

Astronomers publish first imagery of Milky Way's central supermassive black hole

Bryan Dyne
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Astronomers have published the first ever imagery of Sagittarius A* (Sgr A*, pronounced “Sagittarius A-star”), confirming the hypothesis developed in the 1980s that this compact radio source is in fact a supermassive black hole that sits at the center of our Milky Way galaxy. The results were presented at press conferences held simultaneously around the world.

The research was done by the Event Horizon Telescope (EHT) Collaboration, a grouping of 300 astronomers and hundreds more support staff at 60 universities and institutions in 20 countries. The observing campaign was conducted in April 2017 using eight telescopes in Europe, South America, North America and Antarctica. Thousands of terabytes of data recorded by the telescopes were analyzed and processed for five years using supercomputers around the world to produce the simple but stunning graphical result.

NASA's Chandra, NuSTAR and Swift telescopes participated in the experiment to complement the EHT's measurements. The space-based observatories are capable of observing in X-ray and gamma ray wavelengths of light, revealing further details about the large-scale clouds of gas and dust interacting with the black hole.

Sgr A* has been studied for many decades. Karl Jansky, one of the founders of the field of radio astronomy, rose to prominence after detecting radio waves emanating from the center of the Milky Way in 1933. In the decades after, further observations discovered that the source of these observations was a very compact object, suggesting a black hole. Further evidence was presented in the early 2000s when a team of physicists led by Reinhard Genzel at the Max Planck Institute reported on a star orbiting a single massive and invisible object, ruling out the possibility of a cluster of

massive dark objects in the galactic core.

Observations of the black hole itself have only been possible thanks to developments in very-long-baseline interferometry. The technique was first developed in the 1960s as a way to combine observations from multiple telescopes in order to emulate a single, larger telescope that is effectively the size of the distance between the two farthest receivers. Over the years, incremental improvements to the technology have allowed astronomers to shrink the wavelengths used in this method from the 1 meter scale down to 1.3 millimeters, with corresponding increases in resolution.

Moreover, since the actual shape of the radio waves have to be recorded and processed, every aspect of the technology needs to improve: the design of the radio telescopes, more precise pointing of the telescopes and the ability to record titanic amounts of data, transmit the data and recombine them. Using advances made in the past 60 years, particularly in fiber optics and atomic clocks, the EHT team was able to take measurements to within a trillionth of a second between observatories that are separated as far as Spain and the South Pole, making a telescope effectively the size of Earth. In doing so, astronomers were able to achieve the necessary precision to directly image the area around the Milky Way's central black hole.

The data presented is the second set of measurements studying the environment immediately surrounding a black hole, particularly of the radiation produced by matter accreting around and eventually spiraling into the super-dense objects. The first such measurements were also taken by the EHT team and released in 2019, showing the region around the central black hole of galaxy Messier 87 (M87). Those results were deemed so significant that the following year, the 2020 Nobel Prize in Physics was awarded for research into black

holes.

One the most important differences of the observations presented yesterday is that the black holes studied have vastly different masses. The black hole in the center of M87 is 6.5 billion times more massive than our Sun and occupies a region of space on the order of the entire Solar System. In comparison, Sgr A* is about 4.1 million times as massive as the Sun and it extends to about the orbit of Mercury, that is, it is 1,600 times smaller in mass and size than the black hole in M87.

The peculiarities of general relativity also mean that the timescales just beyond the event horizon of the two black holes (the point at which light can escape) also differ by a factor of about 1,600. Changes in the structure of the hot gas orbiting the black hole in M87, for example, might take one month. The same changes of the matter orbiting Sgr A* take about 30 minutes, making the neighborhood around the Milky Way's supermassive black hole much more dynamic than that of its larger counterpart.

The rapidity of events in the region around Sgr A*, however, made it much more difficult to study. The researchers had to keep track of how structures were evolving over the course of a night, and individual observations could rarely last more than a few minutes. In addition, the much lower flow of material into this black hole makes for a fainter target, making it even harder to acquire quality data. Whole new computer algorithms had to be developed and tested in order to account for and surmount these hurdles.

Once these technical challenges had been overcome, a whole new physical regime could be visualized. Despite the vast differences in size, mass and inflow into the two black holes now imaged, both show a characteristic image form which can only be explained by the warping of spacetime predicted by Einstein's general relativity. At the same time, the differences between the two black holes confirms the theory holds even under diverse conditions.

The relative quiescence of Sgr A* also provided an opportunity to observe a super-massive black hole in what is likely the normal state of most of these astronomical objects. In doing so, it served as a chance to more deeply understand how they interact with galaxies more generally, how accretion disks are formed and how jets of energy, such as the one being

emitted from the center of M87, are launched.

The data also provided a measurement of the spin of the black hole, its most important property after its mass. The researchers were thus able to test the validity of the so-called Kerr metric, the mathematical description of in the theory of general relativity of a rotating black hole. It was also determined that one of the poles of Sgr A* is pointing more or less at Earth.

And more is to come. Similar to their observations of M87, the EHT astronomers also collected the polarization of the light (the orientation of the electromagnetic waves) emitted from the accretion disk around Sgr A*, which will let them reconstruct the magnetic fields around the black hole and provide further insight into the dynamics of its environment.

The collaboration also announced further work, including data collected this past March using an upgraded network of telescopes that will potentially be used to make movies of black holes in the near future. They are also planning to try to observe black holes in the center of even more distant galaxies, particularly those with large accretion disks and emitting colossal amounts of radiation.

Skeptics of science and its materialist inquiry into nature once dismissed black holes as artifacts of the imagination. But through the growth of human technique and material theory, science now has images of relatively close ones self-illuminated by their diet of gas. Through the equally new field of gravitational wave astronomy, the last decade has also produced recordings of the ripples of their mergers in the distant Universe. These historic advances must animate the confidence of workers in the scientific method as a whole and in turn animate their drive to overturn the current irrational social order—capitalism—and replace it with a society built on internationalist and scientific principles—socialism.



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