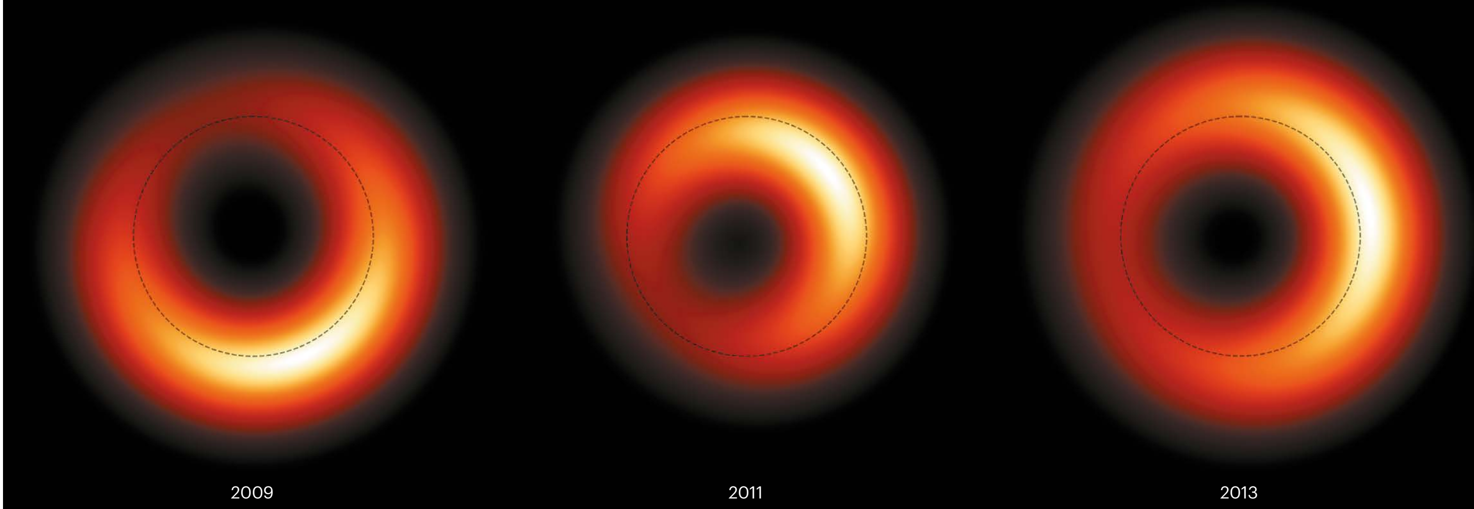
TURBULENT RING

The Event Horizon Telescope team has created a series of images showing the evolution of the black hole M87* over eight years using observational data and mathematical modelling.



EVENT HORIZON TELESCOPE COLLABORATION

The first-ever image of a black hole is now a movie

The historic first image of a black hole unveiled last year has now been turned into a movie. The short sequence of frames shows how the appearance of the black hole's surroundings changes over years as its gravity stirs the material around it into a constant maelstrom.

The images show a lopsided blob of light swirling around the supermassive black hole at the centre of the galaxy M87. To create them, the Event Horizon Telescope (EHT) collaboration — which harnesses a planet-wide network of observatories — exhumed old data on the black hole and combined these with a mathematical model based on the image released in April 2019, to show how the surroundings evolved over eight years. Although it relies partly on guesswork, the result gives astronomers rich insights into the behaviour of black holes, the intense gravity of which sucks in matter and light around them.

"This paper marks a brand new stage in terms of insights into turbulence and the nature of magnetic fields that we believe thread accretion disks," says Priyamvada Natarajan, an astrophysicist at Yale University in New Haven, Connecticut.

The work, which appeared on 23 September in *The Astrophysical Journal*, offers a taste of what the team might be able to do in the near future, as its techniques improve (M. Wielgus *et al. Astrophys. J.* 901, 67; 2020). "In a few years, it could really start to look like a movie," says lead author Maciek Wielgus, a radio astronomer at Harvard University in Cambridge, Massachusetts.

The black-hole image that the EHT collaboration unveiled last year made the front pages of newspapers around the world. It portrayed M87*, the supermassive black hole at the centre of the M87 galaxy, some 17 megaparsecs (55 million light years) away. The researchers constructed the picture by combining radio-frequency signals they had collected from observatories across Earth over two nights in April 2017. The feat has been compared to resolving the shape of a doughnut on the surface of the Moon from Earth.

Although blurry, the image matched the predictions of Albert Einstein's general theory of relativity for what the immediate neighbourhood of a black hole should look like. In particular, it gave researchers the first direct evidence of the shadow of an event horizon, the surface of 'no return' that separates a black hole from its surroundings. This darker disk was set against a ring of light emitted by superheated matter just outside the event horizon.

