European VLBI Network Newsletter

Number 52

January 2019

Contents

Edited by Michael Lindqvist, EVN Secretary (Onsala Space Observatory, Sweden; Michael.Lindqvist@chalmers.se)

Message from the Chairman of the EVN Board of Directors

Dear Users of the EVN,

I wish everyone a happy and scientifically productive 2019; starting of course with the opportunity to submit EVN proposals for the 1st February deadline (see p 3). For this new deadline we have a new EVN webpage accessible by the usual address at https://www.evlbi.org – I urge all to check out this new website which is a huge advance both in terms of aesthetics and internal organisation. Not all information is so far transferred from the old style format – this content will gradually be updated over the next six months or so – the initial priority has been on presenting the tools and information needed for preparing proposals for the coming deadline – a goal which I believe the new website achieves in style. I would very much like to thank the team at JIVE involved in the redesign of the EVN website and also thank others from the EVN community who have given comments during the design process.

As is usual this edition of the EVN newsletter presents a mixture of Scientific, Technical and Organisational highlights. Three EVN projects highlighting HI absorption, Galactic maser and SETI test observations are described on pages 4 to 11 demonstrating the wide variety of EVN science. This variety and the quality of EVN science was clear also at the EVN Symposium in Granada in October. A record 170 applicants attended, most of whom can be seen in the conference photograph on p 18 forming an 'accretion disk' around a local black hole. I would like to thank the LOC and SOC members for organising an impressive meeting. The Granada symposium was also focus for a number of other side meetings including the Technical and Operations Group meeting and a workshop on CASA Fringe Fitting – description of these meetings and several others held during the last six months are included within the pages of this newsletter.

John Conway,

Chairman, EVN Consortium Board of Directors

Call for EVN proposals

The next deadline for submitting EVN proposals is **1 February 2019**. The details of the call can be found here. All EVN and Global proposals must be submitted using the NorthStar online proposal submission tool (http://proposal.jive.eu). Global proposals will be forwarded to NRAO and should not be submitted to NRAO separately.

The EVN facility is open to all astronomers with or without VLBI experience. EVN User Support on proposal preparation, scheduling, correlation, data reduction and analysis can be requested at the Joint institute for VLBI ERIC (JIVE).

Further information on EVN, EVN+MERLIN, Global VLBI and e-VLBI observations, and guidelines for proposal submission (including Target of Opportunity (ToO) and short-observation) are available at: http://www.jive.eu/jivewiki/doku.php?id=evn:guidelines.

Access to the EVN is supported, for eligible projects, by the Trans-national Access programme of the RadioNet project, which is funded by the EC Horizon 2020 Research and Innovation Programme under grant agreement No 730562. This trans-national access support, includes also travel reimbursement for visits to JIVE in order to analyse and process EVN, EVN-MERLIN or global VLBI data.

