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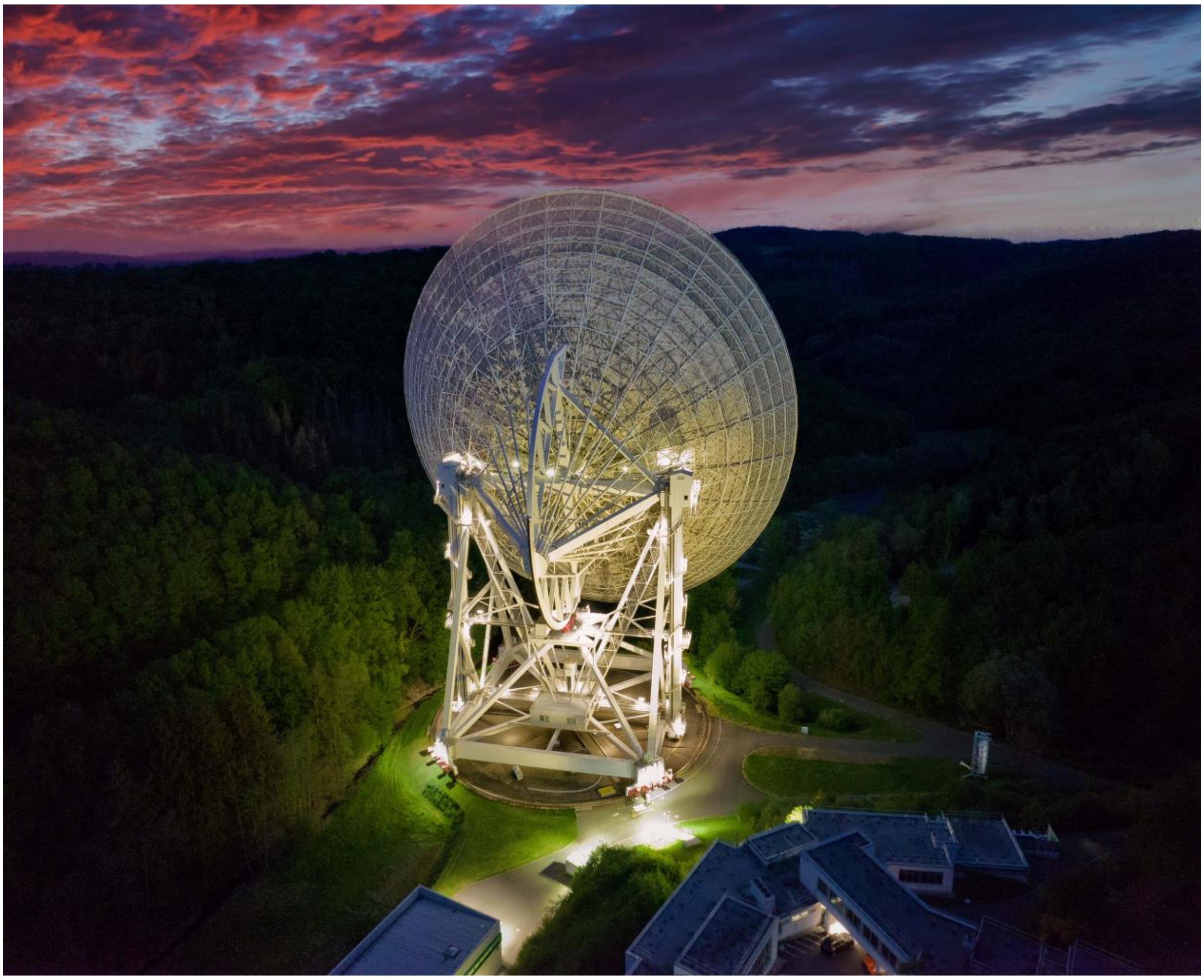

Call for proposals

Deadline Sep 29, 2022, UT 15.00

Observing proposals are invited for the Effelsberg 100-meter Radio Telescope of the Max Planck Institute for Radio Astronomy (MPIfR).

