European VLBI Network Newsletter

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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 Colleagues in the European VLBI Network, Dear Users of the EVN,

It is now less than a month to the EVN Symposium in Granada (see page 13) - a record number of talk submissions were received and the final programme features many excellent new results. The meeting will be a great opportunity for many of us to meet and appreciate this exciting time for the EVN and world VLBI. Also featured during the Granada meeting will be the EVN users meeting and discussion of the EVN future science vision - an open process which all are welcome to contribute to.

The future of the EVN and world astronomical VLBI in general was also a major subject of discussion in Shanghai in May at the EVN Consortium Board of Directors meeting and following round-table discussion on global VLBI. I think all participants left with the certainty of a bright future for world VLBI; with numerous new VLBI capable telescopes coming online and ever expanding technical capabilities for recording high bandwidths. In Shanghai there were discussions of mechanisms for coordination between the world's astronomy VLBI networks to maintain maximum accessibility to users. A good example of what such large global VLBI arrays can now achieve in terms of imaging quality can be found on page 4 which describes gravitational lens observations using a global array of 24 antennas. With even more VLBI telescopes coming online (including simultaneous and combined short baselines using e-MERLIN), plus wider observing bandwidths, there is the future prospect of getting almost complete uv coverage over a factor 1000 in baseline length, and so achieving even more dramatic high fidelity VLBI imaging in the future.

John Conway,

Chairman, EVN Consortium Board of Directors

Call for EVN proposals

The next deadline for submitting EVN proposal is **1 October 2018**. 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.

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.