Kazi Rygl, INAF, Bologna, Italy, EVN PC Chairman

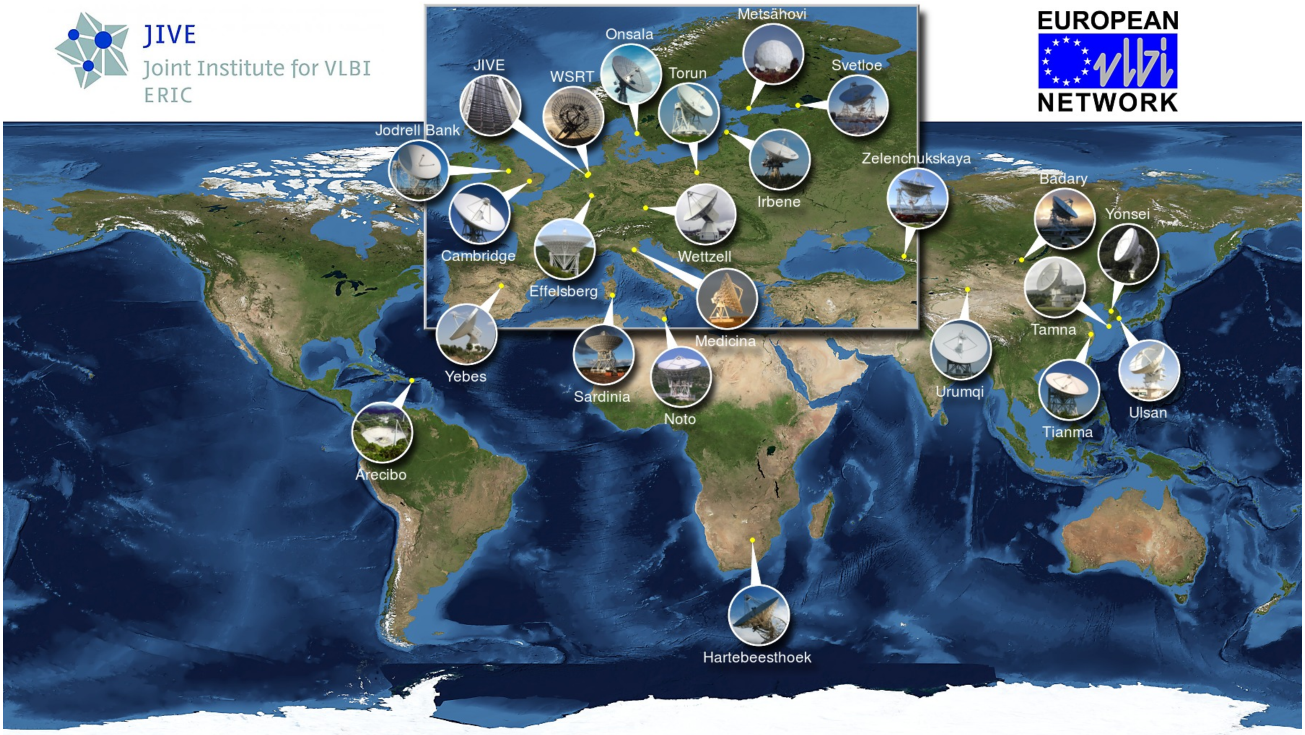


Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

EVN science highlights

Towards an e-MERLIN/EVN SETI Capability

The last few years have seen a huge resurgence of interest in SETI research. Initiatives such as Mr. Yuri Milner's Breakthrough Listen project have transformed the landscape, with the first large systematic surveys now being conducted by appropriately equipped telescopes such as the Green Bank Telescope (GBT) and Parkes (Siemion et al. 2013). NASA has also signaled its intention to begin to fund future radio SETI efforts, in addition to the search for "techno-signatures" in general. While most SETI observations employ large single dishes, the new generation of radio telescopes operating at cm-wavelengths, tend to be composed of distributed dish arrays e.g. the MeerKAT telescope in South Africa is a good example. While the conventional approach of SETI researchers is to beam-form such arrays (essentially making them look like huge single dishes), it's interesting to consider what advantages there might be to conduct SETI observations using interferometric techniques. One well known advantage of employing long baseline interferometers arrays for SETI is that such instruments are significantly less affected by radio frequency interference (RFI), greatly reducing the enormous number of false positives that arise from terrestrial and satellite communication systems (Rampadarath et al. 2012).

In a recent paper presented at the International Astronautics Congress and EVN symposium, Garrett (2018) highlighted some other advantages that interferometer arrays can potentially provide. One important advantage is the presence of multiple, independent interferometer baselines in an array – these provide an important level of redundancy and additional confidence (verification) of faint and potentially transient signals – if a SETI signal is detected in one baseline, it had better also be present in the others. It is also the case that the high time and frequency resolution required by SETI, naturally leads to an interferometer array in which the entire field-of-view (only limited by the extent of the primary beam response) is available for analysis – the result is that thousands of potential SETI targets can be studied simultaneously. These targets typically range from nearby galactic stars (easily identified via their Gaia proper motions) to distant extragalactic systems but solar system objects can also be included. Another advantage of interferometry is that it's possible to make images as a function of either time or frequency (or both) – see Fig. 1. An important observation is that while almost all other aspects of a SETI signal are likely to be changing (especially narrow-band signals suffering from large Doppler accelerations, interstellar scattering etc), the position of the signal on the sky is likely to be invariant (at least on times scales of a few hours). It is also interesting to note, that if a SETI signal were to be detected, radio interferometers distributed on scales of 1000's of km would play a crucial role in pin–pointing the location and nature of the extraterrestrial transmitter and the platform on which the source is fixed – for example, VLBI techniques can easily detect the orbital motion of a transmitter if it is placed on a planet in orbit around its star (note that by definition, 1 milliarcsecond subtends 1 AU at a distance of 1 kpc). Even if the transmitter is located in free space, the motion of objects with velocities in excess of 0.01 c can be detected within 1 day, much slower objects (with velocities similar to the Voyager spacecraft) can be detected within 1 year (again assuming a distance of 1 kpc).