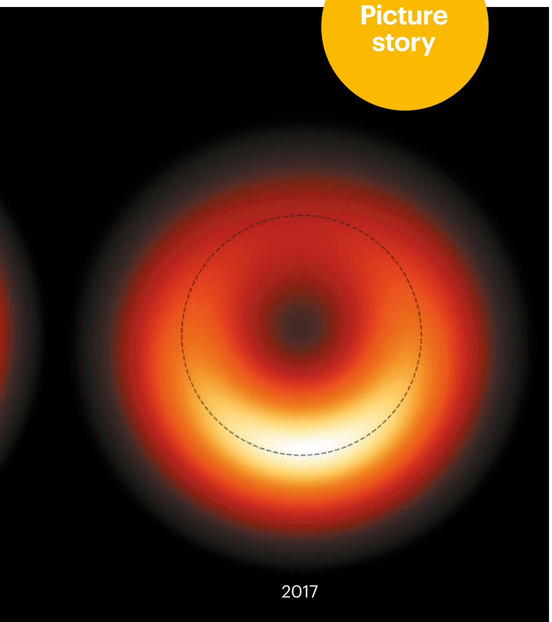
Strikingly, one side of the ring appeared brighter than the other. This was expected, owing to a combination of effects in the complex dynamics around a black hole. In particular, matter falling into the void should spiral at a high velocity outside the black hole's equator, forming what astrophysicists call the accretion disk. The lopsided look is in part to do with the Doppler effect: on the side of the disk that rotates towards the observer, the motion of the matter boosts the radiation, making it look brighter; the opposite happens on receding side.

On the basis of those results, Wielgus wanted to go back and look at the older data from EHT telescopes to see whether he could reinterpret them, using the 2017 picture as a guide. The EHT had been observing M87* since 2009, initially using telescopes at just three locations. As the team added more observatories to the EHT network, the quality of the observations improved. In 2017, the collaboration involved eight observatories that spanned the globe from Hawaii and Chile to Europe and, for the first time, reached the level at which the EHT could produce an actual image.

The older data consisted of four batches, collected in 2009, 2011, 2012 and 2013, two of which had remained unpublished. "To a degree, they were forgotten, because everyone was super-excited about the 2017 data," Wielgus says. With a group of other EHT researchers, he reanalysed the data and found them to be consistent with the results of the 2017 campaign, showing the presence of a dark disk and a bright ring. And although, by themselves, the 2009–13 data batches did not have sufficient resolution to produce pictures, the team was able to generate synthetic images for each of the years by combining the limited data available with a mathematical model of the black hole built from the 2017 data (see 'Turbulent ring').

The results turned out to contain more information than Wielgus expected. Like the 2017 picture, they revealed that one side of the ring was brighter than the other — but that the bright spot moved around. This could be because different regions of the accretion disk became brighter or dimmer, which could enhance or sometimes even

Picture story



cancel out the Doppler brightening.

This was not unexpected, the authors say: although the M87* black hole itself does not change from year to year, the environment around it does. On a scale of several weeks, strong magnetic fields should stir the accretion disk and produce hotter spots that then orbit the black hole. In 2018, a separate team reported evidence of a blob of hot gas circling Sagittarius A*, the Milky Way's central black hole, over the course of around 1 hour. Because M87*, at 6.5 billion times the mass of the Sun, is more than 1,000 times the size of Sagittarius A*, the dynamics around M87* take longer to unfold.

The EHT collaboration attempts to observe M87* and Sagittarius A* every year, in late March or early April. That is when weather conditions are most likely to be good simultaneously at the many sites in its network. The 2020 campaign had to be scrapped because of restrictions owing to the COVID-19 pandemic, but the team hopes to have another chance in 2021. If all goes well, more observatories — including one in Greenland and one in France — will join the effort.

The team also hopes that next year's campaign will include its first global observations using shorter-wavelength radiation. Although more challenging to see through Earth's atmosphere, this would improve the resolution of the EHT images. "We would get even closer to that black-hole shadow, and get sharper images," says EHT member Sara Issaoun, a radio astronomer at Radboud University in Nijmegen, the Netherlands.

By Davide Castelvecchi

ENVIRONMENT RESEARCH IS STILL BEING HUSHED UP, WARN SCIENTISTS

Restrictions on Australian researchers speaking about their work are getting worse, survey finds.

By Dyani Lewis

Environmental scientists in Australia say that they are under increasing pressure from their employers to downplay research findings or avoid communicating them at all. More than half of the respondents to an online survey thought that constraints on speaking publicly on issues such as threatened species, urban development, mining, logging and climate change had become worse in recent years (D. A. Driscoll *et al. Conserv. Lett.* **2020**, e12757; 2020).

The findings, published last month in *Conservation Letters*, reflect how politicized debates about environmental policy in Australia have become, says Saul Cunningham, an environmental scientist at the Australian National University in Canberra. "We need our publicly funded institutions to be more vocal in defending the importance of an independent voice based on research," he says.

Australian scientists aren't the only ones who have reported interference in science or pressure – particularly from government employers – to downplay research findings. Scientists in the United States, Canada and Brazil have also reported such intrusions in the past decade.

Two hundred and twenty scientists in Australia responded to the survey, which was organized by the Ecological Society of Australia and ran from October 2018 until February 2019. Some of the respondents worked in government; others worked in universities or in industry, such as environmental consultancies or non-governmental organizations (see 'Scientists silenced').

SCIENTISTS SILENCED

Roughly one-quarter of environmental scientists have had their work altered by their employer, and one-third have been banned from speaking publicly about their research.