The Effelsberg telescope is one of the World's largest fully steerable instruments. This extreme-precision antenna is used exclusively for research in radio astronomy, both as a stand-alone instrument as well as for Very Long Baseline Interferometry (VLBI) experiments.

Access to the telescope is open to all qualified astronomers. Use of the instrument by scientists from outside the MPIfR is strongly encouraged. The institute can provide support and advice on project preparation, observation, and data analysis.
The directors of the institute make observing time available to applicants based on the recommendations of the Program Committee for Effelsberg (PKE), which judges the scientific merit (and technical feasibility) of the observing requests.

Information about the telescope, its receivers and backends and the Program Committee can be found at
http://www.mpifr-bonn.mpg.de/effelsberg/astronomers
(potential observers are especially encouraged to visit the wiki pages!).

Observing modes

Possible observing modes include spectral line, continuum, and pulsar observations as well as VLBI. Available backends are several FFT spectrometers (with up to 65536 channels per subband/polarization), a digital continuum backend, a number of polarimeters, several pulsar systems (coherent and incoherent dedispersion), and two VLBI terminals (dBBC and RDBE type with MK6 recorders).

Receiving systems cover the frequency range from 0.3 to 96 GHz. The actual availability of the receivers depends on technical circumstances and proposal pressure. For a description of the receivers see the web pages.

Please note, that observing proposals for the new Phased-Array-Feed cannot yet accepted – the system is still being commissioned.

How to submit

Applicants should use the NorthStar proposal tool for preparation and submission of their observing requests. North Star is reachable at https://northstar.mpifr-bonn.mpg.de .

For VLBI proposals special rules apply. For proposals which request Effelsberg as part of the European VLBI Network (EVN) see:
http://www.evlbi.org/proposals/ .

Information on proposals for the Global mm-VLBI network can be found at
http://www3.mpifr-bonn.mpg.de/div/vlbi/globalmm/index.html .

Other proposals which ask for Effelsberg plus (an)other antenna(s) should be submitted twice, one to the MPIfR and a second to the institute(s) operating the other telescope(s) (eg. to NRAO for the VLBA).

Important Remarks

Please note, that the Effelsberg Programme Committee (PKE) is composed of several scientist with different backgrounds. It is hence advisable to write the proposals in a way that they could be understood by readers who are not working in the particular field.

Furthermore, it should be noted that all proposals are treated confidentially. Therefore, it is not necessary to withhold or obscure information, which on the contrary might lead to a downgrading of the proposal.

The following deadlines will be on Feb 2nd, 2023 and on Jun 1st, 2023

Opticon-RadioNet-Pilot Transnational Access Programme

The new Opticon-RadioNet-Pilot (ORP) project (see http://www.orp-h2020.eu) includes a coherent set of Transnational Access (TA) programs aimed at significantly improving the access of European astronomers to the major astronomical infrastructures that exist in, or are owned and run by, European organizations.

Astronomers who are based in the EU and the Associated States but are not affiliated to a German astronomical institute, may also receive personal aid from the Transnational Access (TA) Program of the ORP. This will entail free access to the telescope, as well as financial support of travel and accommodation expenses for one of the proposal team members to visit the Effelsberg telescope for observations.

One – in exceptional cases more – scientists who are going to Effelsberg for observations can be supported, if the User Group Leader (i.e., the PI – a User

Group is a team of one or more researchers) and the majority of the users work in (a) country(ies) other than the country where the installation is located.

Only user groups that are allowed to disseminate the results they have generated under this program may benefit from the access.

For more details see http://www.orp-h2020.eu/TA-VA .