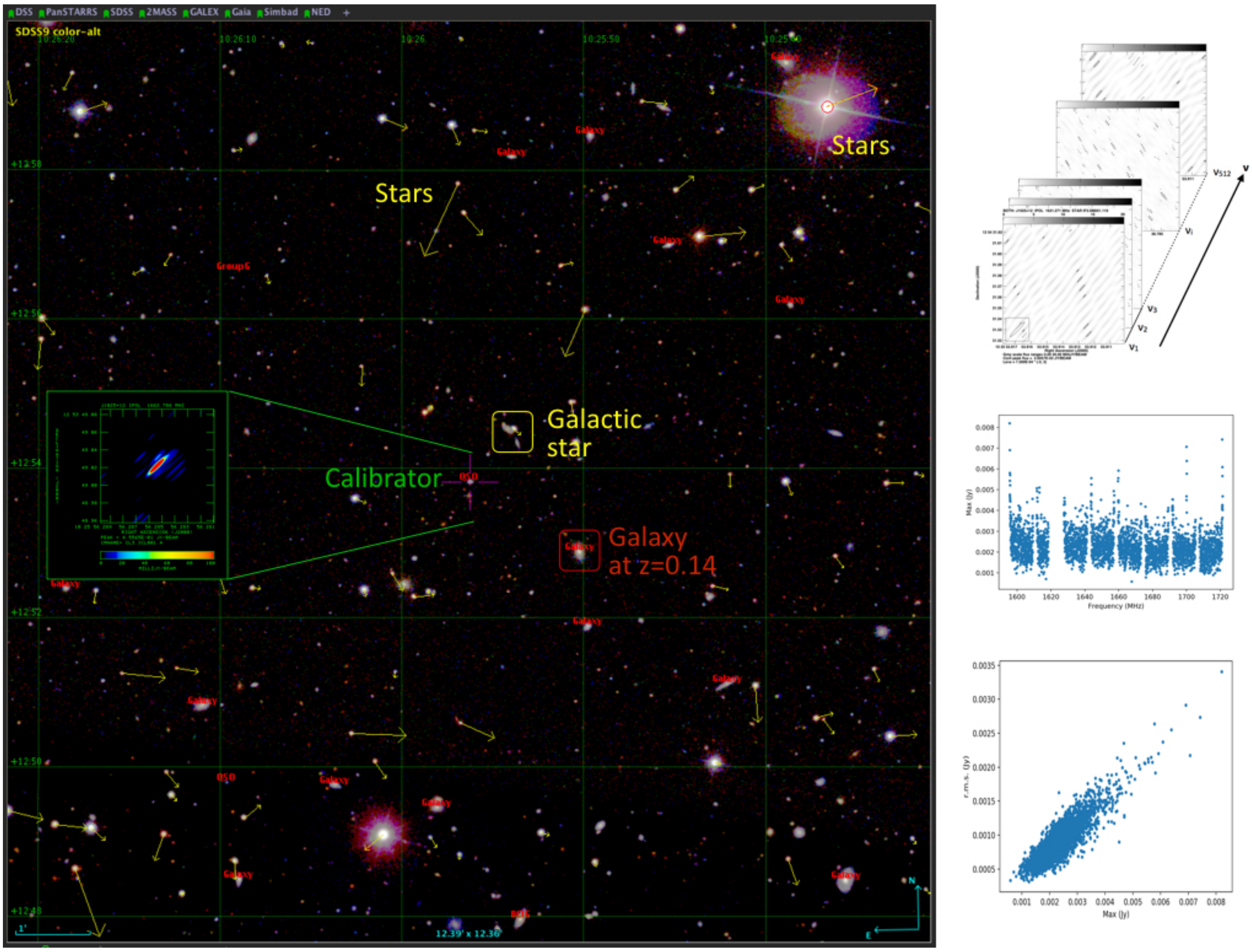


Figure 1. *The Sloan Digital Sky Survey (SDSS) field centred on the calibrator J1025+1253. Two targets are identified. To the extreme right, the main results of searching for peaks in the multi-channel images is presented.*

In order to get a better feel for how this might all work in practice, Garrett (2018) made use of a small subset of high-resolution data associated with EVN project ED038 – extracted from the ever useful EVN archive at JIVE. The first stage of the analysis was to subtract a bright compact calibrator. The data was then phase rotated to two targets within the field – a galactic star located at a distance of 1 kpc and more speculatively, a galaxy with a measured redshift of z=0.14. The next step was to search the data for the presence of "narrow band" signals in both fields as a function of frequency (and time) – no signals above the 4 sigma r.m.s. noise level were detected (see Fig. 1). It should be noted that the data were only coarsely edited, flagging only those data known to be severely affected by gross failures e.g. off-source antennas, missing IFs etc. The data was inspected in a number of different ways – generating power spectra for individual baselines, collapsing individual baselines into a single power-spectrum, and making images of each individual frequency channels. By analysing the statistics of images generated for all available frequency channels, Garrett (2018) was able to place coarse upper limits of 3.5×10^{16} W on the galactic star and 1.4×10^{28} W (Equivalent Isotropic Radiated Power, EIRP) on the galaxy at z=0.14.

While the limits placed on the galaxy are rather large, they are not significantly in excess of the energy resources typically associated with a Kardashev Type II civilisation (~ 10^{26} W) (Kardashev 1964). If one also notes that a distributed array of coherent transmitters with excellent forward gain, could reduce this limit to much more modest levels (an array on the scale of the full SKA for example), SETI observations of extragalactic sources (even those at cosmological distances) might not be as silly as it sounds. Finally, an e-MERLIN/EVN observation optimised for SETI can do much much better – for example, data processed by a modern software correlator can yield much higher frequency/time resolution and a larger data set could provide significantly better sensitivity limits.

Published in: Garrett M.A.: **SETI surveys of the nearby and distant universe employing wide-field radio interferometry techniques**, IAC 2018 Session SETI 1 and EVN Symposium 2018.

M.A. Garrett, Univ. of Manchester, Jodrell Bank Centre for Astrophysics, UK

Global VLBI observation of the neutral HI gas outflow in the radio galaxy 3C 236

The energy released by an active galactic nucleus (AGN) can heat and expel gas from the host galaxy and thereby affect star formation and the accretion of matter onto the supermassive black hole. One of the striking signatures of this interaction are outflows of ionised, molecular and atomic gas that have been observed in a number of AGNs.

The project described here focus on studying the outflow of neutral atomic hydrogen (HI) gas from the cold interstellar medium in a small sample of young and restarted radio galaxies. In these objects, the HI gas is observed in absorption and the radio jets are the likely driver of the outflow. Because of the relatively low redshift of these objects, the 21 cm line of HI falls in the L-band allowing the high angular resolution offered by VLBI.

One of the sources in the sample is the giant radio galaxy 3C 236 which is one of the largest known radio sources with radio emission stemming from different cycles of AGN activity. The radio emission from the currently ongoing cycle is visible in the central compact steep spectrum radio source of about 500 pc in size. At low resolution, the HI absorption spectrum of 3C 236 shows a deep narrow feature related to an HI disk (associated with the large scale dust-lane) and a broad wing discovered with the WSRT (Morganti et al. 2005) and confirmed by the VLA. This wing is blue-shifted and has a width of about 1000 km s^{-1}, which suggests a fast HI outflow.

Schulz et al. 2018 present global spectral-line VLBI observations of 3C 236 (project code: GN002B). The data were correlated at JIVE as a continuum pass with 4 IFs each with 16 MHz bandwidth and 32 channels and a spectral-line pass with 1 IF of 16 MHz and 512 channels. The bandwidth is significantly larger than in the previous HI VLBI observation by Struve & Conway (2012) enabling Schulz et al. 2018 to cover the entire HI absorption system. In addition, 3C 236 was observed at lower resolution with the VLA in A-configuration with 1 IF of 16 MHz and 256 channels.

The VLBI observation, with a resolution of 20 mas, spatially resolves the radio source and recover about 1.35 Jy, about half of the flux at arcsec-scale. Most importantly, it could detect and locate HI gas belonging to the fast outflow. Figure 2 trace a number of HI clouds that do not follow the regular rotation of the disk-related gas. Three of them are observed towards the nucleus of the radio source having a size of less than 40 pc and covering about 600 km s^{-1}. The fourth cloud is detected towards the south-east radio lobe at a distance of about 270 pc and it is extended. These clouds have masses ranging between 0.28 and $1.5\times10^4\ M_\odot$. As in the case of the continuum, Schulz et al. 2018 recover a fraction of the absorption detected at lower spatial resolution (Morganti et al. 2005). This is most likely the result of a combination of resolving-out extended emission due to a lack of short spacings and the changing level of optical depth that can be probed across the continuum source.

