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Pressemitteilung

Max-Planck-Institut für Radioastronomie
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27.08.2024
http://idw-online.de/de/news838699

Forschungsergebnisse
Physik / Astronomie
überregional

Max-Planck-Institut
für Radioastronomie

# A New Milestone in Sharpness

**The Event Horizon Telescope (EHT) recently imaged the shadows around the supermassive black holes in M 87 and Sgr A* at a wavelength of 1.3mm. Since angular resolution increases with decreasing observing wavelength, observations at a shorter wavelength provide an even sharper view into the immediate surroundings of black holes. A new publication on results of a VLBI pilot experiment of EHT telescopes mutually observing at the short wavelength of 0.87 mm now demonstrates the technical feasibility and sets a new record in angular resolution for ground-based radio-interferometry. This achievement opens up a new window for the study of black holes and the origin of radio-jets.**

The Event Horizon Telescope combines radio telescopes across the world to make images of supermassive black holes and their immediate surroundings. These black holes reside at the centers of galaxies and are subject to the most extreme physical conditions in the Universe. The higher the angular resolution of a telescope, the more details it can reveal, providing a unique opportunity to look at the 'unknown' and to test existing models and ideas of black holes and the matter they swallow.

The Event Horizon Telescope (EHT) Collaboration, in collaboration with the Atacama Large Millimeter/sub-millimeter Array ALMA, has conducted new observations yielding the highest resolution ever obtained in Astronomy from the Earth's surface. They achieved this by the detection of light from distant galaxies at a frequency of around 345 GHz, equivalent to a wavelength of 0.87 mm. The Collaboration estimates that they will soon be able to make black hole images 50% more detailed than was possible before, bringing the regions just outside the event horizon of nearby supermassive black holes into sharper focus. They also will be able to produce images of more black holes than they have imaged thus far. The new detections, obtained within a first pilot experiment, were published today in The Astronomical Journal.

The experiment was performed during October 18-21, 2018, on two nights, triggered at a time, when the weather and water vapor content of the atmosphere was suitable for VLBI at this short wavelength. The observations were performed with two groups of telescopes: an eastern sub-array comprising ALMA, APEX, the GLT, IRAM-30m, and NOEMA (one antenna). The western sub-array consisted of ALMA, APEX, the GLT, and the Sub-millimeter Array (SMA) in Hawaii. The two sub-arrays observed in two nights different sets radio-sources (so called blazars), sources which were selected to be bright and compact enough. The interferometric signals of 5 blazars were detected on baseline lengths of up to 9500 km with signal-to-noise ratios of up to ~70. At 0.87 mm, the full EHT with all telescopes participating, could then see details as fine as 13 micro-arcseconds, equivalent to seeing a fruit juice bottle cap on the Moon from the Earth. This means that, at 0.87 mm, the EHT will be able to make images in the near future with a resolution about 50% higher than that of previously released M87* and Sgr A* 1.3-mm images, opening up a new observing window to study black holes.

"With the EHT, we saw the first images of black holes by detecting radio waves at a wavelength of 1.3 mm, but the bright ring we saw, formed by light bending in the black hole's gravity still looked blurry because we were at the absolute limits of how sharp we could make the images," said first author Alexander Raymond, previously at Harvard | Smithsonian

(CfA) and now at NASA's Jet Propulsion Laboratory. "At 0.87 mm, our images will be sharper and more detailed, which in turn will likely reveal new properties, both those that were previously predicted and maybe some that weren't."

EHT Founding Director Sheperd Doeleman, astrophysicist at the CfA and study co-lead adds: "Looking at changes in the surrounding gas at different wavelengths will help us solve the mystery of how black holes attract and accrete matter, and how they can launch powerful jets that stream over galactic distances."

"It was a true challenge to push the VLBI capabilities of APEX to this higher frequency. I am grateful to the entire APEX team, with whom we work so closely together and which allows perform these successful observations", says Alan Roy from MPIFR, the project scientist for mm-VLBI at the APEX telescope.

"With these new observational capabilities we can study the 'shadows' of black holes in greater detail, allowing more accurate measurements of their size and shape, which directly relates to the curvature of space-time near the black hole", says Thomas Krichbaum, co-author from MPIfR, and initiator of mm-VLBI at APEX more than a decade ago. "In addition, there's potential to observe more distant, smaller and fainter black holes beyond the two objects the EHT Collaboration has imaged thus far", he adds. In this context the regular participation of the most sensitive antennas, like ALMA and NOEMA are very important.

This is the first time that the VLBI technique has been successfully used at 0.87 mm wavelength. While the ability to observe the night sky at 0.87 mm existed before the new detections, using the VLBI technique at this wavelength has long presented challenges that took time and technological advances to overcome. For example, water vapor in the atmosphere absorbs radio waves at 0.87 mm much more than it does at 1.3 mm, making it more difficult for radio telescopes to receive signals from black holes at the shorter wavelength. The key was to improve the sensitivity of the EHT by increasing the observing bandwidth of the instrumentation and waiting for good weather at all sites.

"The only way to further improve the angular resolution, and hence the sharpness of images from ground-based radio telescopes has been to observe at radio wavelengths shorter than 1 millimeter. This has been a huge challenge, but our continually improving observing techniques have made it possible. This opens up a new avenue for exciting discoveries", concludes Anton Zensus, Founding Chair of the EHT collaboration and director at the MPIfR.

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Additional Information

The EHT collaboration involves more than 400 researchers from Africa, Asia, Europe, North and South America, with around 270 participating in this paper. The international collaboration aims to capture the most detailed images of black holes using a virtual Earth-sized telescope. Supported by considerable international efforts, the EHT links existing telescopes using novel techniques to create a fundamentally new instrument with the highest angular resolving power that has yet been achieved.

