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Moving towards a close-up of a black hole and its jets

After taking the first images of black holes, the ground-breaking Event Horizon Telescope and the Global mm-VLBI Array poised to reveal how black holes launch powerful jets into space. Now, a research team led by scientists from the Onsala Space Observatory, the University Würzburg and the Max Planck Institute for Radio Astronomy has shown that the EHT will be able to make exciting images of a supermassive black hole and its jets in the galaxy NGC 1052. The measurements, made with interconnected radio telescopes, also confirm strong magnetic fields close to the black hole's edge.

How do supermassive black holes launch galaxy-size streams of high-energy particles – known as jets – into space at almost light-speed? Scientists have now taken an important step towards being able to answer this question, with intricate measurements of the centre of the galaxy NGC 1052, at a distance of 60 million light years from Earth in the direction of the constellation Cetus (the whale).

The research team made coordinated measurements using several radio telescopes, providing new insights into the workings of a galaxy and its supermassive black hole in the centre. Included are arrays of radio telescopes defining the Event Horizon Telescope (EHT) at 1.3 mm wavelength and the Global mm-VLBI Array (GMVA) at 3.5 mm. The technique which connects these telescopes is called very-long-baseline interferometry (VLBI).

"The centre of this galaxy, NGC 1052, is a promising target for imaging with the Event Horizon Telescope, but it's faint, complex and more challenging than all other sources we've attempted so far," says Anne-Kathrin Baczko, the main author of the publication. She is an astronomer at Onsala Space Observatory, Chalmers, and also affiliated to the Max-Planck-Institut für Radioastronomie (MPIfR).

The publication is the culmination of more than eight years of work, originally conceived at the Julius-Maximilians-Universität Würzburg (JMU) by Matthias Kadler in collaboration with Eduardo Ros at MPIfR and then continued during the PhD thesis of Anne-Kathrin Baczko in Bonn under their joint supervision.

The galaxy NGC 1052 hosts a supermassive black hole of about 150 million solar masses that is the source of two powerful jets which stretch thousands of light years outwards through space.

"We want to study not only the black hole itself and its extreme environment, but also the origin of the twin jets emanating from it. We have used the opportunity provided by GMVA and EHT to target a particularly important and key object, in the crossroads of different types of active galaxy," says Eduardo Ros from MPIfR, a member of the research team.

The team made measurements using just five of the telescopes in the EHT's global network – including ALMA (the Atacama Large Millimeter/submillimeter Array) in Chile, in a configuration that would allow the best possible estimate of its potential for future observations, and supplemented with measurements from other telescopes including the

GMVA.

“For such a faint and unknown target, we were not sure if we would get any data at all. But the strategy worked, thanks in particular to the sensitivity of ALMA and complementary data from many other telescopes,” says Anne-Kathrin Baczko.

The scientists are now certain that successful imaging will be possible in the future, thanks to two new key findings. "Our results show that the region around the black hole where the twin jets form is large enough to be imaged with mm-VLBI observations. And it emits at exactly the right frequency of radio waves to take advantage of the strengths of the next generation of VLBI networks," says Matthias Kadler from the JMU Würzburg.

From their measurements, the scientists have also estimated the strength of the magnetic field close to the black hole’s event horizon. The field strength, 2.6 tesla, is about 400 times stronger than the Earth’s magnetic field. That’s consistent with previous estimates for this galaxy.

“This is such a powerful magnetic field that we think it can probably stop matter from falling into the black hole. That in turn can help to launch the galaxy’s two jets,” says Christian Fromm, also from JMU Würzburg, and affiliated to the MPIfR.

Even though the source is as challenging as this, the future looks bright as radio astronomers prepare for much enhanced telescope networks such as the forthcoming NRAO’s new-generation Very Large Array (ngVLA) and future 1.3 mm arrays, with new antennas and improved equipment.

The new measurements give a clearer idea of how the innermost centre of the galaxy shines at different wavelengths. Its spectrum is bright enough at millimetre wavelengths yielding the very sharpest images and is even brighter around wavelength 2.3 mm, which makes it a prime target for the next generation of radio telescopes.

“Thanks to instruments like the EHT and the GMVA, we are now making remarkable observations that show the great progress in radio astronomy through technological innovation and international collaboration. Measurements at NGC 1052, ranging from magnetic field strength to black hole environments, are providing valuable insights into the processes of jet formation and accretion,’ says Anton Zensus, founding chair of the EHT collaboration and director at MPIfR. ‘With new telescopes and the next generation of networks, we will further deepen our understanding of these fascinating cosmic phenomena.”