The findings indicate that the outflow is to some extent clumpy and originates within the central few tens of parsecs of the radio galaxy. This is an important result because numerical simulations predict that the impact of a radio jet on the surrounding ISM is highly enhanced when it enters a clumpy medium. Given that only part of the outflow is recovered, Schulz et al. 2018 cannot rule out the additional presence of a diffuse outflow component.

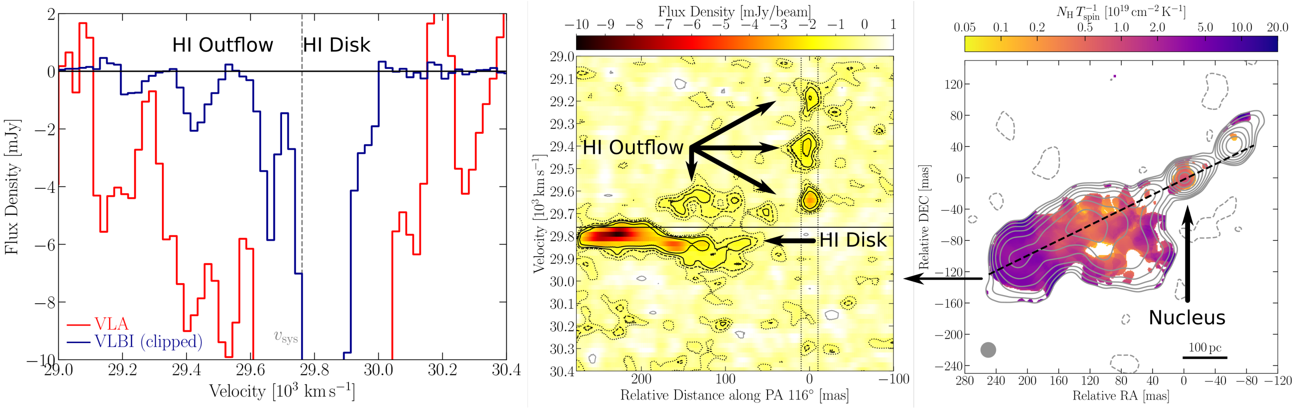


Figure 2. *Left panel: HI absorption spectrum of 3C236. The spatially unresolved spectrum of the VLA is shown in red and the spatially integrated VLBI spectrum in blue. Middle panel: Position-velocity plot along a slice through the nucleus of the radio source. The contours correspond to 2, -2, -3, and -5 times the noise level. Right panel: Radio continuum emission (contours) and spin temperature-normalised column density of the HI gas (color-scale) obtained by the VLBI observation. The dashed line highlights the slice along which the position-velocity plot (middle panel) was extracted. Faint radio emission at larger distances from the nucleus is also recovered.*

The results illustrate the importance of VLBI for the understanding of the physical condition of the medium around active black holes: in the context of the upcoming large-scale blind HI absorption surveys conducted at lower angular resolution, VLBI will provide key follow-up observations.

Published in: Schulz R., Morganti R., et al.: **Mapping the neutral atomic hydrogen gas outflow in the restarted radio galaxy 3C 236**, A&A, 617, A38, 2018.

R. Schulz, ASTRON, Dwingeloo, The Netherlands
R. Morganti, ASTRON, Dwingeloo, The Netherlands

The feedback of an hypercompact HII region on its parental molecular core

Hypercompact (HC) HII regions (typically, ≤ 0.03 pc in size and ≥ 10^{10} pc cm^{-6} in emission measure) represent the first step in the ionisation/expansion of an ionised region around a newly born early-type star. The study of their physical and dynamical properties is fundamental to shed light on the process of formation of more massive (≥ 15 $M_\odot$) stars, specifically to investigate how the ionisation and radiation pressure affect the preexisting accretion/ejection structures.

Inside the most prominent molecular core (named A1) of the high-mass star forming region G24.78+0.08 (bolometric luminosity of ~ $2x10^5$ $L_\odot$ at a distance of 7.2 ± 1.4 kpc), previous VLA A-Array (1.3 cm and 7 mm) observations have revealed an intense (~ 10 mJy $beam^{-1}$ at 1.3 cm), hypercompact (size ≈ 1000 AU) HII region. Recent high-angular resolution (0.2") ALMA observations has detected strong emission in the H30α line (at 231901 MHz) emerging from the HC HII region (Cesaroni et al. 2017). The kinematics of the ionised gas has been probed by studying how the position of the compact H30α emission peak changes in velocity, by fitting the emission in the channel maps with a 2-D Gaussian. Figure 3 reveals that a well-defined V_{LSR} gradient is observed in the H30α line. It is directed at PA = 39 degrees (about parallel to the major axis of the VLA 7 mm continuum image) and extends over quite a large velocity range, from ≈ 85 km s^{-1} to ≈ 139 km s^{-1} going from SW to NE. The velocity gradient, 22 km s^{-1} mpc^{-1}, is one of the highest so far observed towards HC HII regions. The dynamical mass inferred from this V_{LSR} gradient is $M_{dyn} \geq 96$ $M_\odot$, much larger than the mass of the ionising star, ≈ 20 $M_\odot$, estimated from the radio and bolometric luminosity. That rules out the interpretation of the V_{LSR} pattern in terms of rotation/infall. The simplest interpretation of the observed V_{LSR} gradient in the H30α line is in terms of a fast, bipolar outflow blowing from the massive YSO, placed at the centre of the H30α pattern and responsible for the gas ionisation.