The EHT consortium consists of 13 stakeholder institutes; the Academia Sinica Institute of Astronomy and Astrophysics, the University of Arizona, the Center for Astrophysics | Harvard & Smithsonian, the University of Chicago, the East Asian Observatory, the Goethe University Frankfurt, the Institut de Radioastronomie Millimétrique, the Large Millimeter Telescope, the Max Planck Institute for Radio Astronomy, the MIT Haystack Observatory, the National Astronomical Observatory of Japan, the Perimeter Institute for Theoretical Physics, and the Radboud University.

The telescopes participating in this endeavor include ALMA, APEX, the IRAM 30-meter Telescope, the IRAM NOEMA Observatory, the James Clerk Maxwell Telescope (JCMT), the Large Millimeter Telescope (LMT), the Submillimeter Array (SMA), the Submillimeter Telescope (SMT), the South Pole Telescope (SPT), the Kitt Peak Telescope (KP), and the Greenland Telescope (GLT). Data have been post-processed at correlator facilities at the MPIfR in Bonn, Germany and MIT/Haystack Observatory in Westford, MA, USA. Further analysis was performed in the framework of the global EHT collaboration.

IRAM is an international research organization for millimeter and submillimeter astronomy supported by the CNRS (France), the Max-Planck Gesellschaft (Germany), and the IGN (Spain). The organization operates two world-class research facilities, the IRAM 30-meter telescope in Spain, and NOEMA (Northern Extended Millimeter Array), the largest millimeter interferometer of the northern hemisphere, in the French Alps.

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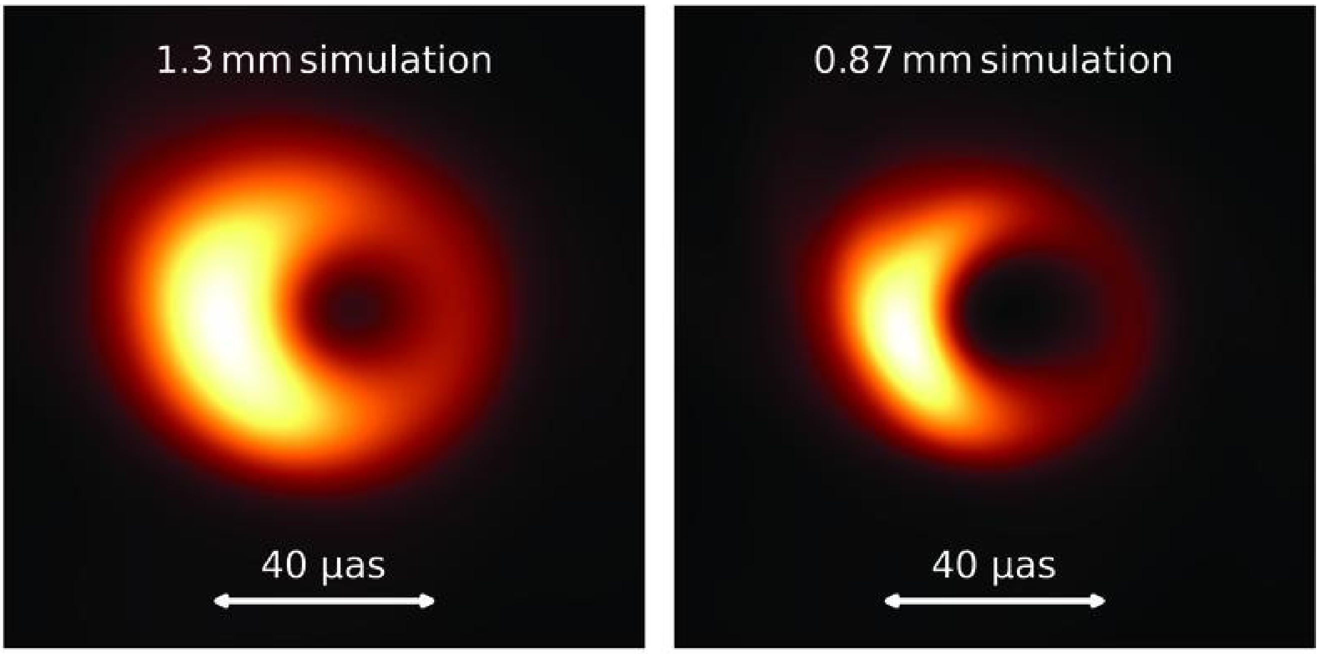
Originalpublikation:

Alexander W. Raymond et al.: First Very Long Baseline Interferometry Detections at 870μm, Astronomical Journal, August 2024, DOI: 10.3847/1538-3881/ad5bdb

https://iopscience.iop.org/journal/1538-3881

Preprint: https://cloud.mpifr-bonn.mpg.de/index.php/s/55ZLeP23kqicogE

URL zur Pressemitteilung: https://www.mpifr-bonn.mpg.de/pressreleases/2024/9




Computer simulated images of the Event Horizon scale emission around a black hole resembling Sgr A* at observing wavelength of 1.3 mm (left) and 0.87 mm (right). At the shorter wavelength the shadow of the black hole appears sharper and more prominent.
Christian Fromm, Julius Maximilian University, Würzburg, Germany


Observatories participating in a pilot experiment conducted by the EHT Collaboration at a wavelength of 0.87 mm. By observing radio emission at this short wavelength, the highest resolution ever obtained from the surface of the Earth was achieved.
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