After completion of their observations, TA supported scientists are required to submit their feedback to the ORP project management and the EU. Publications based on these observations should be acknowledged accordingly:

The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004719 [ORP].

by Alex Kraus

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Unraveling Pulsar Twinkling

Three-year monitoring of scintillating pulsar B1508+55 has revealed dramatic variations and enabled precision measurements of the scattering geometry

Scintillation is caused by multipath propagation through the interstellar medium. As approximate point sources, pulsars emit spatially coherent radiation, which makes them twinkle like stars in the night sky or the lights of a distant city. These strong variations in flux are a nuisance to pulsar timing, but for astronomers in the field of scintillometry they offer precise information on tiny turbulent regions within the interstellar medium.

The findings of a team of scientists consisting of Tim Sprenger, Robert Main, Olaf Wucknitz, Geetam Mall, and Jason Wu, who are all affiliated with the MPIfR, are published in a paper in "Monthly Notices of the Royal Astronomical Society" in August 2022.

Scintillation manifests in a "criss-cross" interference pattern when the flux of the pulsar is integrated over its pulses and plotted over time and frequency. In order to resolve the small contiguous patches of power – the so-called "scintles" – often tens of thousands of frequency channels are needed. In its high demand on spectral resolution and its usual disregard for details in the pulse profile, scintillation observations and data processing often differ significantly from pulsar timing.

Another difference comes from the fact that the important information lies in the Fourier domain, which is called the secondary spectrum. In this space, the complicated interference pattern greatly simplifies to an ordered structure, directly mapping the distribution of scattered paths. Long observations are needed to fully characterise the scintillation pattern in time, and individual scattering structures could be tracked over months. This pulsar is circumpolar at the 100-m telescope in Effelsberg, which provided ideal conditions. Contrary to most pulsars, the secondary spectra of B1508+55 showed horizontal "stripes" on top of the ordered scattering structures, which defy an explanation by usual scattering. To explain this enigmatic feature was one motivation for this study.

The pulsar B1508+55 has the highest known transverse velocity, moving at almost one thousand kilometers per second along the sky, while rotating with a period of three quarters of a second. During the 7000 years radio waves need to travel from the pulsar through the interstellar medium to Effelsberg, they cross at least one region of increased scattering, previously located to a distance of about 400 light years by Olaf Wucknitz in 2018 via observations with the Low-Frequency Array, of which one station is located at Effelsberg. Each scattered path has a different optical path length, which results in delays of the time of arrival. Olaf Wucknitz showed that for B1508+55 these delays are large enough such that visible echoes are trailing the main pulse. At low frequencies structures of a hundred times larger size are observed due to larger bending angles. The echoes could be located as scattered images on the sky using very long baseline interferometry. Intriguingly, the pulsar was on a direct path to cross one of them at some point in 2020, which was a major motivation to observe the same regions in small-scale view as offered by higher frequencies at Effelsberg.