The interaction of the fast-moving ionised gas with the surrounding molecular environment is suitably traced with both water and methanol masers. While water masers arise just at the border of the ionised gas, methanol masers are observed at relatively larger separation from the centre of the HC HII region (see Fig. 3). Figure 4 shows the 3-D velocities of the water and methanol masers, derived via multi-epoch, sensitive VLBA and EVN observations, respectively. The water maser proper motions witness the fast (≈ 40 km s^{-1}) expansion of dense, shocked circumstellar gas towards N and E of the HC HII region. Methanol masers are observed to the N, SE and S of the HC HII region, and their overall motion indicates expansion away from the ionised gas at significantly lower velocities (mainly ≤ 10 km s^{-1}) than the water masers.

This work on the G24.78+0.08 HC HII region illustrates the power of complementing thermal interferometric and maser VLBI observations for a detailed view of the massive star formation. Future studies on this object aim at determining the degree of collimation of the ionised flow to test whether we are observing the onset of the stellar wind from an O-type star.

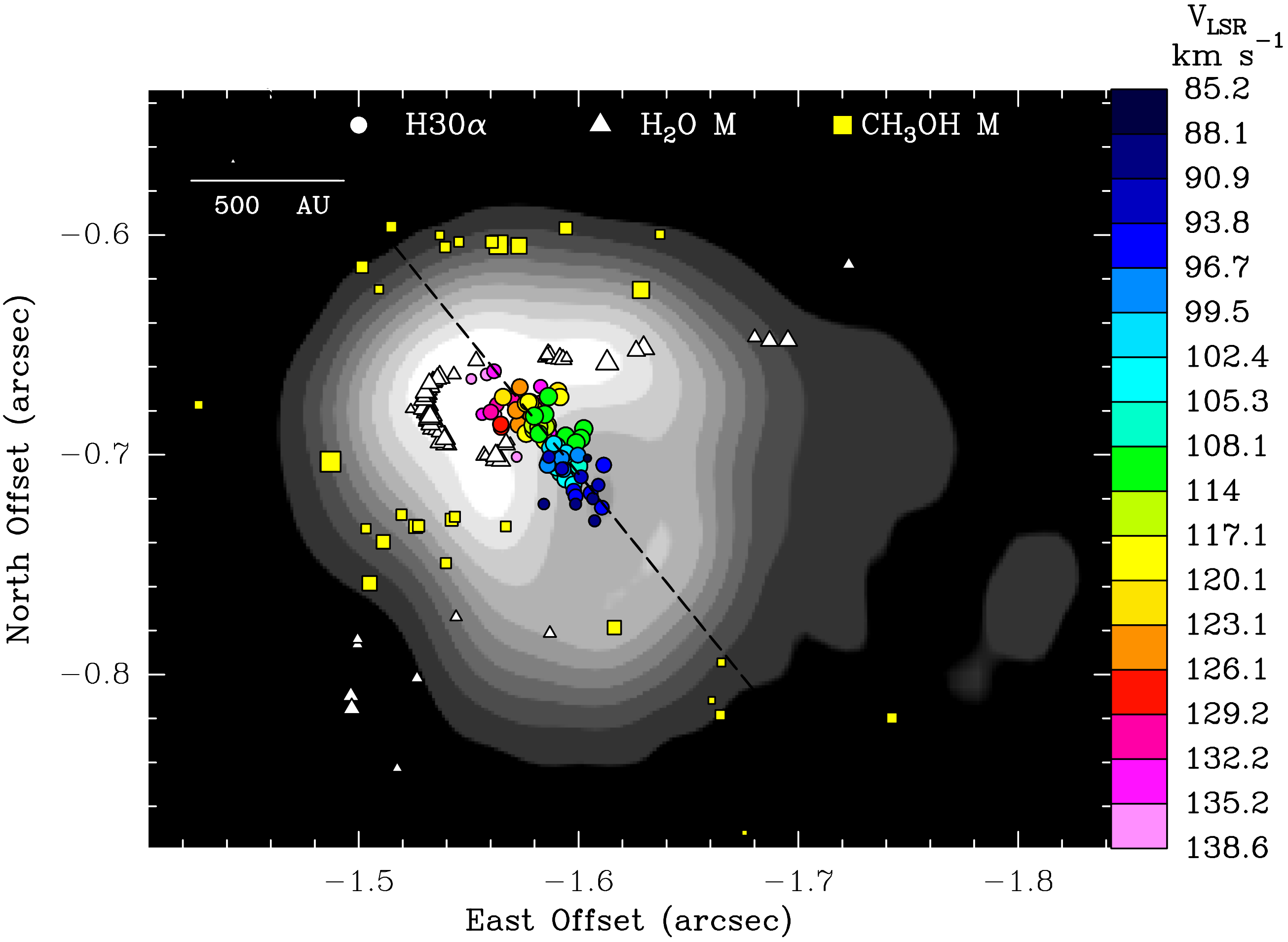


Figure 3. *The grey-scale image represents the 7 mm continuum emission observed with the VLA A-Array. The white triangles and yellow squares mark the VLBI positions of the H_2O 22 GHz and CH_3OH 6.7 GHz masers, with symbol area proportional to the logarithm of the maser intensity. The coloured dots give the channel peak positions of the H30α line emission, with colours denoting V_{LSR} as indicated in the wedge on the right of the plot. The dashed black line marks the axis of the spatial distribution of the H30α peaks. The VLBI maser and VLA continuum absolute positions have been corrected for the apparent motion between the corresponding observing epochs and the ALMA observations, and should be accurate within 10 mas. The H30α positions has been offset by 10 mas (less than the expected ALMA position accuracy) both to E and S, to obtain a better alignment with the axis of the radio continuum emission.*