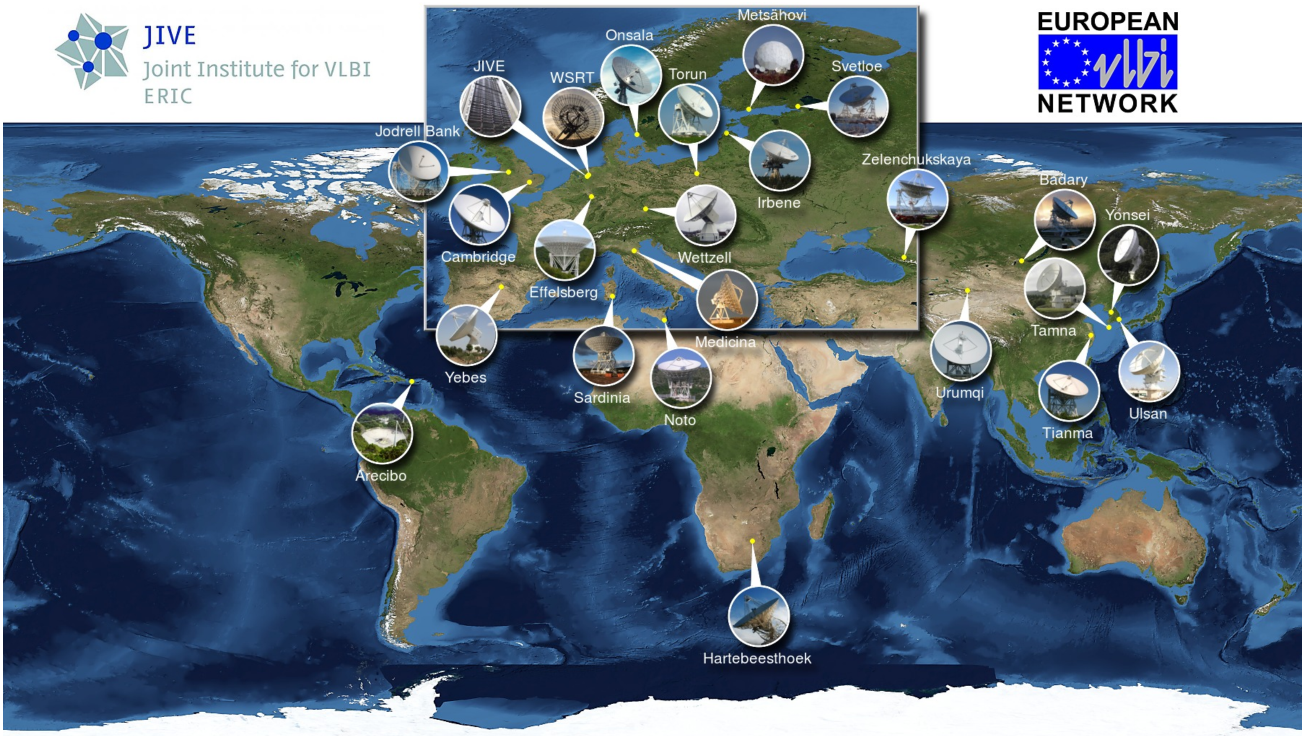


Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

Antonis Polatidis, ASTRON, EVN PC Chairman

EVN science highlights

Gravitationally-lensed radio arcs observed with global VLBI

The Strong lensing at High Angular Resolution Program (SHARP) led by McKean (ASTRON) has obtained a deep global VLBI observation of the gravitational lens MG J0751+2716 at 1.65 GHz (project GM070; PI: McKean). The 18.5 hours observation comprised 24 antennas from the EVN and the VLBA, and included the the large (> 50 m) Lovell, Effelsberg, Robledo and Green Bank telescopes. The data were recorded at 512 Mbps and correlated at JIVE to produce 8 spectral windows (IFs) with 8 MHz bandwidth and 32 channels each, through both circular polarisations. MG J0751+2716 is one of the few quadruply imaged radio-loud gravitationally lensed quasars that show extended arcs on VLBI-scales. The global VLBI L-band deep imaging detects all of the extended arcs at high significance, showing the complex surface brightness structure of the background source in unprecedented detail (Fig. 1). Because of the complexity of this system, the imaging was performed using multi-scale cleaning within the wsclean algorithm (Offringa et al. 2014). The total flux density of the target is 350 mJy and the off-source rms is 41 µJy/beam. Never before have such extended (200-600 mas) gravitational arcs been detected at an angular resolution of a few mas. The excellent uv-coverage and surface brightness sensitivity provided by the global VLBI array have been fundamental for a precise study of the structure of the extended arcs on mas-scales from MG J0751+2716.

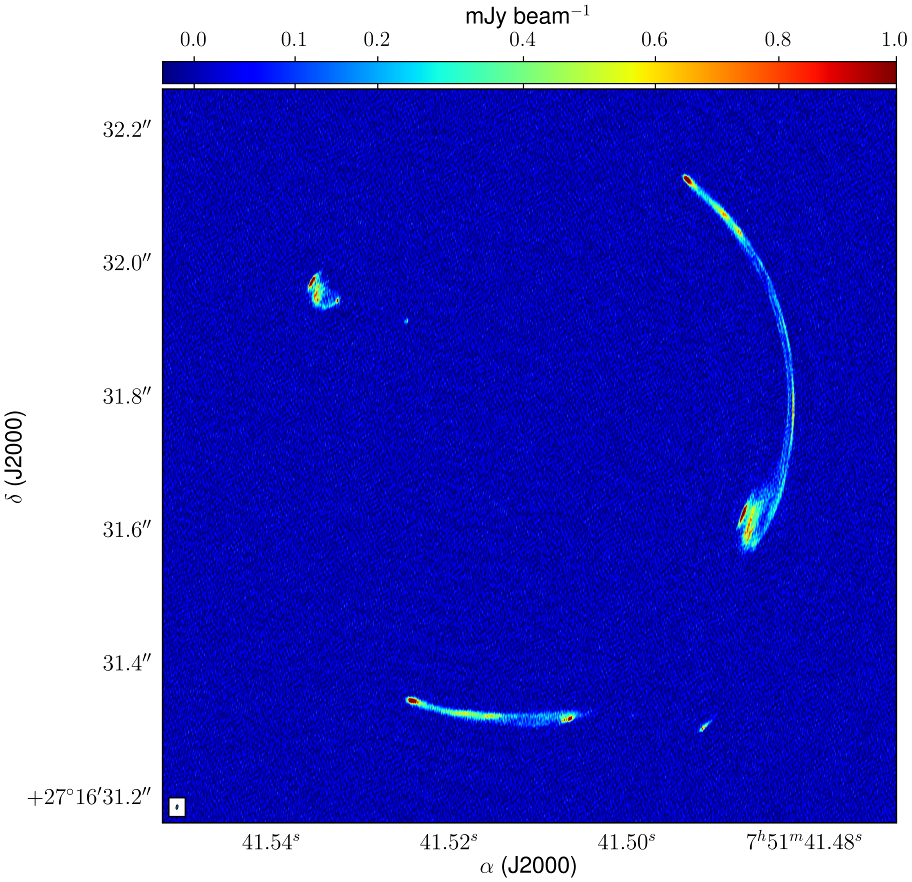


Figure 1. *Global VLBI imaging of MG J0751+2716 at 1.65 GHz (Spingola et al. (2018)). The off-source rms is 41 µJy/beam and the peak surface brightness is 2.9 mJy/beam. The restored beam is 5.5x1.8 mas^2, and is shown within the white box in the bottom left hand corner.*