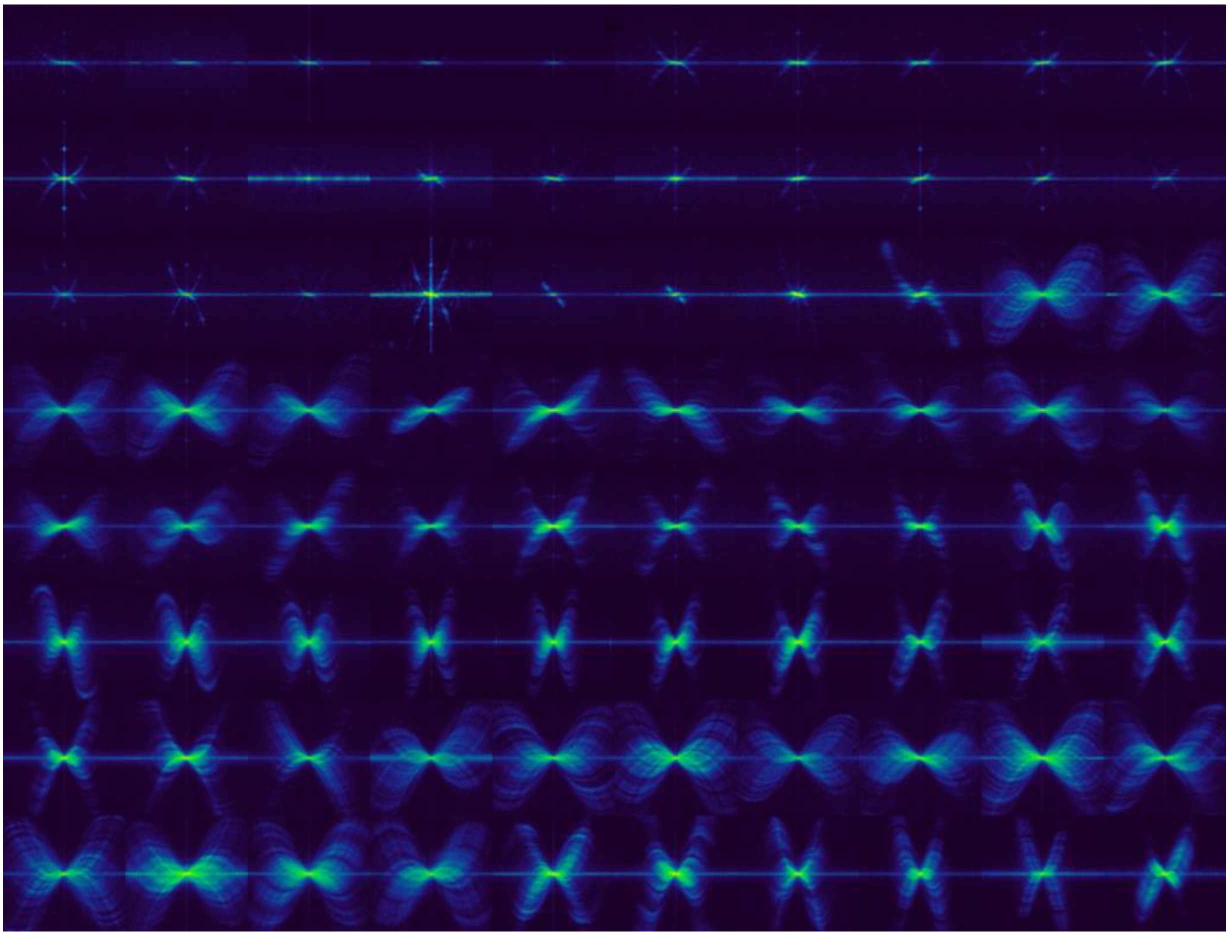


Fig 1: *Scintillation arcs of 80 observations conducted at Effelsberg. These spectra resemble holographic images of scattered paths of radio wave propagation.*
© Tim Sprenger

Transition to strong scattering

The first dense observing campaign was conducted by Robert Main and the operators of the telescope from March to June in 2020 during the first months of the pandemic. An annual variation of the shape of parabolic scintillation arcs within the secondary spectra was observed, due to the motion of the Earth around the Sun which causes varying Doppler shifts on the incoming scattered paths of radiation. Furthermore, individual scattering structures, which are in some cases as small as the distance to the Moon, could be tracked over several observations, which puts strong constrains on their distance and orientation.

However, no unexpected findings were made that could be connected to an echo crossing.

A follow-up observation in early November 2020 then revealed a sudden and dramatic change of scintillation (see Fig. 1). The scattering had become very strong, such that the direct line of sight to the pulsar ceased to exist. It was replaced by a collection of images of the same pulsar on the sky, arranged along a single line. This is a sign of strong anisotropy in the scattering material, which is often observed for the special regions that are responsible for pulsar scintillation. The significance of this transition triggered the continuation of the monitoring campaign of B1508+55 throughout the following two years. In between, the flooding of 2021 caused a switch to the EDD system. Thanks to Jason Wu, this system was already tested for this project earlier and could be applied without problems.