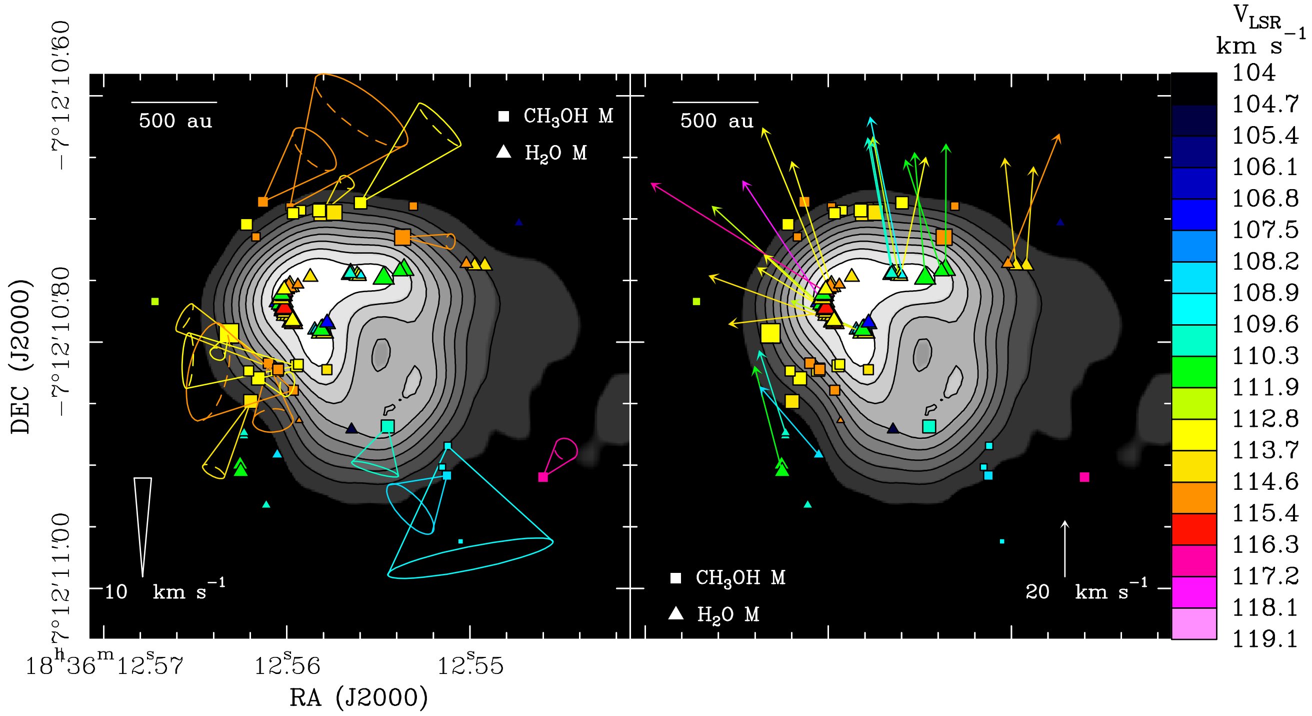


Figure 4. *3-D motions of the methanol (left panel) and water (right panel) masers in G24.78+0.08 A1. In both panels, the grey-scale image and black contours (10 to 90 %, at step of 10 % of the image peak of 11 mJy beam^{-1}) reproduce the VLA A-Array 7 mm continuum. Coloured triangles and squares report the absolute positions (evaluated at the date 2003 September 4) of the 22 GHz water and 6.7 GHz methanol masers, respectively, with colours denoting $V_{\rm LSR}$ as coded in the wedge on the right of the plot. In the left panel, the 3-D velocities of the methanol masers are shown with cones, with opening angle representing the uncertainty in the direction of motion. The white cone in the left bottom corner gives the scale for the velocity amplitude. In the right panel, the sky-plane velocities of the water masers are indicated with arrows. The white arrow at the right bottom shows the velocity scale.*

Published in: Moscadelli et al.: **The feedback of an HC HII region on its parental molecular core. The case of core A1 in the star-forming region G24.78+0.08**, A&A, 616, A66, 2018.

L. Moscadelli, INAF-Osservatorio Astrofisico di Arcetri, Italy

25th anniversary of the JIVE

The technique of Very Long Baseline Interferometry (VLBI) was not even 25 years old, when it became clear that there was room for a dedicated operational institute to streamline the VLBI efforts in Europe. The European VLBI Network (EVN) was becoming a globally leading endeavour, and needed a central institute where data could be correlated, and scientists could receive assistance with the data processing and analysis. After several years of discussions and negotiations, this vision became a reality: the Joint Institute for VLBI in Europe (JIVE) was formally founded on 21 December 1993, and hosted in Dwingeloo by ASTRON, the Netherlands Institute for Radio Astronomy.

“The Americans wondered if I knew what the acronym meant”, says Richard Schilizzi, one of the founders and first director of JIVE, “but the name stood out in a forest of European institutes named with an E”. Since its inception, JIVE has become a global brand name for VLBI in Europe and beyond, and the institute is a key player in technological and scientific development of VLBI.

The core business of JIVE has always been to correlate and support EVN observations and users. The first correlator was completed in 1998, when data was still shipped on large video tapes. Increasing computing capacity enabled the development of a software correlator, and eventually real-time data transfer via internet (e-VLBI). The current correlator has significantly larger performance than the first, but takes up only a fraction of the space.

A major asset of JIVE is its support staff. They provide help at all stages of an EVN project, from proposal preparation to analysis of the data, and are at the core of EVN operations. After honing their VLBI skills at JIVE, they often continue their career abroad, spreading the knowledge of VLBI and the JIVE brand around the globe.

