Astronomers image magnetic fields at the edge of M87's black hole

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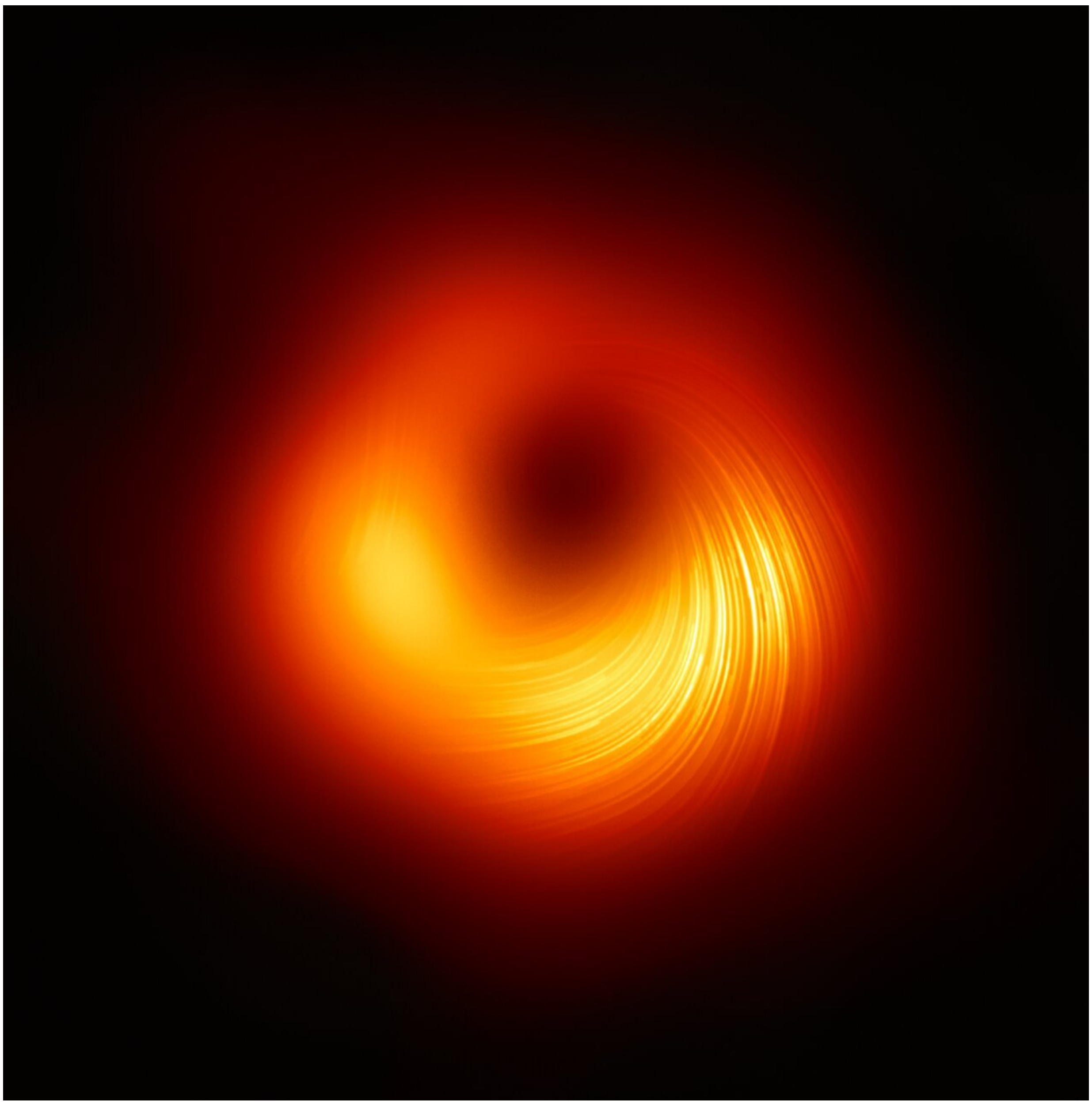