An accompanying change is the appearance of inverted arclets on top of the scintillation arcs. In recent years, Tim Sprenger, Olaf Wucknitz, and Robert Main, in collaboration with Canadian scientists from the University of Toronto, developed numerous new analysis methods for strong scattering with arclets, just in time to be applied now to B1508+55. They led to the discovery of an underlying second scintillation pattern that is already present before the scattering at about 400 light years in distance.

A model of two screens

The analysis of this data became the main project of Tim Sprenger's PhD thesis. Theoretically, scintillation is usually modeled by thin scattering screens. These are a consequence of the large distances involved and the sparsity of sufficiently disturbed material, which makes its locations along the line of sight effectively discrete. For B1508+55, the data clearly supported the intertwined effects of two scattering screens, yet the current theory was insufficiently developed. For this study, a two-screen model based on total anisotropy of both screens was derived by Tim Sprenger. In this context, the various quantitative observables of scintillation for two screens were derived analytically for the first time.

By fitting this model to the extensive data set acquired over almost three years of monitoring, it could be shown that two screens, with the second one being very close to the pulsar, are sufficient to describe all observables. Numerical simulations even reproduced the hitherto enigmatic stripes. For the transition, the model only had to invoke two changes: The increasing strength of scattering as well as a small change in the orientation of the line of images on the sky.

Finally, the obtained model could be compared with the locations of the echoes observed at lower frequencies, because now the location and orientation of scattering material as seen from Effelsberg are known. As a result, the increase in strength of scattering as well as the change in the angle of orientation of scattering material agree with the crossing of one of the echoes and even its inferred orientation. Thus, observations at the Low Frequency Array predicted the observed effects at Effelsberg more than two years prior, showing the power of a holistic multi-frequency approach to pulsar observations.

In summary, this study has been one of the most constraining scintillation studies so far. The analysis methods and theoretical models developed here are already in the process of being applied to other pulsars and by other groups. The data itself will be combined with other data of B1508+55 to constrain its scintillation even further. The authors believe that this data set will be of great help also to other authors in the future as the understanding of pulsar scintillation is rapidly evolving. It provides an excellent test case for new methods and models.

by Tim Sprenger and Robert Main

Original Paper: *Double-lens scintillometry: the variable scintillation of pulsar B1508+55*
Tim Sprenger, Robert Main, Olaf Wucknitz et al.

Monthly Notices of the Royal Astronomical Society, Volume 515, Issue 4, pp.6198-6216

Images at the Highest Angular Resolution in Astronomy

How a Binary Black Hole may be Bending the Relativistic Jet in the Quasar OJ287

An international team of researchers including several scientists from the Max Planck Institute for Radio Astronomy has obtained an image of radio emission in the active galaxy OJ 287 at an angular resolution of 12 micro arcseconds, which is presently the highest resolution achieved in astronomical observations. This has been made possible with the technique

of Very Long Baseline Interferometry (VLBI) which combines signals recorded at multiple radio telescopes simultaneously observing the same object and uses this combination to create a virtual telescope whose effective diameter is set by the largest distance between the participating telescopes.