Spingola et al. (2018) analysed these observations and identified lensed emission corresponding to the same source component, providing a very large number of constraints on the mass model that also sampled a large radial and tangential extent. When performing the mass modelling of this system, they found a discrepancy between the observed and predicted positions of the lensed images, with an average position rms of the order of 3 mas, which is much larger that the measurement errors (40 µas on average). A possible explanation for the offset between the observed and model-predicted positions is the presence of some additional mass structure (e.g. Metcalf & Madau 2001). However, since the lensing galaxy lies in a small group of galaxies, it is not clear whether this extra mass is in the form of sub-haloes within the lens or along the line of sight, or from a more complex halo for the galaxy group. Furthermore, the lens mass model suggests an inner density slope for the main lensing galaxy that is steeper than isothermal. This is consistent with studies of other low-mass early-type satellite galaxies in dense environments, and is in agreement with the two-phase galaxy formation scenario (Guo & White 2008).

Published in: C. Spingola et al.: **SHARP – V. Modelling gravitationally lensed radio arcs imaged with global VLBI observations**, MNRAS, 478, 4816, 2018

Cristiana Spingola, Kapteyn Astronomical Institute, University of Groningen, the Netherlands

A dust-enshrouded tidal disruption event with a resolved radio jet in a galaxy merger

Tidal disruption events (TDEs) are transient flares produced when a star is ripped apart by the gravitational field of a supermassive black hole (SMBH). In a TDE, roughly half of the star's mass is ejected, whereas the other half is accreted onto the SMBH, generating a bright flare that is normally detected at X-ray, ultraviolet (UV), and optical wavelengths. TDEs are also expected to produce radio transients, lasting from months to years and including the formation of a relativistic jet, if a fraction of the accretion power is channelled into a relativistic outflow.

An international team of astronomers have, for the first time, directly imaged the formation and expansion of a fast-moving jet of material ejected when the powerful gravity of the SMBH in the nucleus of Arp 299-B (D=45 Mpc) ripped apart a star that wandered too close to the cosmic monster in Arp 299-B. It is one of the two merging galaxies (Arp 299-A and Arp 299-B) forming the Arp 299 system, which hosts prolific supernova factories in its nuclear regions.

The team tracked the event with radio and infrared telescopes, including the EVN, for over a decade. The patient, continued observations with the EVN and other radio telescopes around the world, eventually showed the source of radio emission expanding in one direction, just as expected for a jet (Fig. 2). The measured expansion indicated that the material in the jet moved at an average of about one-fourth the speed of light. The crucial piece of information solving the puzzle of this event was provided by VLBI observations, as the inferred angle of the jet to the line-of-sight was in clear disagreement with expectations from a "normal" AGN jet, while in the case of a TDE this angle can have any value.

