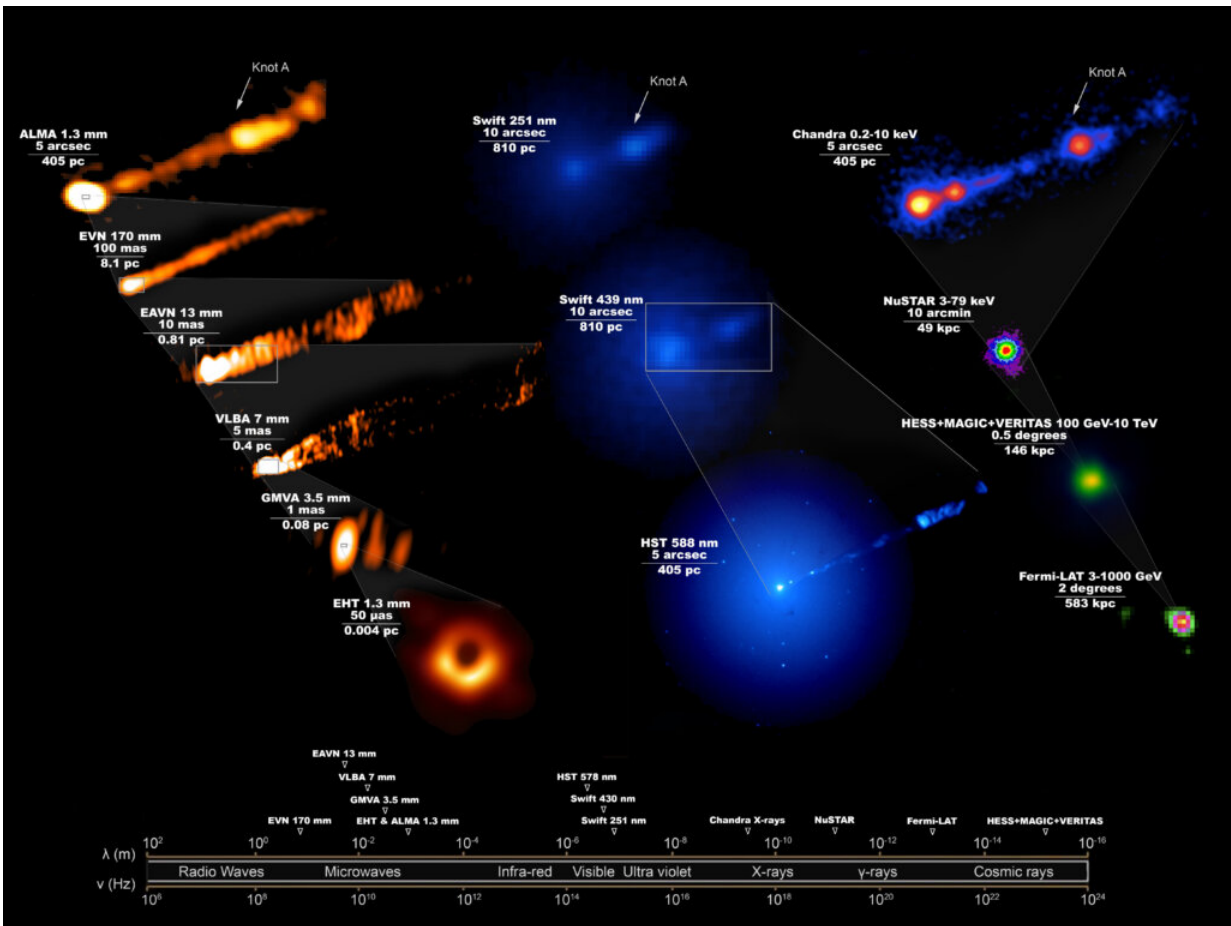


Telescopes unite in unprecedented observations of famous black hole

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To better understand the black hole at the core of galaxy M87, the EHT Collaboration mounted a multi-wavelength observing campaign. Observations across the electromagnetic spectrum in radio, visible-light, ultraviolet, X-ray, and gamma-ray revealed the far-reaching impact of the supermassive black hole on its surroundings. Credit: EHT Collaboration; NASA/Swift; NASA/Fermi; Caltech-NuSTAR; CXC; CfA-VERITAS; MAGIC; HESS

In April 2019, scientists released the first image of a black hole in galaxy M87 using the Event Horizon Telescope (EHT). However, that remarkable achievement was just the beginning of the science story to be told.

[Data from 19](#) observatories released today promise to give unparalleled insight into this black hole and the system it powers, and to improve tests of Einstein's General Theory of Relativity.

"We knew that the first direct image of a black hole would be groundbreaking," says Kazuhiro Hada of the National Astronomical Observatory of Japan, a co-author of a new study published in *The Astrophysical Journal Letters* that describes the large set of data. "But to get the most out of this remarkable image, we need to know everything we can about the black hole's behavior at that time by observing over the entire electromagnetic spectrum."

The immense gravitational pull of a supermassive black hole can power jets of particles that travel at almost the speed of light across vast distances. M87's jets produce light spanning the entire electromagnetic spectrum, from radio waves to visible light to gamma rays. This pattern is different for each black hole. Identifying this pattern gives crucial insight into a black hole's properties—for example, its spin and energy output—but is a challenge because the pattern changes with time.