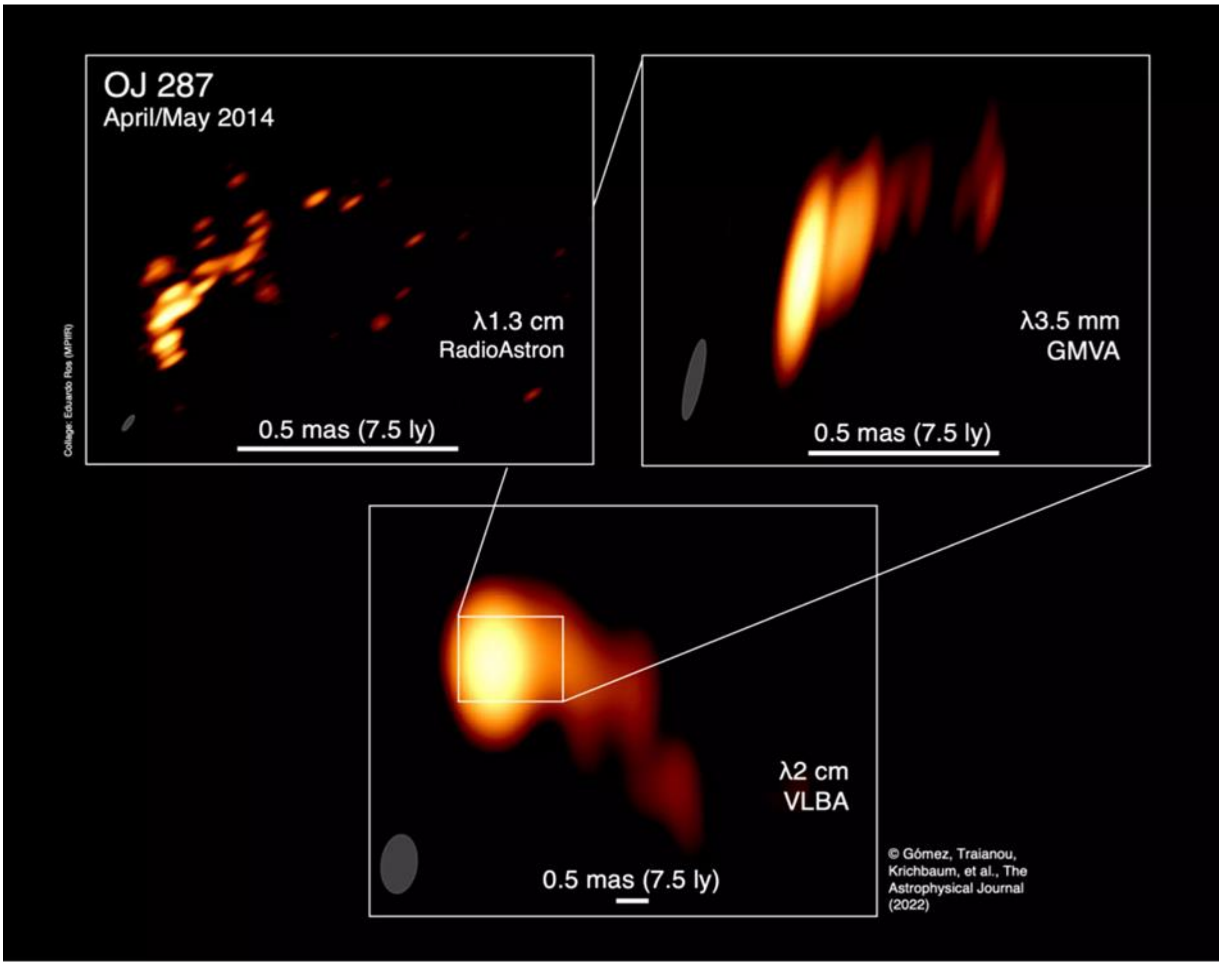
Combining together twelve radio telescopes distributed across the globe (including the 100m-telescope at Effelsberg) and an orbiting 10-metre antenna on board of the satellite Spektr-R, the researchers have effectively constructed a radio telescope with a diameter of 193,000 km and used it to peer into the very heart of the galaxy OJ 287 believed to host a pair of supermassive black holes.

VLBI observations of the galaxy OJ 287 were performed at four different wavelengths. Observations including the space-borne antenna were carried out at a wavelength of 1.3 cm and amended with additional VLBI observations made with Earth-based telescopes only at wavelengths of 2, 0.7, and 0.3 cm wavelengths. The resulting images reach a record-breaking resolution of about 12 micro arcseconds at 1.3 cm, which is equivalent to being able to discern a 20 cent coin on the surface of the Moon.

The galaxy OJ 287, located at a distance of 5 billion light-years from Earth in the direction of the constellation Cancer, belongs to the class of blazar galaxies which manifest through powerful and variable emission originating in the close vicinity of the supermassive black hole residing in their centers.