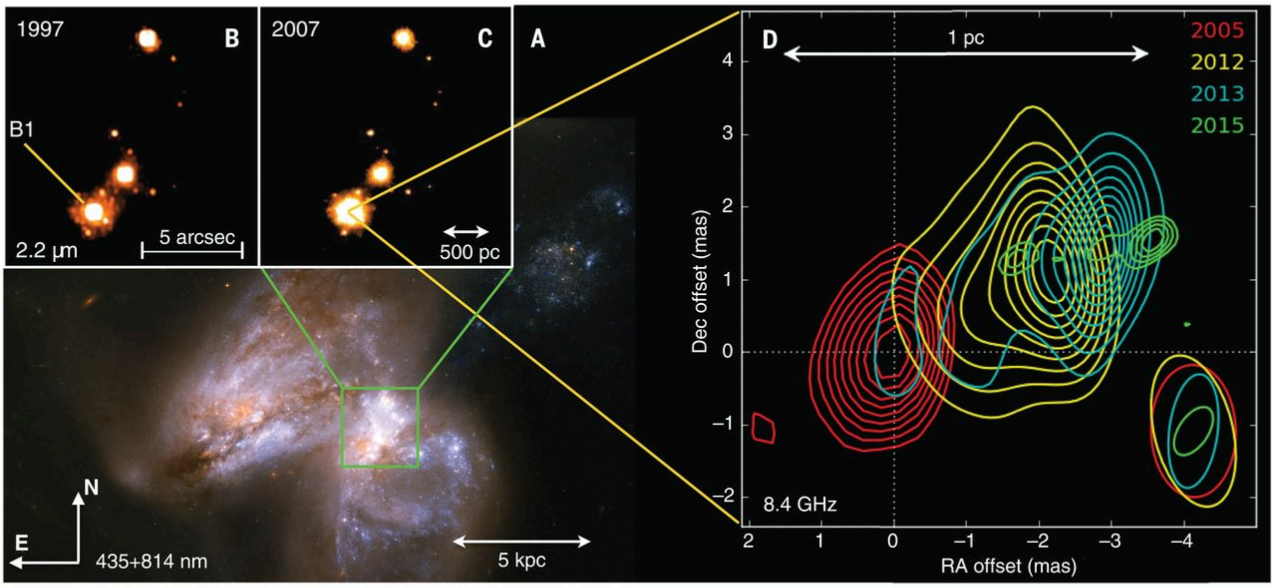


Figure 2. *The tidal disruption event Arp 299-B AT1 and its expanding radio jet. (A) A color-composite optical image from the HST, with high-resolution, near-IR 2.2 micron images [insets (B) and (C)] showing the brightening of the B1 nucleus. (D) Radio evolution of Arp 299-B AT1 as imaged with VLBI at 8.4 GHz [7× 7 milli-arcsec (mas) region with the 8.4-GHz peak position in 2005, right ascension (RA) = 11h28m30.9875529s, declination (Dec) = 58°33'40''.783601 (J2000.0), indicated by the dotted lines]. The VLBI images are aligned with an astrometric precision better than 50 microarcsec. The initially unresolved radio source develops into a resolved jet structure a few years after the explosion, with the centre of the radio emission moving westward with time at an average intrinsic speed of 0.22 times the speed of light. The radio beam size for each epoch is indicated in the lower-right corner.*

The gravitational field of the SMBH in Arp 299-B, with a mass 20 million times that of the Sun, shredded a star with a mass more than twice that of the Sun. This resulted in a TDE that was not seen in the optical or X-rays because of the very dense medium surrounding the SMBH, but was detected in the near-infrared and radio. The soft X-ray photons produced by the event were efficiently reprocessed into UV and optical photons by the dense gas, and further to infrared wavelengths by dust in the nuclear environment. Efficient reprocessing of the energy might thus resolve the outstanding problem of observed luminosities of optically detected TDEs being generally lower than predicted.

The case of Arp 299-B AT1 suggests that recently formed massive stars are being accreted onto the SMBH in such environments, resulting in TDEs injecting large amounts of energy into their surroundings. However, events similar to Arp 299-B AT1 would have remained hidden within dusty and dense environments, and would thus not be detectable by optical, UV or soft X-ray observations. Such TDEs from relatively massive, newly formed stars might provide a large radiative feedback, especially at higher redshifts where galaxy mergers and luminous infrared galaxies like Arp 299 are more common.

Published in: Mattila S., Pérez-Torres M., et al.: **A dust enshrouded tidal disruption event with a resolved radio jet in a galaxy merger**. Science, 2018

Miguel Pérez-Torres, IAA, Granada, Spain, Seppo Mattila, Tuorla Observatory, Finland

News from JUMPING JIVE

Everyone involved in the ten work packages of the Horizon2020 JUMPING JIVE project have been very busy in Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization (JUMPING) of JIVE. The project has passed the 18 month mark and will soon undergo its mid-term review, which is planned in Granada after the EVN symposium. Some short highlights follow of the excellent results recently delivered by the JUMPING JIVE collaboration.

Work is in progress to improve the geodetic capabilities of the JIVE correlator. Now, the Mark4 format output has been fully implemented, including visibilities from the SFXC correlator, correlator-model information and phase-cal information. The latter is used to align phases in the various observed sub-bands, permitting the estimation of meaningful multi-band delays, which is mandatory for geodetic data processing, unlike in standard astronomical analysis. Initial testing has consisted of loading the resulting Mark4-format data into HOPS (the standard fringe-fitting package used for VLBI geodesy) and comparing the content with that derived after accomplishing correlation through DIFX (a software correlator widely-used to process geodetic data), and exporting the data in the usual way into HOPS.

