Highlights on Spanish Astrophysics X, Proceedings of the XIII Scientific Meeting of the Spanish Astronomical Society held on July 16 – 20, 2018, in Salamanca, Spain. B. Montesinos, A. Asensio Ramos, F. Buitrago, R. Schödel, E. Villaver, S. Pérez-Hoyos, I. Ordóñez-Etxeberria (eds.), 2019

What can VLBI do for your research? The EVN and JIVE.

F. Colomer[1]

[1] Joint Institute for VLBI ERIC (JIVE)

Abstract

Very Long Baseline Interferometry (VLBI) is providing key information to the study of processes in the Universe, from star formation regions and circumstellar envelopes around evolved stars, to galactic structure and cosmology. The European VLBI Network (EVN) offers superb observational capabilities and, most importantly, expert support to users through the Joint Institute for VLBI ERIC (JIVE), ensuring that the EVN research infrastructure is fully accessible for the best science to emerge.

1 Introduction

Very Long Baseline Interferometry (VLBI) is a radio astronomy technique in which an array of telescopes, distributed many hundreds and thousands of kilometres apart, provide milliarcsecond resolution images of bright radio sources on the sky. VLBI is sensitive to special conditions in many astrophysical objects, from AGN to Galactic masers. Among other applications, this technique allows for kinematic studies of objects, even when they are at cosmological distances and astrometry delivering parallax distances. The sub-arcsecond resolution is also attractive for studying transient phenomena, which has become very relevant recently and is associated with the development of real-time VLBI.

The European VLBI Network (EVN, Fig. 1) is an interferometric array of up to 21 radio telescopes spread throughout Europe (and beyond) that conducts unique, high resolution, radio astronomical observations of cosmic radio sources. It is the most sensitive VLBI array in the world, thanks to the collection of extremely large telescopes that contribute to the network. The EVN is a large scale astronomical facility that is open to all astronomers. It operates for 3 periods per year, known as "VLBI sessions", each of which are approximately 3-4 weeks long and typically involve 3-4 different observing frequencies. In addition, there are about ten 24-hour runs per year in real time (e-EVN), approximately once per month outside the main EVN sessions, and out-of-session (OoS) observations to accommodate special projects.