The Event Horizon Telescope (EHT) collaboration, who produced the first ever image of a black hole released in 2019, has today a new view of the massive object at the centre of the Messier 87 (M87) galaxy: how it looks in polarised light. This is the first time astronomers have been able to measure polarisation, a signature of magnetic fields, this close to the edge of a black hole. This image shows the polarised view of the black hole in M87. The lines mark the orientation of polarisation, which is related to the magnetic field around the shadow of the black hole. Credit: EHT Collaboration

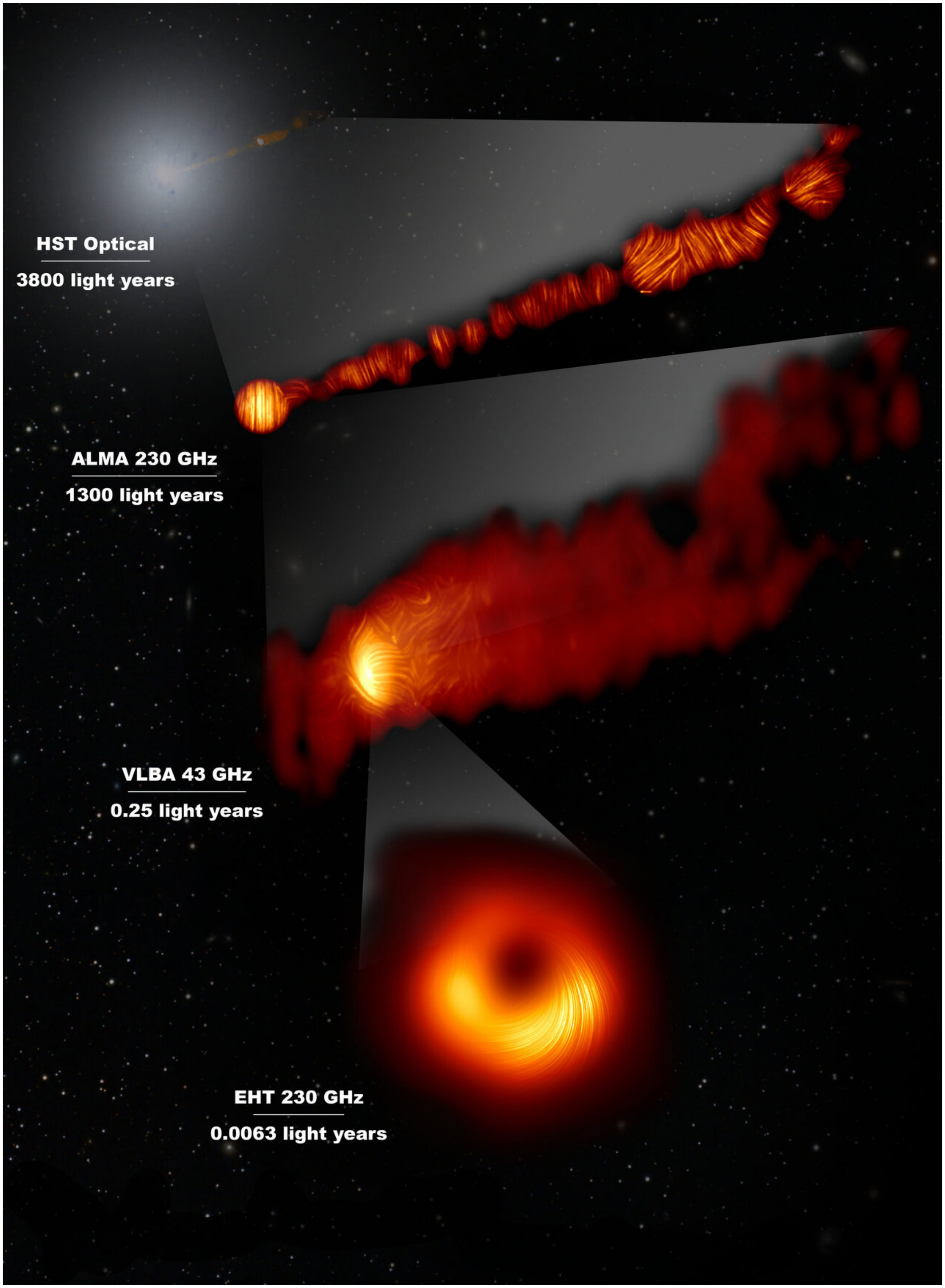
The Event Horizon Telescope (EHT) collaboration, which produced the first-ever image of a black hole, has today revealed a new view of the massive object at the center of the Messier 87 (M87) galaxy: How it looks in polarized light. This is the first time astronomers have been able to measure polarization, a signature of magnetic fields, this close to the edge of a black hole. The observations are key to explaining how the M87 galaxy, located 55 million light-years away, is able to launch energetic jets from its core.