Figure 3. *Ross Burns (JIVE), Jay Blanchard (JIVE), Eskil Varenius (JBO) and the DARA 2018 Ghana/Kenya Cohorts during their Unit 2/3 training at the Ghana Radio Astronomy Observatory in April 2018.*

JUMPING JIVE has supported two trainees from Africa for the ASTRON/JIVE Traineeship program, which run from 7th May to 23rd July. In addition, the project supported VLBI basic training in direct association and collaboration with the Development in Africa with Radio Astronomy (DARA) training programme. This has included JUMPING JIVE supporting and sending multiple trainers as part of the Unit 2/3 (technical and observing training) and Unit 4 (data reduction and analysis) modules across 6 different countries (Figure 3).

With regard to VLBI with the SKA, it has been a very intense period for JUMPING JIVE and the SKA-VLBI scientist Cristina García-Miró (Fig. 4). In 2018, the SKA project is undergoing the Critical Design Reviews for the different Elements of the Observatory. Thousands of documentation pages containing the architecture, design and requirements of the SKA1 Elements have been reviewed to make sure the VLBI capability is appropriately supported. As a result, from the reviews, the Interface Control Documents for VLBI are being produced.

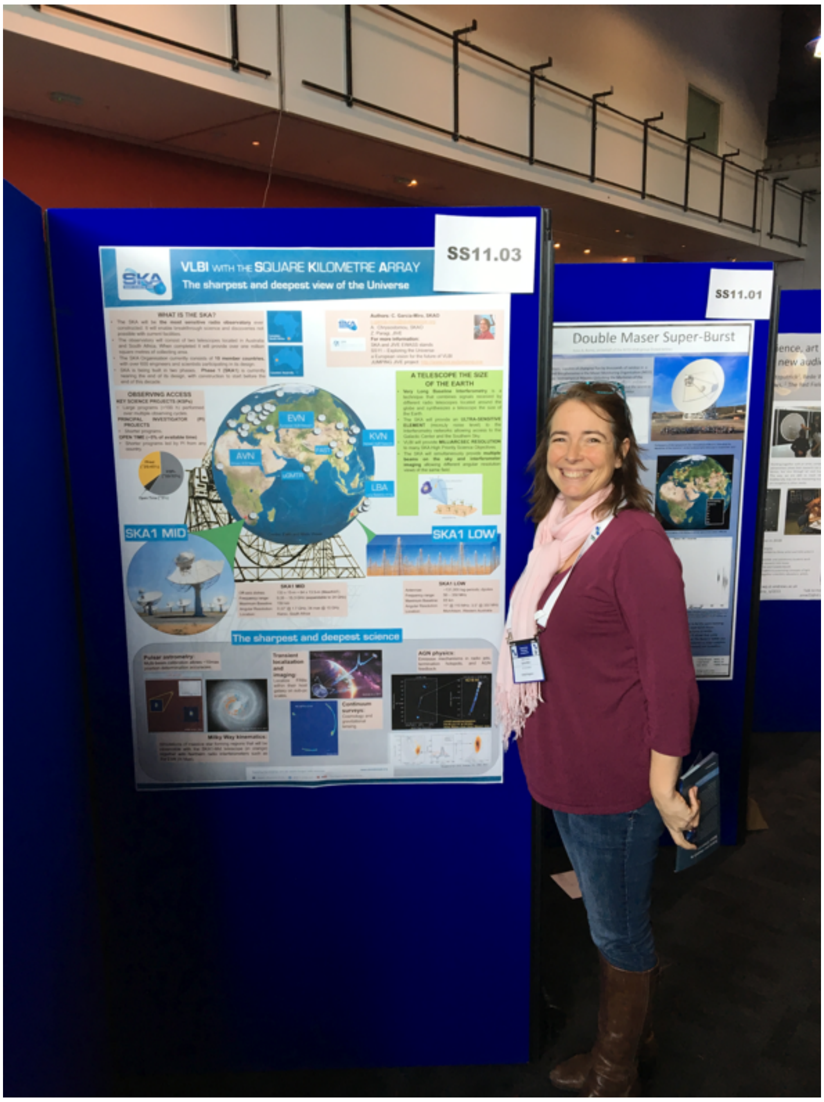


Figure 4. *Cristina García-Miró, the SKA-VLBI scientist, advertising the SKA-VLBI opportunities at the EWASS 2018 in Liverpool.*

Giuseppe Cimò (JUMPING JIVE Project Manager), The Netherlands

EVN/JIVE Technical Developments

Demonstration of VLBI fringes with MeerKAT

Adding the phased up SKA - or its precursors - to a VLBI array is scientifically highly desirable, as it adds extremely sensitive and/or long baselines to the array.