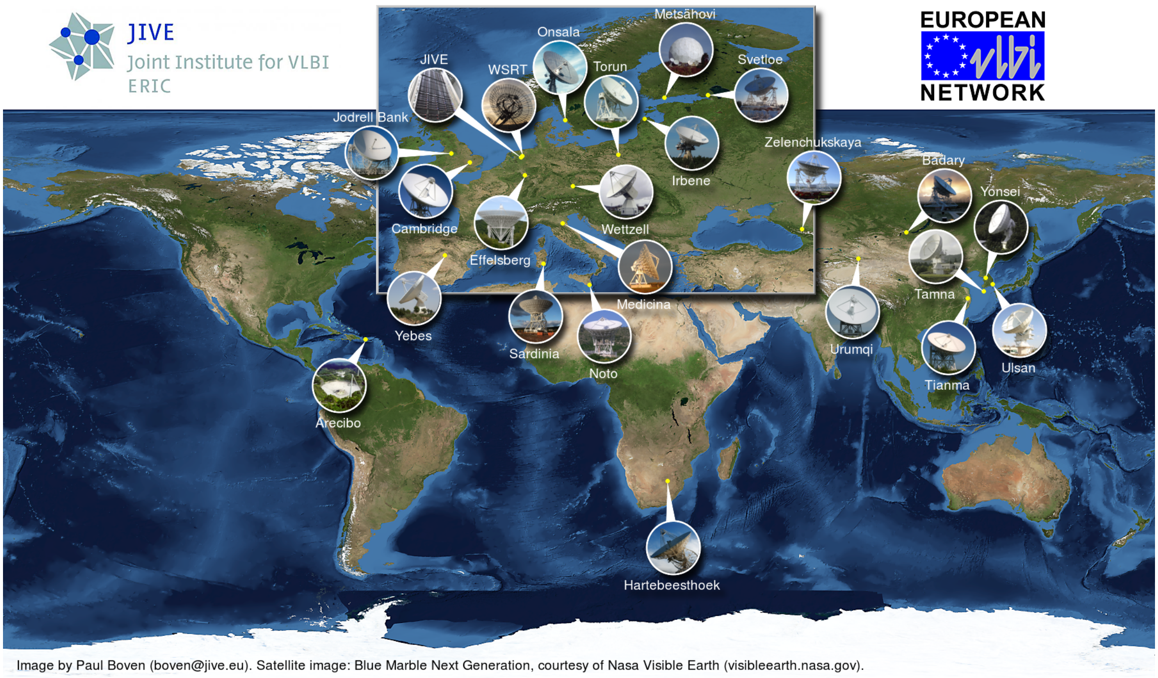

Figure 1: Map of the EVN telescopes and JIVE.

The central organisation of the EVN is the Joint Institute for VLBI – European Research Infrastructure Consortium (JIV-ERIC, JIVE), which at present unifies as its member-countries France, Latvia, The Netherlands (host), Spain, Sweden, United Kingdom as well as associated research organisations in China, Germany, Italy and South Africa.

As the EVN telescopes observe the same cosmic radio source simultaneously, the data are recorded and later combined at a special purpose data processor, often referred to as the "correlator". The EVN software correlator (SFXC) at JIVE processes since 2012 essentially all of the EVN observations.

In addition to these "EVN-only" observations, the EVN array often links-up with (e-)MERLIN, an interferometer network of telescopes distributed around the UK. In this extended mode, the coverage of the EVN-MERLIN array ranges from a few tens to many thousands of kilometers. The EVN-MERLIN array is thus sensitive to a wide range of radio structures from the arcsecond scale to the milliarcsecond scale. The EVN also observes simultaneously with other VLBI arrays such as the USA VLBA in a "global VLBI" configuration, obtaining sub-milliarcsecond resolution at frequencies higher than 5 GHz. The EVN also participates in Space VLBI observations as part of a ground array of radio telescopes observing simultaneously with the Russian RadioAstron satellite.

In Spain, the National Geographic Institute (IGN, Ministerio de Fomento) operates a 40m radio telescope at Yebes Observatory (Guadalajara) which is member of EVN. The NASA DSN MDSCC (Robledo de Chavela, near Madrid) are also associated EVN telescopes.

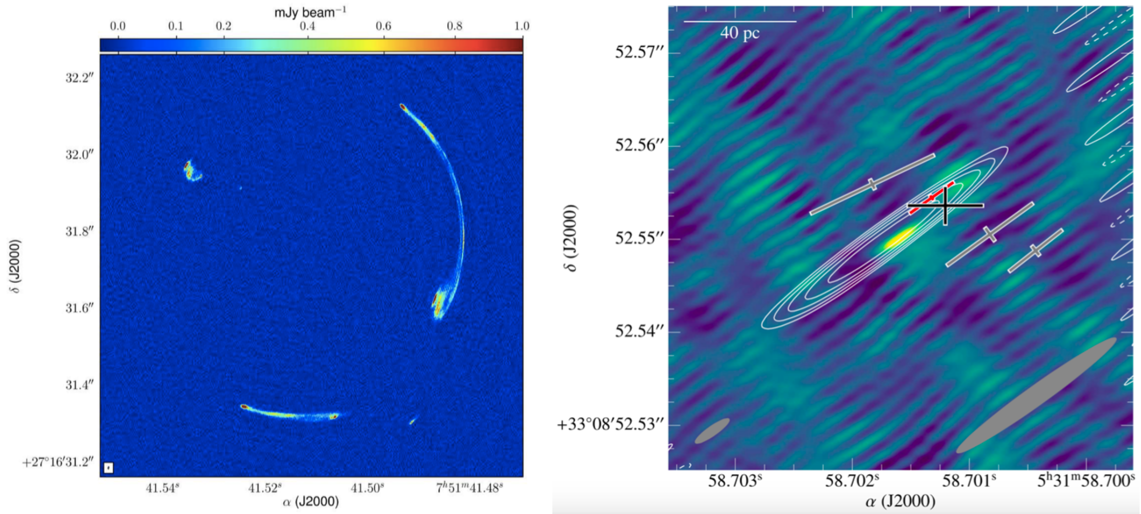

Figure 2: Recent examples of EVN science: (Left) Gravitational lens helps understanding dark matter [8]. (Right) The detected pulses related to FRB121102, near a persistent radio source as detected by the EVN. The location of the transient source was narrowed down to a star forming region within a dwarf galaxy at a redhsift of z=0.193 [4].

