The image featured the massive black hole at the center of Messier 87 galaxy*

Background

The idea of the black hole, a celestial body so massive that even light cannot escape its gravity, was first proposed by John Michell in 1784. After that, Albert Einstein predicted the presence of black holes in his theory of general relativity. The black holes are described using three physical quantities: mass, charge, and angular momentum.

A black hole consists of 6 main parts: the singularity, event horizon, photon sphere, relativistic jet, innermost stable orbit, and accretion disc. The singularity is the point at the center of the black hole where the matter has collapsed into infinite density. The event horizon is the radius around the singularity where matter and energy cannot escape the gravity of the black hole, giving it a black appearance. The photon sphere is a bright ring around the event horizon formed by hot plasma which emits photons. The gravity of the black hole is so strong that it bends the light paths making them appear as a bright ring. The relativistic jets are produced when the black hole feeds on stars, gas, or dust. The innermost stable orbit is the area where matter can orbit the black hole safely without being pulled to the point of no return. The accretion disc is a disc of superheated gas and dust that orbits the black hole. This disc plays an important role in revealing the location of the black hole by emitting electromagnetic radiation.

Messier 87 (M87) is a supermassive black hole located at the center of Messier 87 galaxy. Its mass is billions of times that of our sun at 6.5 ±0.7 ×10^9 M⊙ (solar masses). Although we had done a good bit of research on black holes, all of our information was merely theoretical until April 10, 2019.

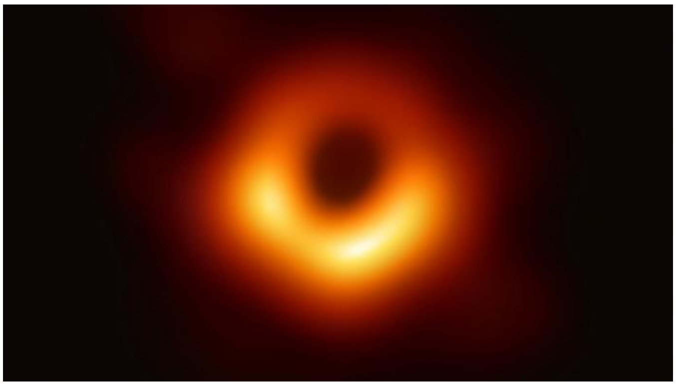

Figure 1: The image of M87 black hole

The Event Horizon Telescope

The Event Horizon Telescope (EHT) was launched in 2009. It is a large telescope array that consists of a global network of radio telescopes around Earth. It combines data collected from several very-long-baseline interferometry stations with high angular resolution that enable it to observe supermassive black holes. The main targets of the Event Horizon Telescope were Sagittarius A*, the black hole at the center of Milky Way galaxy, and M87, the supermassive black hole at the center of the elliptical galaxy Messier 87.

The EHT fielded a global VLBI array of 8 stations spread over 6 geographical locations. These 8 stations are the Atacama Large Millimeter/submillimeter Array and Atacama Pathfinder Experiment telescope in Chile, the Large Millimeter Telescope Alfonso Serrano in Mexico, the IRAM 30 m telescope in Pico Veleta in Spain, the Submillimeter Telescope Observatory in

Arizona, the James Clerk Maxwell Telescope and the Submillimeter Array in Hawaii, and the South Pole Telescope in Antarctica.

Taking the First Picture

Using 1.3mm wavelength, the EHT was able to observe M87 black hole on 2017 April 5, 6, 10, and 11. This was possible due to the good to excellent weather then. The EHT took many scans at night ranging from 7 (April 10) to 25 (April 6). After that, the images were reconstructed using two different classes of algorithms: CLEAN and RML. The CLEAN is an imaging algorithm used to enhance signals from recorded data, thus improving their quality. RML methods improve the fidelity and effective angular resolution of images. After applying CLEAN and RML, the final image, shown in figure 1, was reconstructed and published on April 10, 2019.

Conclusion

Taking the first image of a black hole is an important step towards understanding these celestial objects. Having showed the shadow of M87, the image of the black hole proved that Albert Einstein's assumptions about black holes in his theory of general relativity were correct. After taking said picture, many parameters were determined. Its mass was determined to be 6.5 ×10^9 solar masses. The diameter of its event horizon was calculated to be 40 billion kilometers. Finally, it was found that it rotates clockwise.

Many approaches can be taken to obtain a better image in the future. A better resolution image can be captured by using a shorter wavelength like 0.8 mm. Additionally, using more telescopes could potentially lead to better results. The scientific community hopes that space-based interferometry will provide more precise information in the future

References

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