The interferometric images at all four wavelengths consistently reveal several knots of emission in a strongly bent plasma jet. The jet bending becomes progressively stronger with increasing angular resolution and towards the jet origin, supporting the hypothesis of a supermassive binary black hole model powering the active galaxy. Analysis of the polarization properties reveals that the magnetic field has predominantly toroidal structure indicating that the innermost radio emitting region is threaded by a helical magnetic field, in agreement with jet formation models. The investigation of spectral properties demonstrates that the jet plasma is composed of electrons and positrons whose kinetic energy is balanced by the magnetic field. Repeated injections of more energetic particles into the jet plasma break this balance and flare up some portions of the inner jet.

OJ 287 is one of the best candidates for a binary supermassive black hole system we know so far in our cosmic neighborhood. The secondary black hole in this system is believed to be on a tight, elliptical orbit passing through the accretion disk of the primary twice every twelve years, producing powerful flares and driving the precession of the rotational axis of the primary black hole.



The curved jet in the active galaxy OJ 287 from radio images taken at three different wavelengths and resolutions. Top left: RadioAstron at 1.3 cm wavelength – a global array including the space radio telescope Spektr-R in orbit around Earth. Top right: the Global mm-VLBI Array at 3.5 mm wavelength. Bottom: the Very Long Baseline Array at 2 cm wavelength – an array of ten antennas across the USA. The ellipses at the bottom left indicate the image resolution in each case, the angular and linear scale are shown by a horizontal white bar at the bottom. The top panel shows a record-breaking resolution of about 12 micro arc seconds, achieved when the space radio telescope is 15 earth diameters away from the ground telescopes (a distance of about 190.000 km, corresponding to half the distance between Moon and Earth).

“One of the main questions related to the evolution of supermassive black holes today is how a pair of so massive black holes could end up merging – the so-called final parsec problem. Theory suggests that separation between the two black holes stops shrinking after they expel all surrounding stars and gas. This is where gravitational radiation comes into the game and causes the two black holes to keep approaching each other until they would ultimately merge," says Andrei Lobanov from the Max Planck Institute for Radio Astronomy (MPIfR), one of the leading authors of the work. The expected binary supermassive black hole system in OJ287 is so close that it should emit gravitational waves which could soon be detectable with pulsar timing measurements.

A substantial fraction of the energy released by the matter accreted by these black holes is channeled through bipolar jets of relativistic plasma jets which can be observed and studied in detail with VLBI. "The observed detailed fine structure of the inner jet region is ideally suited to the test the validity of the binary black hole model or if the observed jet bending is caused by other effects, such as helical magnetic fields, which are anchored in the rotating space time near the black hole", adds Thomas Krichbaum, also from the MPIfR.

"These results helped us to move a step forward on broadening our knowledge on the morphology of relativistic jets close to the central engine, confirming the role of magnetic fields in jet launching and record one more time indirect signs of the existence of a proximate super massive black hole binary system deep in the heart of OJ 287", says Thalia Traianou who is after her doctoral work at MPIfR at the Instituto de Astrofísica de Andalucía (IAA-CSIC) now.

"The objective of reaching the highest resolutions in astronomy has experienced a big step forward with the contribution of the RadioAstron mission and with the developments of millimetre-wavelength VLBI such as the MPIfR-operated Global mm-VLBI Array. Our pioneering work over the last decades is now collecting results, such as our exciting findings in OJ 287", concludes J. Anton Zensus, director at the MPIfR, member of the RadioAstron International Science Council, and also co-author in the reported work.

Original Paper:

Probing the Innermost Regions of AGN Jes and Their Magnetic Fields with RadioAstron. V. Space and Ground Millimeter-VLBI Imaging of OJ 287

José L. Gómez, Efthalia Traianou, Thomas P. Krichbaum, et al., The Astrophysical Journal, Vol. 924, 122 (19 January 2022). DOI: 10.3847/1538-4357/ac3bcc

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