# VIEW OF A COSMIC DONUT

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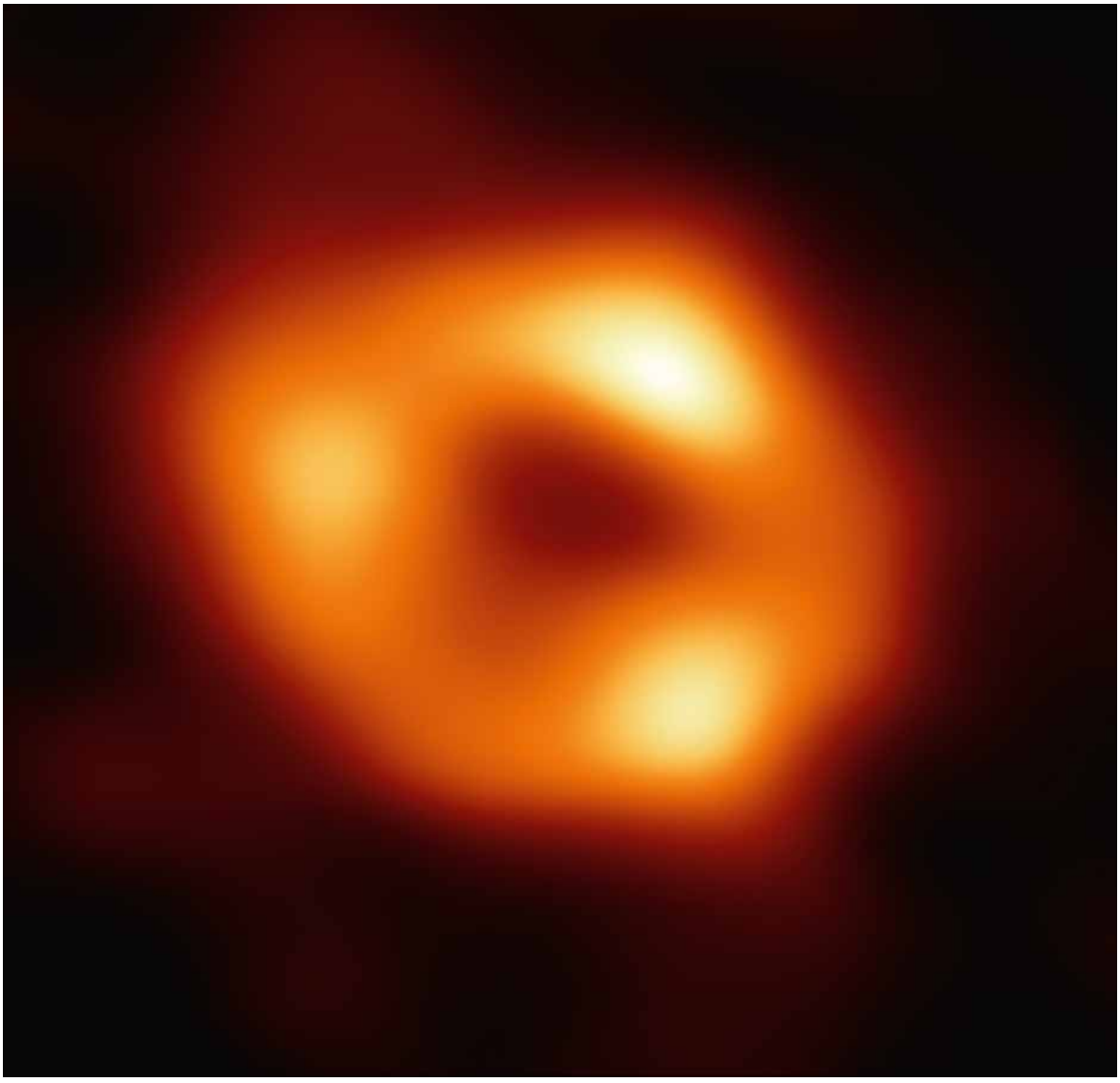

IMAGE: EHT COLLABORATION

Ring of fire in space: this is the first image of Sagittarius A*, the black hole at the center of our Milky Way. It was taken by the Event Horizon Telescope (EHT), which includes the 12-meter Apex telescope of the Max Planck Institute for Radio Astronomy and the 30-meter antenna of the Institut de Radioastronomie Millimétrique (Iram). The image is a false-color rendering and depicts the shadow of the black hole surrounded by a bright, ring-shaped formation of swirling gas.