2 EVN recent science highlights

As recent examples, it is worth mentioning the production of one of the sharpest astronomical images ever [8], using a global VLBI array: a gravitational lens demonstrating that dark matter is distributed unevenly across a distant galaxy, which distorts the image of the background source (a black hole with radio jets) into extended arcs (Fig. 2).

Another outstanding result is in the field of fast transient research, and pioneering work in millisecond-duration transient signal detection with the VLBI technique has resulted in the detection of single pulses observed in Rotating Radio Transients (RRATS). The first known repeating fast radio burst, FRB121102, following the initial localization with the JVLA, was successfully detected with the EVN and its location refined. These observations provide the ultimate evidence that FRBs are indeed extragalactic [1] [4]. This work was the outcome of several years of research in the area of short transient localization, which itself was made possible by the advanced features added to the EVN Software Correlator (SFXC) at JIVE, and are now available to the whole astronomical community.

The first direct evidence for jet-induced AGN feedback has been obtained through spectral line global VLBI imaging of 4C12.50 [6]. The observations revealed a compact region of atomic hydrogen at high velocity at the terminating point (and its surroundings) of the jet, providing a direct connection to the large scale molecular outflow seen on larger scales. The result showcase the unique power of the EVN and global VLBI, thanks to the large collecting area needed to detect the weak spectral feature related to the high-velocity outflows.

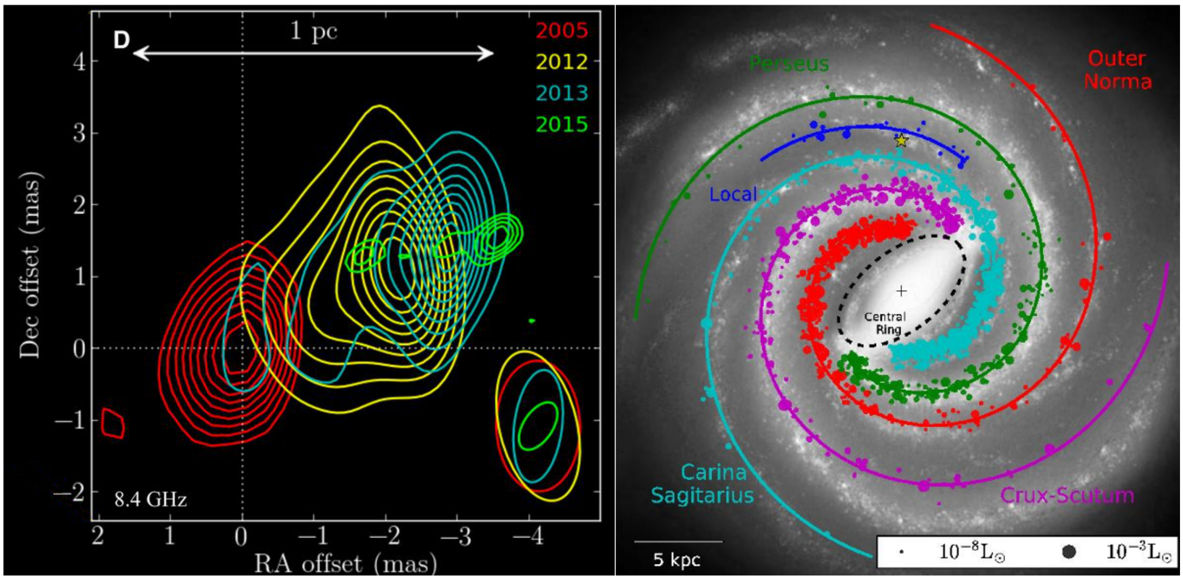

Figure 3: (Left) The powerful gravity of a SMBH rips apart a star that has wandered too close [5]. (Right) Simulation of how VLBI observations of methanol masers can identify spiral arms in our galaxy [7].