The recently inaugurated MeerKAT telescope has started to produce data, however, its sampling rate and data formats are not yet VLBI compatible.

The bandwidth and frequency band covered by the currently installed receivers on MeerKAT, 856 MHz at L-band, should amply cover those observed by the EVN. Theoretically, this allows for extraction and generation of a VLBI compatible data stream from that signal through appropriate post-processing.

In February 2018, during commissioning of the MeerKAT array, a time slot became available for co-observing with the N18L1 Network Monitoring Experiment, which had previously been scheduled as part of the EVN VLBI Session I/2018.

During scans 3 - 11 varying types and amounts of output were captured from the MeerKAT system by South African Radio Astronomy Observatory (SARAO) staff. Some 10 TB of output of the beamformer, the correlator, and that of the digitiser of one polarisation of a single dish were captured and e-shipped to JIVE for processing and correlation.

Python-based software developed by JIVE staff, heavily relying on the numpy and SciPy modules, was subsequently used to extract ten seconds worth of 64 MHz bandwidth (2x32 MHz - upper- and lower side band), overlapping with the 8 x 8 MHz bands observed by the EVN stations. The filtered and resampled data were reformatted to the VLBI Data Interchange Format (VDIF) standard. JIVE's software correlator SFXC was used to correlate the mixed-bandwidth observations.

Fig. 5 shows fringes between MeerKAT (Me) single dish digitiser output from antenna m011v for N18L1 scan 11 (source J0530+1331) and the EVN stations Effelsberg, Germany (Ef) and Hartebeesthoek, South Africa (Hh) in all eight EVN 8 MHz bands (increasing frequency to the right). The plot shows time averaged uncalibrated correlation coefficient value (y-axis) versus lag offset (x-axis, time domain) for each 8 MHz band.

Fringes to Me appear at about equal strength in the LR and RR polarization combinations because the MeerKAT receivers are linearly polarized whilst the EVN observes in circular polarization instead. The 'V' polarization state time series was captured from the Me dish and relabelled as 'R' in the software. The LL and RL combinations, containing no signal, are not shown for clarity.

The fringe amplitude is observed to decline towards higher sub bands, i.e. towards higher frequency. This is likely due to the fact that the highest observed band was 1682.49 - 1690.49 MHz, getting close to MeerKAT's band edge at 1712 MHz.

Readily finding VLBI fringes using a single 13.5 m MeerKAT dish on an 8000+ km baseline clearly demonstrates the excellent quality of the dish, receiver and timing system as well as the accuracy of the array reference position.