"We are now seeing the next crucial piece of evidence to understand how magnetic fields behave around black holes, and how activity in this very compact region of space can drive powerful jets that extend far beyond the galaxy," says Monika Moscibrodzka, Coordinator of the EHT Polarimetry Working Group and Assistant Professor at Radboud University in the Netherlands.

On 10 April 2019, scientists released the first image of a black hole, revealing a bright ring-like structure with a dark central region—the black hole's shadow. Since then, the EHT collaboration has delved deeper into the data on the supermassive object at the heart of the M87 galaxy collected in 2017. They have discovered that a significant fraction of the light around the M87 black hole is polarized.

"This work is a major milestone: The polarization of light carries information that allows us to better understand the physics behind the image we saw in April 2019, which was not possible before," explains Iván Martí-Vidal, also coordinator of the EHT Polarimetry Working Group and GenT distinguished researcher at the University of Valencia, Spain. He says, "Unveiling this new polarized light image required years of work due to the complex techniques involved in obtaining and analyzing the data."

Light becomes polarized when it goes through certain filters, like the lenses of polarized sunglasses, or when it is emitted in hot regions of space where magnetic fields are present. In the same way that polarized sunglasses improve vision by reducing reflections and glare from bright surfaces, astronomers can sharpen their view of the region around the black hole by looking at how the light originating from it is polarized. Specifically, polarization allows astronomers to map the magnetic field lines present at the inner edge of the black hole.


HST Optical
3800 light years
ALMA 230 GHz
1300 light years
VLBA 43 GHz
0.25 light years
EHT 230 GHz
0.0063 light years

This composite image shows three views of the central region of the Messier 87 (M87) galaxy in polarised light and one view, in the visible wavelength, taken with the Hubble Space Telescope. The galaxy has a supermassive black hole at its centre and is famous for its jets, that extend far beyond the galaxy. The Hubble image at the top captures a part of the jet some 6000 light years in size. One of the polarised-light images, obtained with the Chile-based Atacama Large Millimeter/submillimeter Array (ALMA), in which ESO is a partner, shows part of the jet in polarised light. This image captures the part of the jet, with a size of 6000 light years, closer to the centre of the galaxy. The other polarised light images zoom in closer to the supermassive black hole: the middle view covers a region about one light year in size and was obtained with the National Radio Astronomy Observatory's Very Long Baseline Array (VLBA) in the US. The most zoomed-in view was obtained by linking eight telescopes around the world to create a virtual Earth-sized telescope, the Event Horizon Telescope or EHT. This allows astronomers to see very close to the supermassive black hole, into the region where the jets are launched. The lines mark the orientation of polarisation, which is related to the magnetic field in the regions imaged. The ALMA data provides a description of the magnetic field structure along the jet. Therefore the combined information from the EHT and ALMA allows astronomers to investigate the role of magnetic fields from the vicinity of the event horizon (as probed with the EHT on light-day scales) to far beyond the M87 galaxy along its powerful jets (as probed with ALMA on scales of thousand of light-years). The values in GHz refer to the frequencies of light at which the different observations were made. The horizontal lines show the scale (in light years) of each of the individual images. Credit: EHT Collaboration; ALMA (ESO/NAOJ/NRAO), Goddi et al.; NASA, ESA and the Hubble Heritage Team (STScI/AURA); VLBA (NRAO), Kravchenko et al.; J. C. Algaba, I. Martí-Vidal

"The newly published polarized images are key to understanding how the magnetic field allows the black hole to 'eat' matter and launch powerful jets," says EHT collaboration member Andrew Chael, a NASA Hubble Fellow at the Princeton Center for Theoretical Science and the Princeton Gravity Initiative in the US.

