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Space

First image of our galaxy's black hole

The Event Horizon Telescope collaboration has released the first ever picture of the supermassive black hole at the centre of the Milky Way, reports **Leah Crane**

FOR the first time, scientists have taken a picture of the black hole at the centre of our galaxy. This is the second image of a black hole ever created.

The image was captured by the Event Horizon Telescope (EHT), a network of observatories around the world operating as a single enormous radio telescope. In 2017, EHT observed two supermassive black holes: the one in the Milky Way, which is called Sagittarius A* or Sgr A*, and the one at the centre of the M87 galaxy known as M87*. The image of M87* was released in 2019, and now, after three more years of painstaking data analysis, the collaboration has finally released its picture of Sgr A*.

"It was a bit like trying to take a clear picture of a puppy quickly chasing its tail"

"This is what we wanted to deliver on all along," says EHT researcher Ziri Younsi at University College London. "This is what our black hole looks like."

Black holes don't emit any light, so the image shows the silhouette of Sgr A* against a glowing background of hot plasma swirling around and being pulled into it as part of a structure called an accretion disc.

That process occurs much more quickly with this black hole than with M87*, which is one reason why the new image took so much longer to produce. M87* is one of the largest known black holes in the universe at about 6.5 billion times the mass of the sun, more than 1000 times the mass of Sgr A*. As a result, it takes days to weeks for the plasma around M87* to complete an orbit, whereas it takes only minutes for hot plasma to circle Sgr A*.

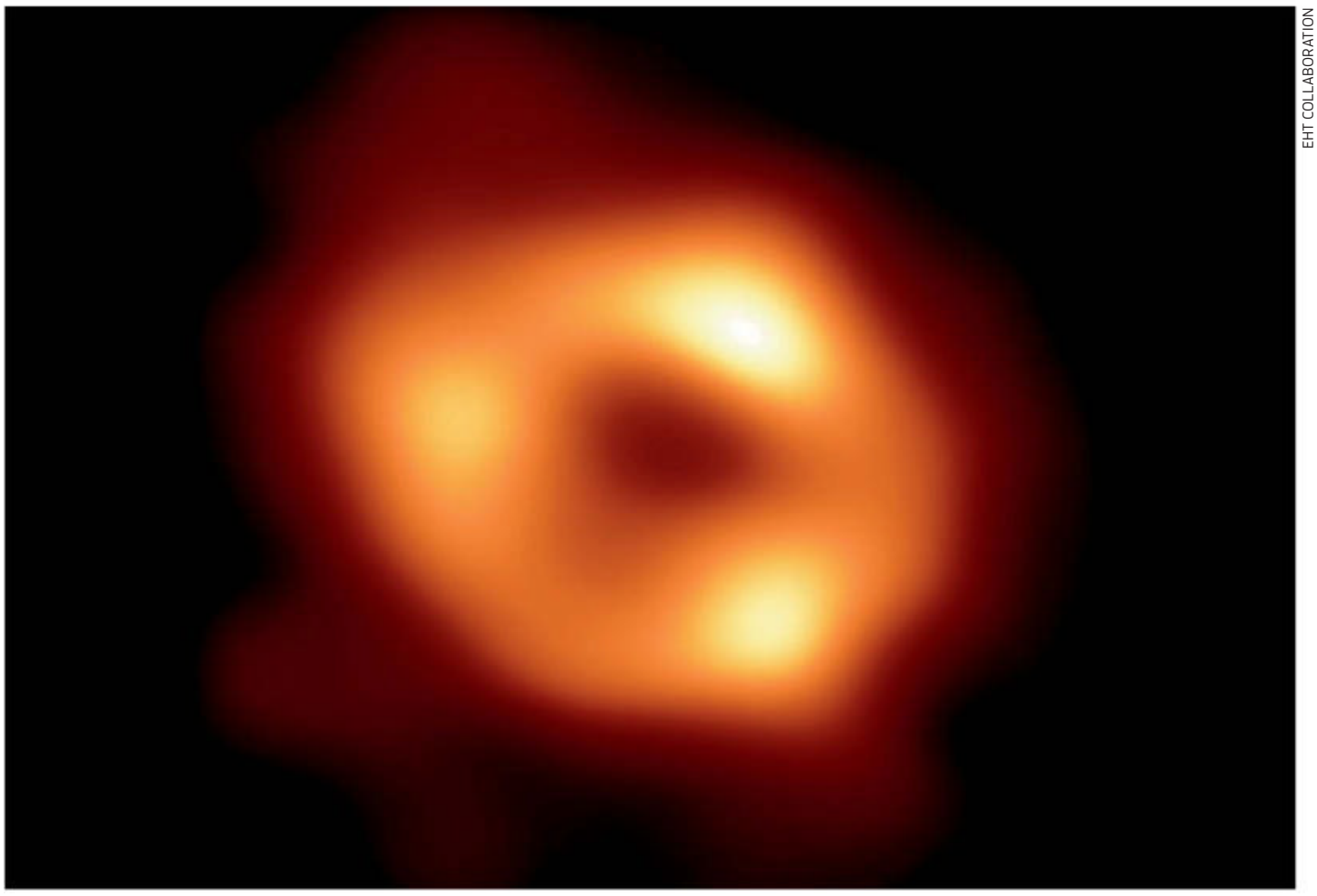
"This means the brightness and pattern of the gas around Sgr A* was changing rapidly as the EHT collaboration was observing it – a bit like trying to take a clear picture of a puppy quickly chasing its tail," said EHT researcher Chi-kwan Chan at the University of Arizona in a statement.