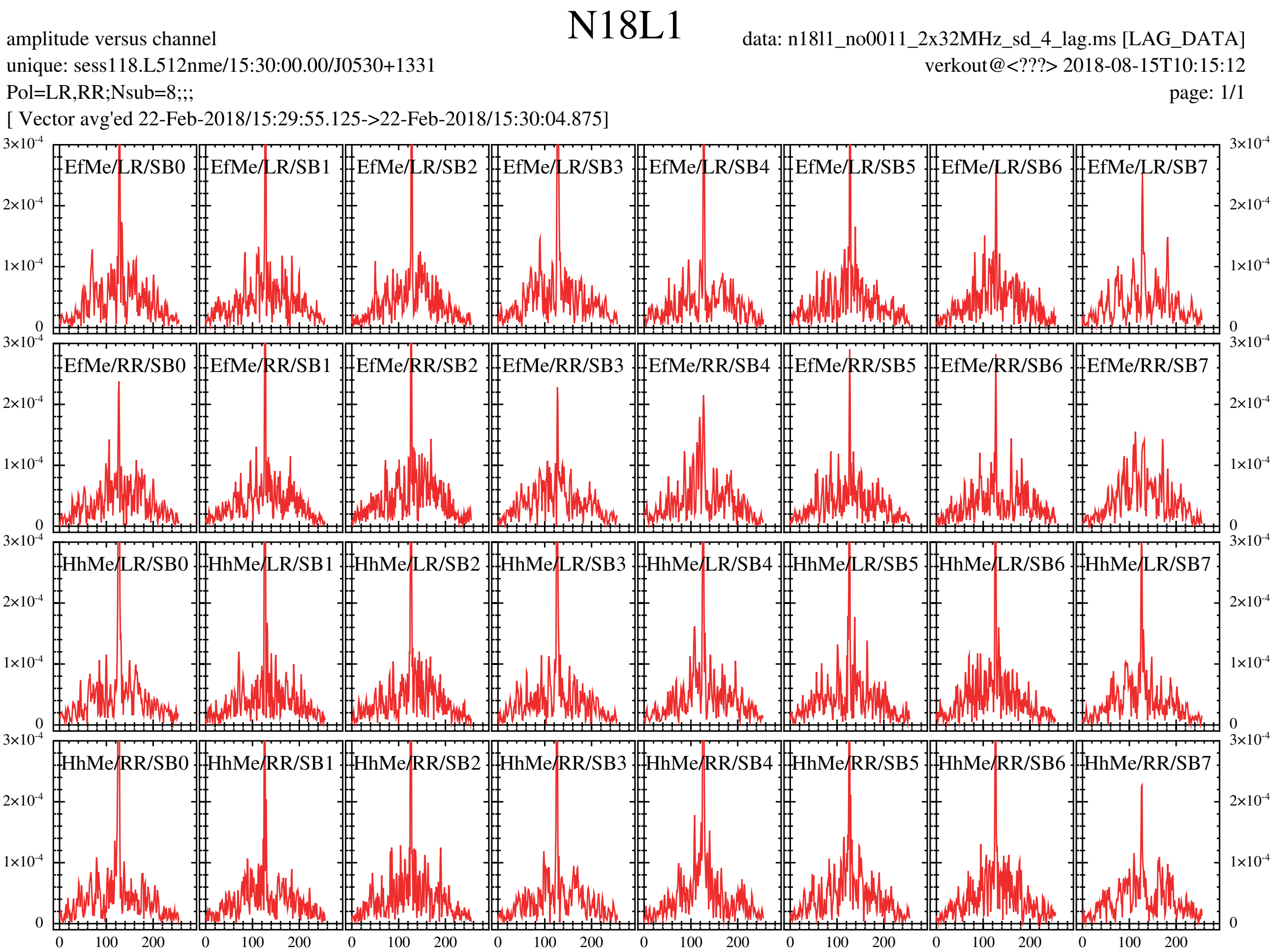


Figure 5. *Fringes between MeerKAT (Me) single dish digitiser output from antenna m011v for N18L1 scan 11 (source J0530+1331) and the EVN stations Effelsberg and Hartebeesthoek.*

Fringes were also found using the beamformed output, using the same signal processing chain, and they are still being investigated.

This result is an important first step towards including the phased-up MeerKAT, and eventually the SKA, in global VLBI observations.

The current software can only serve as a demonstration and verification platform to illustrate the required signal processing. Its (lack of) performance prohibits production use. It takes well over an hour to extract and convert ten seconds from the single polarisation single dish time series. Converting the beamformer output takes an order of magnitude longer.

These successful fringes are the result of a close cooperation between staff at the SKA-SA/SARAO office and JIVE.

Harro Verkouter, Joint Institute for VLBI ERIC (JIVE)

Dwingeloo has fringes (again)!