The bright jets of energy and matter that emerge from M87's core and extend at least 5,000 light-years from its center are one of the galaxy's most mysterious and energetic features. Most matter lying close to the edge of a black hole falls in. However, some of the surrounding particles escape moments before capture and are blown far out into space in the form of jets.

Astronomers have relied on models of matter behavior near the black hole to better understand this process. But they still don't know exactly how jets larger than the galaxy itself are launched from its central region, which is comparable in size to the solar system, nor how, exactly, matter falls into the black hole. With the new EHT image of the black hole and its shadow in polarized light, astronomers managed for the first time to look into the region just outside the black hole where this interplay between matter flowing in and being ejected out is happening.

The observations provide new information about the structure of the magnetic fields just outside the black hole. The team found that only theoretical models featuring strongly magnetized gas can explain what they are seeing at the event horizon.

"The observations suggest that the magnetic fields at the black hole's edge are strong enough to push back on the hot gas and help it resist gravity's pull. Only the gas that slips through the field can spiral inward to the event horizon," explains Jason Dexter, assistant professor at the University of Colorado Boulder, US, and coordinator of the EHT Theory Working Group.

To observe the heart of the M87 galaxy, the collaboration linked eight telescopes around the world—including the northern Chile-based Atacama Large Millimeter/submillimeter Array and the Atacama Pathfinder EXperiment, in which the European Southern Observatory (ESO) is a partner—to create a virtual Earth-sized telescope, the EHT.

The impressive resolution obtained with the EHT is equivalent to that needed to measure the length of a credit card on the surface of the moon.

"With ALMA and APEX, which through their southern location enhance the image quality by adding geographical spread to the EHT network, European scientists were able to play a central role in the research," says Ciska Kemper, European ALMA Program Scientist at ESO. "With its 66 antennas, ALMA dominates the overall signal collection in polarized light, while APEX has been essential for the calibration of the image."

"ALMA data were also crucial to calibrate, image and interpret the EHT observations, providing tight constraints on the theoretical models that explain how matter behaves near the black hole event horizon," adds Ciriaco Goddi, a scientist at Radboud University and Leiden Observatory, the Netherlands, who led an accompanying study that relied only on ALMA observations.

The EHT setup allowed the team to directly observe the black hole shadow and the ring of light around it. The new polarized-light image clearly shows that the ring is magnetized. The results are published today in two separate papers in *Astrophysical Journal Letters* by the EHT collaboration. The research involved over 300 researchers from multiple organizations and universities worldwide.

"The EHT is making rapid advancements, with technological upgrades being done to the network and new observatories being added. We expect future EHT observations to reveal more accurately the magnetic field structure around the black hole and to tell us more about the physics of the hot gas in this region," concludes EHT collaboration member Jongho Park, an East Asian Core Observatories Association Fellow at the Academia Sinica Institute of Astronomy and Astrophysics in Taipei.

This research was presented in two papers by the EHT collaboration published today in The *Astrophysical Journal Letters*: "First M87 Event Horizon Telescope Results VII: Polarization of the Ring" (DOI: 10.3847/2041-8213/abe71d) and "First M87 Event Horizon Telescope Results VIII: Magnetic Field Structure Near The Event Horizon" (DOI: 10.3847/2041-8213/abe4de). Accompanying research is presented in the paper "Polarimetric properties of Event Horizon Telescope targets from ALMA" (DOI: 10.3847/2041-8213/abee6a) by Goddi, Martí-Vidal, Messias, and the EHT collaboration, which has been accepted for publication in The *Astrophysical Journal Letters*.

More information: Research papers:

Paper VII - www.eso.org/public/archives/re … eso2105/eso2105a.pdf

Paper VIII - www.eso.org/public/archives/re … eso2105/eso2105b.pdf

Goddi et al. - www.eso.org/public/archives/re … eso2105/eso2105c.pdf

Provided by ESO

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