Over its lifetime, four directors have served JIVE, each leaving a personal imprint of their visions. Mike Garrett took over from Richard Schilizzi, and was succeeded by Huib Jan van Langevelde. Since 2018 Paco Colomer is at the helm, facing new scientific, technological and political challenges in the era where the Square Kilometre Array is becoming a reality.

Confident in its strong legacy, and with 25 years of experience in uniting European and global radio telescopes, JIVE is ready for a long and prosperous future.

Ilse van Bemmel, for the JIVE Outreach Team.

Update on the JUMPING JIVE project

Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization (JUMPING) of JIVE is a project rich in successful activities. The excellent work of the first 18 months of the Horizon2020 JUMPING JIVE collaboration culminated on 12 October 2018 in Granada with a very positive mid-term review. The reviewer commented that our project "has delivered exceptional results with significant immediate or potential impact".

All ten work-packages have achieved remarkable results. In particular, the reviewer has identified areas of enhanced excellence that will have a very positive impact in the short and long term. These are the African activities of WP9 and the efforts of WP7 to write a collective book about the future of VLBI in Europe with wide participation of astronomers.

In Africa, JUMPING JIVE in collaboration with Development in Africa with Radio Astronomy (DARA) is creating a basis for developments that will boost VLBI, SKA activities and is already having a noticeable societal impact (see some highlights in the EVN newsletter #51)

The work towards "The VLBI Future" and the chapters of the white paper about the Vision of VLBI have been presented at the 14th EVN Symposium in Granada, stimulating a discussion within the community of EVN users.

All JUMPING JIVE activities aim to maximize the globalization of JIVE and the EVN. From attracting new users, or promoting the project's efforts in Africa, to developing new tools for VLBI astronomers, JUMPING JIVE outreach team (WP2) is supporting all other work-packages to communicate and exploit their results. A number of promotional materials have been produced. The initial step was to design a brochure as "first contact" with non-VLBI astronomers. The concept of VLBI is often perceived as difficult. Therefore, the brochure is based on the familiar research process and highlights the support available from JIVE at each step. The resulting brochure is a 3 page folder with short messages and clear graphics to make it easy to digest (see also JUMPING JIVE highlights on EVN Newsletter #50). Using the same style of the brochure, a number of roll-up banners have been designed, as well as a portable booth display for use in large conferences, Fig 6.

Brochures, banners and other promotional materials (pens, stickers, business cards) are available for all EVN institutes to use. Feel free to contact us at communications@jive.eu and the JUMPING JIVE outreach team will be happy to assist you.

Giuseppe Cimò (JUMPING JIVE Project Manager), JIVE, The Netherlands

Figure 6. *Banners and portable booth display about EVN and JIVE.*

Reports from Meetings

EVN Technical Operation Meeting, Granada, Spain

The EVN Technical Operation Group (TOG) met in Granada on October 4, 2018 at the Instituto de Astrofísica de Andalucía (IAA). This meeting was followed the day after by the Global mm-VLBI Array (GMVA) Technical Group (GTG) meeting. Both meetings were subsidised by RadioNet and organised by the Instituto Geográfico Nacional and the IAA and were attended by 34 people from 14 different countries. The meeting time and location was chosen to be close to the EVN symposium (see next section). This allowed the technical staff to get into direct contact with the astronomers – the users of the European VLBI Network – in order to receive feedback allowing to further improve the quality of the infrastructures. The general objective of the TOG+GTG meeting is to identify operational issues and discuss strategies to mitigate those in the future. Permanent agenda items deal with improving the quality of calibration, maintenance of the data acquisition and recording equipment as well as of the used software components.

Several issues were identified that will improve the current operation of the EVN. The TOG also discussed a schedule for testing up to 32 Gbps recording rates in 2019. These gradual and sequential tests require a DBBC3 as backend. Currently only a limited subset of EVN stations satisfy this requirement. The minutes of the meeting can be found here.

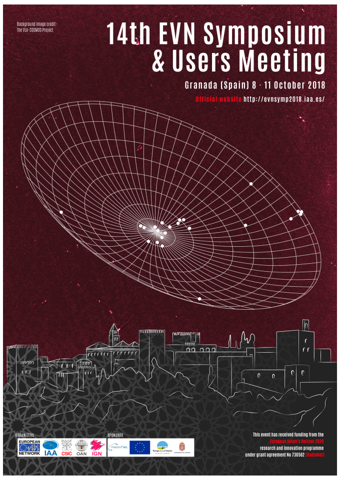
One of the main issues in the GTG meeting was setting the strategy of doubling the GMVA recording capability from currently 2 Gbps to 4 Gbps. Such an upgrade would have a major impact on the scientific capabilities and would enable new science for the GMVA users. Whereas the European GMVA stations are technically ready for the upgrade of the VLBA stations (USA) will require replacement of the recording hardware. Funds for the required hardware changes have been secured by the US partners and upgrades are ongoing. Doubling the recorded bandwidth also requires doubling the data storage capabilities at the stations and the Bonn correlator. All partners have agreed to provide these capabilities. A schedule containing a number of test observations in the course of 2018 and early 2019 was worked out. In case of a positive outcome of the tests, the GMVA would be able to offer the 4 Gbps mode as the new standard mode starting from fall 2019.

Pablo de Vicente, OAN, Spain

The 14th EVN Symposium and Users Meeting, Granada, Spain

The 14th European VLBI Network (EVN) Symposium and Users Meeting (http://evnsymp2018.iaa.es/) was hosted by the Instituto de Astrofísica de Andalucía-CSIC (IAA-CSIC) in Granada (Spain) on behalf of the EVN Consortium Board of Directors. The meeting took place on October 8-11, 2018 at the main auditorium of the "Parque de las Ciencias" of Granada, the science museum of the city.