Sitting deep in the heart of the Milky Way, it is 27,000 light years from Earth and resembles a donut: this is how the black hole at the center of our galaxy looks in the image obtained by researchers using the Event Horizon Telescope (EHT).

Astronomers have been peering into the center of the Milky Way for more than three decades, watching stars orbiting around an invisible, compact, and very massive something. In 2020, Andrea Ghez from the University of California and Reinhard Genzel from the Max Planck Institute for Extraterrestrial Physics were awarded the Nobel Prize for this work.

The researchers' findings, obtained with their precise measurements, have now been confirmed: "Our discovery indicates that the object at the center of the galaxy must indeed be a black hole," explains Anton Zensus, director at the Max Planck Institute for Radio Astronomy and founding chairman of the EHT Supervisory Board. The image is the first direct visual proof of this. The black hole itself is not visible in the image because, by its nature, it does not emit any radiation. But the glowing gas swirling around this cosmic gravity well exhibits a telltale signature – a dark central region ("shadow") surrounded by a bright ring. The immense gravity bends the light, so to speak.

This shadow is about two and a half times the diameter of what is known as the event horizon – the boundary of the black hole past which light is unable to escape. In the sky, its radius looks only the size of a ten-millionth of an arcsecond – the size of a one euro coin on the moon. This indicates that the galactic black hole has a natural diameter of about 24 million kilometers.

To obtain an image of the mass monster, eight radio observatories scattered halfway around the globe were connected to serve as a single virtual telescope the size of the Earth. With this method, which is called interferometry, the researchers were able to observe the dark heart of the Milky Way, which is known as Sagittarius A*, over several nights in April 2017. The individual antennas collected data for many hours at a wavelength of 1.3 millimeters. Two supercomputers – one at the Max Planck Institute for Radio Astronomy, the other at the Haystack Observatory in the United States – analyzed the data.

The latest observation comes on the heels of the first image of a black hole (M 87*) at the center of the galaxy Messier 87 published earlier in 2019. That the images of the two objects resemble each other may be surprising: indeed, M 87* is about 2000 times farther away from us than Sagittarius A*. The black hole in the distant galaxy, however, has a significantly greater mass and thus a diameter 1500 times larger than that in our Milky Way. As a result, the two images in the earthly firmament appear at a similar angle.

Data interpretation for Sagittarius A* was more difficult than for M 87*. Although the gas swirls around each of the two black holes at virtually the same speed – almost as fast as light – it takes weeks to orbit M 87* but only a few minutes to orbit Sagittarius A*. This meant that the brightness and structure of the ring of fire changed very quickly during the observations causing the photo to be "blurred". The solution: the image is not a snapshot of a single moment, but the average of hundreds of images obtained over two days in April 2017 at the Event Horizon Telescope. The data analysis was made even more difficult by the fact that Earth is in the galactic plane and hot gas with charged particles and magnetic fields are "dancing around" in the line of sight.

## Observations confirm the model



The image of Sagittarius A* can be used to test models of how gravity and matter behave in the vicinity of such mass monsters. "Thanks to previous measurements like those made by Reinhard Genzel, we now know both the distance and the mass of the black hole very precisely," says Michael Kramer, director at the Max Planck Institute for Radio Astronomy and one of the leaders of the European Black Hole Cam project that is part of the Event Horizon Telescope. Because of this, it had been possible to calculate the shadow's expected size.

"The value calculated by the EHT team is consistent with the model of a black hole with the mass of four million suns, just as my group determined," says Max Planck Director Genzel, who sees the work of his colleagues as a "wonderful confirmation of our observations." Going forward, he said, the goal is to find out how fast the black hole is rotating. And the pitch of the plane of rotation is also still uncertain, he said.

***www.mpg.de/black-holes***