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GMRT helps discover longest-ever black hole jets in a remote galaxy 7.5 billion light-years away.

A team of international astronomers has used the GMRT to discover the biggest pair of plasma jets that has ever been seen to emanate from a supermassive black hole, spanning a size of 23 million light-years from end to end. The size of the jets is more than a hundred times the size of the Milky Way: "This pair is not just the size of a solar system, or a galaxy; we are talking about 140 Milky Way diameters!" says Martijn Oei, a postdoctoral scholar at the California Institute of Technology (Caltech) and the lead author of a new Nature paper reporting the findings.

The jet megastructure, nicknamed Porphyrion after a giant in Greek mythology, dates to a time when our universe was 6.3 billion years old. These powerful outflows—with a total power output equivalent to trillions of Suns—shoot out from either side of a supermassive black hole at the heart of a remote galaxy. "In the center of every major galaxy, there is a big black hole of about a million to a billion solar masses," Oei explains. "It swallows stars, dust, and plasma, basically everything that comes close, but a small fraction of the material that comes close to the black hole is ejected outward in the form of such jets."

The gigantic jet system is one of thousands of faint megastructures originally found using Europe's LOFAR (LOw Frequency ARray) radio telescope. "The existence of these giants was known before we started the campaign, but we had no idea that there would turn out to be so many," says Martin Hardcastle, second author of the study and a professor of astrophysics at the University of Hertfordshire in England.

To determine the length of the jets, a powerful radio telescope was needed that could trace the jets back to the galaxy from which they emerged. This is where the GMRT comes in. Oei's team used sensitive, high-resolution GMRT observations to identify the host galaxy that spawns the jets. Once the host was identified using the GMRT, the researchers then used the Keck I optical telescope in Hawaii to obtain the distance. Porphyrion is 7.5 billion light-years from Earth, which means it existed when our universe was less than half its present age of 13.8 billion years. Without the precise position provided by the GMRT observations, it would have been impossible to identify the optical host galaxy and to determine the giant extent of the radio megastructure.

"Up until now, these giant jet systems appeared to be a phenomenon of the recent universe," Oei says. "But the universe was smaller in the past and the wispy filaments of the cosmic web that crisscrosses the space between galaxies were closer together, which means that Porphyrion and its siblings from that distant epoch had an extreme reach across the baby cosmic web." In fact, the diameter of the sphere of influence of Porphyrion's black hole is a third of a cosmic void, where voids are the vast empty stretches of space between the filaments. "If jets can reach the scale of the cosmic web, then no place in the universe is remote enough to guarantee safety from black hole activity," Oei says.

Having a greater reach implies the jumbo jets could also have a wider influence on nearby galaxies. "We believe that galaxies and their central supermassive black holes co-evolve, and one key aspect of this is that they put out huge amounts of energy in the form of jets that can affect the growth of their host galaxies and other galaxies near them," says co-author George Djorgovski, professor of astronomy and data science at Caltech. "This discovery shows that their effects can extend much further out than we thought."

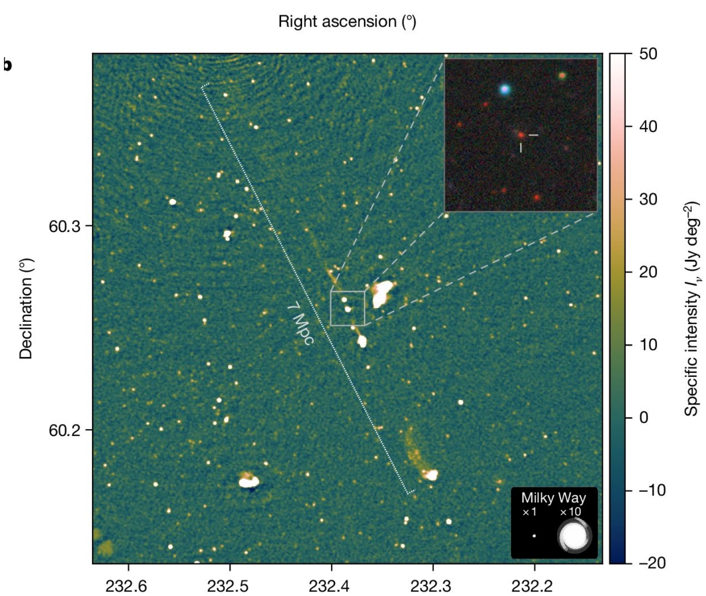
"We may be looking at the tip of the iceberg," Oei says. "Our LOFAR survey only covered 15 percent of the sky. And most of these giant jets are likely difficult to spot, so we believe there are many more of these behemoths out there." The triumvirate of telescopes — LOFAR, GMRT and Keck— working in tandem could discover many more giants like Porphyrion in the years to come.

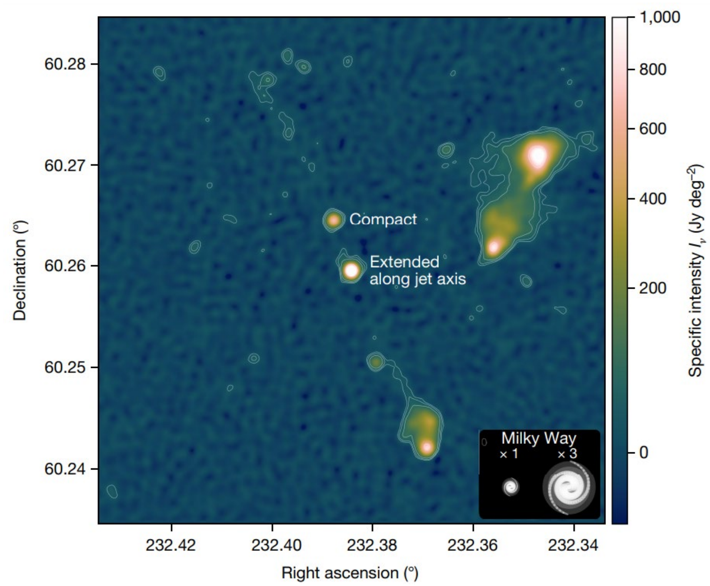
How the jets can extend so far beyond their host galaxies without destabilizing is still unclear. "Martijn's work has shown us that there isn't anything particularly special about the environments of these giant sources that causes them to reach those large sizes," says Hardcastle, who is an expert in the physics of black hole jets. "My interpretation is that we need an unusually long-lived and stable jet around the central supermassive black hole to allow it to be active for so long—about a billion years—and to ensure that the jets keep pointing in the same direction over all of that time. What we're learning from the large number of giants is that this must be a relatively common occurrence."

As a next step, Oei wants to better understand how these megastructures influence their surroundings. Oei is specifically interested in finding out the extent to which these giant jets spread magnetism. "The magnetism on our planet allows life to thrive, so we want to understand how it came to be," he says. "We know magnetism starts in the cosmic web, then makes its way into galaxies and stars, and eventually to planets, but where does it start? Have these giant jets spread magnetism through the cosmos?"

The study of supermassive black hole jets in radio galaxies has been an area of research where the GMRT has made several important contributions over the last two decades. The discovery of Porphyrion is another achievement for the GMRT in this active area of research in astrophysics.

The Nature study, "Black hole jets on the scale of the cosmic web," appeared in the September 18, 2024 issue of the prestigious journal Nature. (doi:10.1038/s41586-024-07879-y)





Figures: Left panel: uGMRT image at a wavelength of 46cm with a resolution of 4.3 arcseconds. Right panel: The uGMRT image of the central region at a higher resolution of 3.6 arcseconds.
Image credits: Martin Oei.

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