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 measurements of NGC 1052 were made by five telescopes in the EHT network: ALMA (the Atacama Large Millimeter/submillimeter Array) in Chile, the IRAM 30-metre telescope in Spain; the James Clerk Maxwell Telescope (JCMT) and the Submillimeter Array (SMA) in Hawaii; and the South Pole Telescope (SPT) in Antarctica. These were supplemented with measurements from 14 other radio telescopes in the GMVA network (Global Millimetre VLBI Array), in Spain, Finland and Germany, including the 100-metre Effelsberg radio telescope, the 20-metre telescope at Onsala Space Observatory, Sweden, and the telescopes of the VLBA (Very Long Baseline Array) in the US.

Researchers affiliated with the Max Planck Institut für Radioastronomie, include Anne-Kathrin Baczko, the first author (main affiliation: Onsala Space Observatory, Chalmers University of Technology), and also Eduardo Ros, Christian M. Fromm, Maciek Wielgus, Thomas P. Krichbaum, Michael Janssen,Walter Alef, Rebecca Azulay, Uwe Bach, Silke Britzen, Gregory Desvignes, Sergio A. Dzib, Ralph Eatough, Ramesh Karuppusamy, Dong-Jin Kim, Joana A. Kramer, Michael Kramer, Jun Liu, Kuo Liu, Andrei P. Lobanov, Ru-sen Lu, Nicholas R. MacDonald, Nicola Marchili, Karl M. Menten, Cornelia Müller, Hendrik Müller, Aristeidis Noutsos, Gisela Ortiz-Leon, Georgios Filippos Paraschos, Felix Poetzl, Helge Rottmann, Alan L. Roy, Tuomas Savolainen, Lijing Shao, Pablo Torne, Efthalia Traianou, Jan Wagner, Robert Wharton, Gunther Witzel, J. Anton Zensus, and Guang-Yao Zhao.