Another difficulty was the fact that Earth sits towards the edge of the Milky Way, so the researchers had to deal with light from all the stars, dust and gas between our planet and Sgr A*. To make the final image, they aggregated many snapshots taken over several nights and used a supercomputer to process the data.

"With M87*, everyone was just elated, but this was a much harder image to make, so everyone was really cautious this time," says Younsi. "We approached it quite a bit more conservatively – everyone had their scientist hats on instead of their party hats, really."

The final image looks remarkably similar to 2019's picture of M87* despite the different sizes and environments of the black holes. "We have two completely different types of galaxies and two very different black hole masses, but close to the edge of these black holes they look amazingly similar," said EHT scientist Sera Markoff at the University of Amsterdam in the Netherlands in a statement. "This tells us that [Albert Einstein's] general relativity governs these objects up close, and any differences we see further away must be due to differences in the material that surrounds the black holes."

The most visible prediction of general relativity is that the ring of light around the black hole ought to be a little lopsided. The gravitational pull of Sgr A*



EHT COLLABORATION

The first image of Sagittarius A*, the supermassive black hole at the centre of our galaxy

2
Number of black holes imaged by the Event Horizon Telescope

5
Years of data analysis it took to produce the above image of Sgr A*

8
Number of observatories around the world used to make the image

is so strong that it bends the light, making the plasma circling towards us appear brighter than that spinning away towards the black hole's backside.

When the researchers compared the image of Sgr A* to a library of hundreds of thousands of simulated black holes modelled in scenarios that don't follow general relativity, they found that Sgr A* appears to hew closely to relativistic models. "One of the things which surprises me personally was just how similar these images are to what theory predicts," says Younsi. "Einstein's doing well, again, and for people who have all their other theories of what gravity could be it might be a little disappointing."

The only thing that doesn't line up with what was expected is that the accretion disc around Sgr A* appears to be tilted out of alignment with the disc of the galaxy. Instead of viewing the black hole and its disc from the side, we appear to be viewing it face-on. It isn't clear why there is this mismatch in the spin axes of the black hole and the Milky Way, but it could be related to ancient events in which Sgr A* may have devoured black holes at the centres of smaller galaxies.

As researchers continue to analyse data from EHT and figure out how the two black holes compare with one another, they also have a new set of observations to examine. Three telescopes were added to the EHT network before the most recent observing campaign in March 2022, which means future pictures should be sharper and should illuminate subtle details in the areas around the black holes (see "What's next for the Event Horizon Telescope?", right). The team is also working on making a video showing how Sgr A* changes over time. ▮

Astronomy

What's next for the Event Horizon Telescope?

NOW that the Event Horizon Telescope (EHT) has taken images of both the Milky Way's black hole, called Sagittarius A* (Sgr A*), and the one at the centre of the M87 galaxy, known as M87*, it is time for the collaboration to move on to new scientific pursuits. So, what is next?

First, the researchers will examine the data they have already collected. The images of Sgr A* and M87* were both assembled from data gathered in 2017, but there have since been two more observation periods, with extra telescopes added to the collaboration's original network of eight.

"Data does exist. We have taken data in 2018 with one additional telescope, [in] 2022 with three additional telescopes, and we are working very, very hard to get that to you… as soon as we possibly can, but I can't make any promises about when," said EHT researcher Lia Medeiros at the Institute for Advanced Study in New Jersey during a 12 May press event. It will probably take years before the results of that analysis are released. "We're not just waiting around to create anticipation, we are very, very hard at work for many years to go from an observation to the image," she said.

The analysis of extra data is expected to clarify the structure of the material around Sgr A*, particularly the three bright "knots" of light seen in the new image. Because of the way the image was made, the bright spots could just be artefacts. "Those knots tend to line up with the directions in which we have more telescopes," said EHT researcher Feryal Özel at the University of Arizona during the press event. "Even though it's natural in theory to expect these brighter spots, we don't trust them in our data that much yet."

While the images are consistent with Albert Einstein's general theory of relativity so far, deeper analysis may give us another check on how that theory might break down in the extreme areas around black holes. "It should give us a hint, at some point, of maybe something different than how we formulate gravity with the theory of general relativity right now," said Özel. "We don't see a crack in that theory yet."

Another major goal of the EHT collaboration is to make videos of Sgr A* and M87* as the material around them moves and changes over time.

"We tried to use the data that we got to try to recover a movie," said EHT researcher Katie Bouman at the California Institute of Technology during the press briefing. Although the researchers do have some data they could use, there currently isn't enough to make movies of the black holes, she said.

"We tried to use the data that made the pictures to recover a movie of a black hole"

The additional telescopes recently added to the array should help with that. These will collect data in multiple wavelengths, which will increase the resolution of the images and could produce colour pictures; the images that have been released up to now have had colour added to indicate brightness.

So far, these two black holes are the only ones we know of that can be imaged by EHT with high enough resolution to see their silhouettes against the light of the hot plasma around them – Sgr A* because of its proximity to Earth, and M87* because of its colossal size.

Work is ongoing to spot other supermassive black holes the researchers could observe and compare with these two. Based on statistical studies, there should be other black holes that are enormous enough and not too distant for the EHT to resolve, but researchers haven't found them yet. ▮ **LC**

ESO/C.MALIN

The ALMA array in Chile is part of the Event Horizon Telescope