Scientists compensated for this variability by coordinating observations with many of the world's most powerful telescopes on the ground and in space, collecting light from across the spectrum. These 2017 observations were the largest simultaneous observing campaign ever undertaken on a supermassive black hole with jets.

Three observatories managed by the Center for Astrophysics | Harvard & Smithsonian participated in the landmark campaign: the Submillimeter Array (SMA) in Hilo, Hawaii; the space-based Chandra X-ray Observatory; and the Very Energetic Radiation Imaging Telescope Array System (VERITAS) in southern Arizona.

Beginning with the EHT's now iconic image of M87, a new video takes viewers on a journey through the data from each telescope. Each consecutive frame shows data across many factors of ten in scale, both of wavelengths of light and physical size.

The sequence begins with the April 2019 image of the black hole. It then moves through images from other radio telescope arrays from around the globe (SMA), moving outward in the field of view during each step. Next, the view changes to telescopes that detect visible light, ultraviolet light, and X-rays (Chandra). The screen splits to show how these images, which cover the same amount of the sky at the same time, compare to one another. The sequence finishes by showing what gamma-ray telescopes on the ground (VERITAS), and Fermi in space, detect from this black hole and its jet.

Each telescope delivers different information about the behavior and impact of the 6.5-billion-solar-mass black hole at the center of M87, which is located about 55 million light-years from Earth.

"There are multiple groups eager to see if their models are a match for these rich observations, and we're excited to see the whole community use this public data set to help us better understand the deep links between black holes and their jets," says co-author Daryl Haggard of McGill University in Montreal, Canada.

The data were collected by a team of 760 scientists and engineers from nearly 200 institutions, spanning 32 countries or regions, and using

observatories funded by agencies and institutions around the globe. The observations were concentrated from the end of March to the middle of April 2017.

"This incredible set of observations includes many of the world's best telescopes," says co-author Juan Carlos Algaba of the University of Malaya in Kuala Lumpur, Malaysia. "This is a wonderful example of astronomers around the world working together in the pursuit of science."

The first results show that the intensity of the light produced by material around M87's supermassive black hole was the lowest that had ever been observed. This produced ideal conditions for viewing the 'shadow' of the black hole, as well as being able to isolate the light from regions close to the event horizon from those tens of thousands of light-years away from the black hole.

The combination of data from these telescopes, and current (and future) EHT observations, will allow scientists to conduct important lines of investigation into some of astrophysics' most significant and challenging fields of study. For example, scientists plan to use these data to improve tests of Einstein's Theory of General Relativity. Currently, uncertainties about the material rotating around the black hole and being blasted away in jets, in particular the properties that determine the emitted light, represent a major hurdle for these General Relativity tests.

A related question that is addressed by today's study concerns the origin of energetic particles called "cosmic rays," which continually bombard the Earth from outer space. Their energies can be a million times higher than what can be produced in the most powerful accelerator on Earth, the Large Hadron Collider. The huge jets launched from black holes, like the ones shown in today's images, are thought to be the most likely source of the highest energy cosmic rays, but there are many questions

about the details, including the precise locations where the particles get accelerated. Because cosmic rays produce light via their collisions, the highest-energy gamma rays can pinpoint this location, and the new study indicates that these gamma-rays are likely not produced near the event horizon—at least not in 2017. A key to settling this debate will be comparison to the observations from 2018, and the new data being collected this week.

"Understanding the particle acceleration is really central to our understanding of both the EHT image as well as the jets, in all their 'colors'," says co-author Sera Markoff from the University of Amsterdam. "These jets manage to transport energy released by the black hole out to scales larger than the host galaxy, like a huge power cord. Our results will help us calculate the amount of power carried, and the effect the black hole's jets have on its environment."

The release of this new treasure trove of data coincides with the EHT's 2021 observing run, which leverages a worldwide array of radio dishes, the first since 2018. Last year's campaign was canceled because of the COVID-19 pandemic, and the previous year was suspended because of unforeseen technical problems. This very week, for six nights, EHT astronomers are targeting several supermassive black holes: the one in M87 again, the one in our Galaxy called Sagittarius A*, and several more distant black holes. Compared to 2017, the array has been improved by adding three more radio telescopes: the Greenland Telescope, the Kitt Peak 12-meter Telescope in Arizona, and the NOthern Extended Millimeter Array (NOEMA) in France.

"With the release of these data, combined with the resumption of observing and an improved EHT, we know many exciting new results are on the horizon," says co-author Mislav Balokovic of Yale University.

"I'm really excited to see these results come out, along with my fellow

colleagues working on the SMA, some of whom were directly involved in collecting some of the data for this spectacular view into M87," says co-author Garrett Keating, a Submillimeter Array project scientist. "And with the results of Sagittarius A*—the massive black hole at the center of the Milky Way—coming out soon, and the resumption of observing this year, we are looking forward to even more amazing results with the EHT for years to come."

More information: J. C. Algaba et al. Broadband Multi-wavelength Properties of M87 during the 2017 Event Horizon Telescope Campaign, *The Astrophysical Journal Letters* (2021). [DOI: 10.3847/2041-8213/abef71](https://doi.org/10.3847/2041-8213/abef71)

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