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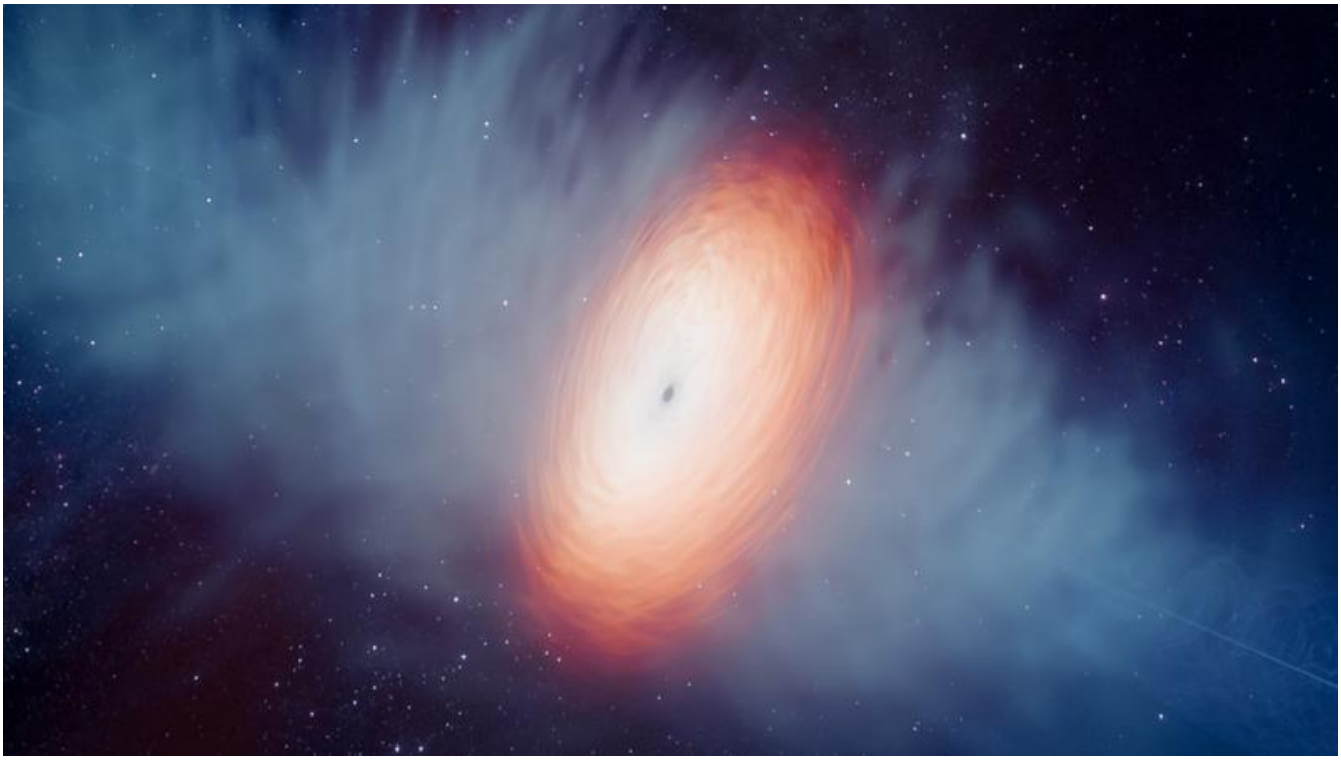
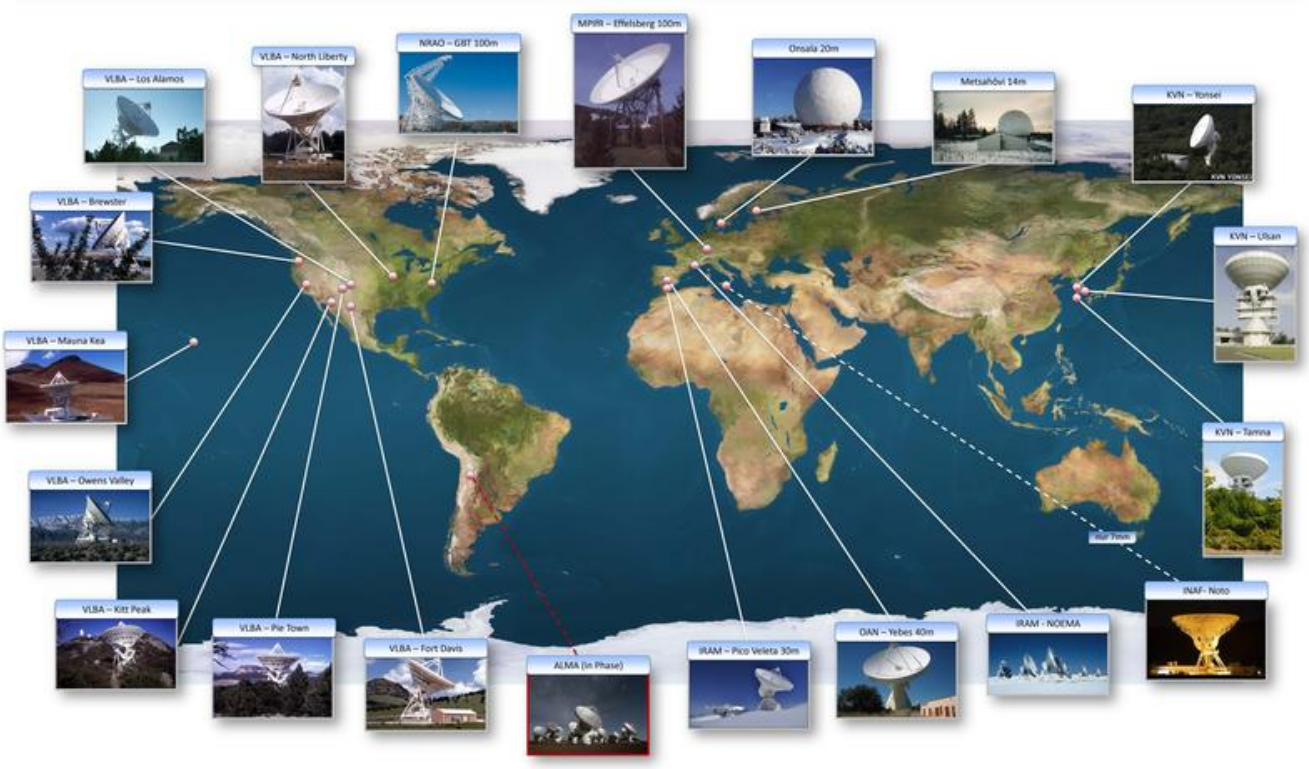


Artist's impression of the centre of galaxy NGC 1052, almost revealing the central supermassive black hole. New measurements now show that the final close-up of the black hole – and the origin of its jets – are within the reach of the EHT.
Chalmers University of Technology | 3dVision | Johan Bournonville | Anne-Kathrin Baczko



The Global mm-VLBI Array (GMVA), utilized for the observations of galaxy NGC 1052 at 3.5 mm wavelength. The 100-m Effelsberg telescope plays an important role within the GMVA.
Compilation: Helge Rottmann / MPIfR