The discovery with the EVN of the double compact nature of the inner core of an already confirmed dual AGN identifies a system as an excellent candidate to represent a triple active supermassive black hole. While this result needs confirmation, similar systems have received a lot of attention because close pairs of binary supermassive black holes are the parent population for SMBH mergers to be discovered by the LISA mission in the future [3].

A tidal disruption event, or TDE, occurs when a star is being pulled apart by a supermassive black hole. Following the evolution of Arp299B during several years with the EVN and VLBA, it could track the radio emission of jets of material launched outwards from the poles of a rotating disk that had formed of material around the black hole [5] (Fig. 3).

There are also some very good examples of the application of VLBI to the study of astrophysical masers in the Universe, from star formation regions or circumstellar envelopes around evolved stars, to Galactic structure and cosmology, through precise astrometry (see [2] and references therein).

Late–type stars on the Asympthotic Giant Branch (AGB) have circumstellar envelopes (CSEs) rich in molecules, in different layers. VLBI maps the maser emission, which is compact and very intense, of SiO, H_2O and OH, providing extremely valuable information on the spatial structure and dynamics of the circumstellar shells around AGB stars. These masers can provide accurate distances to significant numbers of variable stars, and a critical check on Gaia parallaxes. Moreover, methanol class II masers at 6.7 GHz are well known tracers of high-mass star-forming regions, but their origin is still not clearly understood. Studies with the EVN have provided high sensitivity images with milliarcsecond angular resolution.

Figure 4: (Left) EVN SFXC correlator at JIVE. (Right) JIVE support scientists in action.

Hundreds of trigonometric parallaxes and proper motions for masers associated with young, high-mass stars have been measured with VLBI arrays, including the EVN, some with accuracies of ± 10 microarseconds. These measurements provide strong evidence for the existence of spiral arms in the Milky Way, accurately locating many arm segments, with the widths of spiral arms increasing with distance from the Galactic center (Fig. 3).

Water megamasers can be used to test the unified model for AGNs, the need for a torus, and the physics of the central engine; actually, they currently provide the only way to map the structure of circumnuclear accretion disks within a parsec of AGN supermassive black holes. Maser distance estimations can also be used to measure H0 accurately and constrain cosmological parameters.

Many astronomical areas of research benefit from complementary VLBI observations. An updated science vision for VLBI in the next decade is being produced by EC H2020 project JUMPING JIVE.

3 User access to the EVN and JIVE

The EVN is a research infrastructure open to all astronomers. Observing proposals will be assessed based exclusively on scientific merit and technical feasibility by the EVN Programme Committee.

A EVN User Guide can be consulted for help with proposing, scheduling, observing and reducing EVN data. Additionally, EVN users can obtain assistance and support from JIVE via its support scientists on many different aspects of EVN observations, including proposal preparation (to be submitted using the tool *NorthStar*) and best technical feasibility, scheduling, quality assurance for correlator data products, and/or data analysis. In this way, usage of the EVN becomes easier for astronomers not specialised in the VLBI technique.

Financial support may be available to EVN users who wish to visit JIVE in order to analyze correlated EVN data under the Trans-National Access program of EC H2020 project RadioNet.

Acknowledgments

This publication has received support from JUMPING JIVE (for “Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization of JIVE”), an H2020-INFRADEV-2016-1 project under contract grant agreement N^o 730884.

References

[1] Chatterjee, S. et al., 2017, Nature 541, 58

[2] Colomer, F. & van Langevelde, H.J., 2018, In: ”Astrophysical Masers: Unlocking the Mysteries of the Universe”, Proceedings of the IAU Symposium, Volume 336, pp. 411-416

[3] Deane, R. et al., 2014, Nature 511, 57

[4] Marcote, B., et al., 2017, ApJ 834, 8

[5] Mattila, S., Pérez-Torres, M., et al. 2018, Science, 361, 482

[6] Morganti, R. et al., 2013, Science 341, 1082

[7] Quiroga, L. et al., 2017, A&A 604, 72

[8] Spingola, C., et al. 2018, MNRAS, 478, 4816