This biennial meeting is the main forum for discussion of the latest VLBI scientific results and technical and technological developments within the EVN member countries. At this 14th EVN Symposium there was also a chance for user input into the future Science Vision for the EVN and, as usual, an EVN User's Meeting was organised within the scientific program.



Topics discussed during this edition of the symposium included:

- Powerful active galactic nuclei science
- Starburst galaxies, extragalactic masers, and supernovae
- Stellar evolution and stellar masers
- Transient sources and pulsars
- Astrometric, geodetic & space applications
- VLBI technology developments
- Current and future VLBI facilities and international cooperation

On this occasion, the EVN Symposium was also focused on the role of EVN on:

- Very-high sensitivity VLBI with SKA
- Future multi-wavelength and multi-messenger astronomy including high angular-resolution astronomy at other wavelengths

As a parallel activity of the EVN Symposium, a CASA-VLBI tutorial with over 80 participants was organised by JIVE for the late afternoon of October 11th, 2018 on the premises of the IAA-CSIC. A visit to the IRAM 30 m millimetre radio telescope, in the Sierra Nevada Mountains close to Granada, was also organised.

There were 170 registered participants from 25 countries world-wide, Fig. 7. There was a more than significant participation from South Korean colleagues (24 attendees), followed by Spain (23), Russia (17), Italy (15), Germany (14), and the Netherlands (13). About 21 % of attendees were women, and a significant fraction of participants were young researchers and students. There were 91 oral presentations (including 11 reviews) that were distributed in 11 sessions, of which four of them had to be organised in parallel sessions (AGN/Stellar Evolution) for the first time in an EVN Symposium. This was needed in this occasion to alleviate the large pressure to obtain time for contributed talks.

Almost 80 posters were also presented during the Symposium. The last talk of the meeting was an excellent summary made by Tiziana Venturi and Huib Jan van Langevelde of the results presented during the symposium.

Figure 7. *Conference group picture taken at the hall of the "Parque de las Ciencias" of Granada.*

The large number of attendees, and the variety of results presented on new astrophysical topics that are far from traditional for the VLBI community, especially with regard to astrophysics of transient phenomena, multi-messenger science and synergies with observations at other spectral ranges, indicates that the EVN community is evolving and growing.

The proceedings of the 14th EVN Symposium will be published in "Proceedings of Science" (http://pos.sissa.it/344) during the next months.

As usual, the EVN Users Meeting gave attending astronomers the opportunity to provide feedback about EVN proposal evaluation, operations, correlation and data distribution and archiving. The traditional EVN Symposium Football match took place on the first evening of the meeting. It was a lot of fun and there was no serious injuries, which can be called a complete success. A number of additional social activities were enjoyed by the attendees. These included a welcome reception at the gardens of the Nazari Palace "Cuarto Real de Santo Domingo", a night visit to the historic Alhambra Palaces, and the conference dinner in the historic rooms of Palacio de Santa Paula.

A grateful acknowledgement goes to the members of the Scientific Organising Committee, to the members of the Local Organising Committee, and to everyone else who helped to make the 14th EVN Symposium a successful event from many perspectives.

The event received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730562 [RadioNet URL: www.radionet-org.eu]).

Iván Agudo, Instituto de Astrofísica de Andalucía-CSIC, Granada, Spain

The 7th International VLBI Technology Workshop, Krabi, Thailand

The 7th International VLBI Technology Workshop was hosted by NARIT, the National Astronomical Research Institute of Thailand, in Krabi, Thailand, from 12 to 15 November 2018. There were 40 registered participants, Fig. 8.

The International VLBI Technology Workshops have evolved from the highly successful 10 year series of International e-VLBI workshops. The scope of the technology workshops is to encompass all areas of hardware and software development relevant to VLBI.

NARIT is in the process of establishing the Thai Radio Astronomy Observatory (TNRO) in Chiang Mai, which will host a new 40 m Radio Telescope and a 13.2 m VGOS station on the same site, expected to see first light in early 2020. With the ambition to become an active participant in VLBI, hosting the IVTW provided a perfect opportunity for the Thai and international VLBI astronomy communities to meet and discuss.

The meeting covered a wide range of topics, with many excellent presentations and plenty of time for discussions. Overview talks dealing with RadioNet and the Vision for the Future of the EVN were given by the RadioNet chair Anton Zensus and by Michael Lindqvist. A first for the IVTWs, three remote presentations were given, by Weintroub and Vanderlinde on SWARM and CHIME, and one by Victor Pankratius on cloud correlation.

Although the focus of the meeting this year was on correlators, there were many interesting side topics, with for example Maria Rioja presenting multi-frequency calibration.

Figure 8. *Participants in the 7th International VLBI Technology Workshop in Krabi, Thailand.*

Quite a few talks dealt with "universal" or software backends. This definitely seems to be the way of the future, and several are being developed, at Parkes, in Bonn, or are in the planning phase like at the VLBA.

As far as VLBI correlators go, Chris Phillips showed that a gain of a factor two in correlator capacity could be achieved by switching to GPU correlation. Needless to say, at the cost of a not inconsiderable amount of software engineering. The new software correlator at Shanghai will definitely be built on a GPU cluster, as is the Russian RASFX correlator. In general, it looks like FPGA VLBI correlators are on the way out, and existing software correlators will eventually be adapted to run on CPU-GPU clusters.

At the end of the last day a quite lively open discussion was held, chaired by Tasso Tzioumis, which quickly turned to universal backends. Cormac Reynolds volunteered to lead a group that will investigate universal backend solutions for VLBI.

In conclusion, this was a wonderful meeting, and we owe many thanks for the excellent organisation and warm hospitality of our hosts.

Next years' meeting will probably be hosted by CSIRO, in Sydney.

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