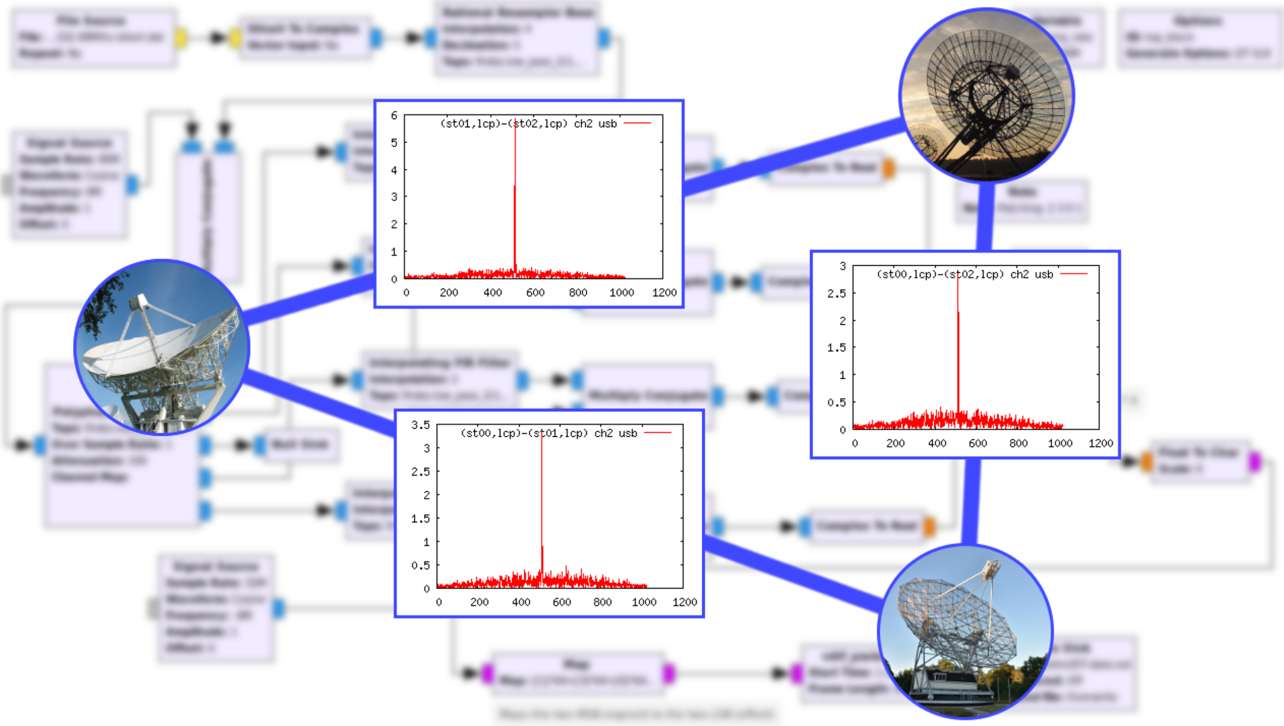


Figure 6. *Fringes between Dwingeloo (!) and the EVN stations Westerbork and Jodrell Bank.*

On Wednesday the 29th of August 2018, the Dwingeloo radio telescope took part in a test VLBI observation and we managed to obtain fringes to Westerbork and Jodrell Bank right away. This is more than 40 years after its first appearance as a VLBI telescope (Schilizzi et al., 1979).

The Dwingeloo telescope, once the largest fully steerable dish in the world, is now operated by the C.A. Muller Radio Astronomy Station (CAMRAS) volunteer organisation. They have, with great support from ASTRON, restored and rejuvenated the historical instrument. Its return to VLBI is a huge milestone and a testament to the great work by all these volunteers.

Fig. 6 shows the fringes in one of the 8 subbands that were recorded. The background image depicts the 'flowchart' created in the open source GnuRadio program to convert the input from raw samples, into properly timestamped VDIF data for the JIVE correlator.

Just like the previous time that Dwingeloo did VLBI, the frequency reference is again a borrowed Rubidium clock. However, as part of the ASTERICS project, we are working to transport the H-maser frequency reference signal from Westerbork over fiber to the Dwingeloo telescope. This still requires a bit of digging to bridge the last few hundred meters to the telescope, but expect even better fringes soon.

Paul Boven (JIVE/CAMRAS)

Reports from EVN stations

Medicina station

Antenna
The replacement of the azimuth wheel track and a preventive maintenance on the second azimuth wheel of the 32 m telescope (Fig. 7) has been completed in the last week of July. At the same time the refurbishment of the control room has been completed: the renewing of the rooms of the building and the acoustic isolation of the zone where apparatus are located with new computers and monitors are now finalised. Currently the checking of the whole observing system is in progress. The re-start of the operations was August 20th. The air conditioning system on the antenna will be completely changed in September. This will imply a further stop of the operations for maximum three weeks.

VLBI backend
The Flexbuff system of Medicina has been upgraded with new disks. Now the capacity available is 360 TB. Medicina has also provided the same amount of TB for the JIVE correlator.

Figure 7. *Medicina radio telescope in silhouette (Fabrizio Melandri).*

A. Orfei, G. Maccaferri, Medicina, Italy

Upcoming Meetings

The 14th EVN Symposium

Registration is still open until one week before the start of the symposium
The final program is already available at the official web site:

http://EVNSymp2018.iaa.es

The 14th European VLBI Network (EVN) Symposium and Users Meeting will be hosted by the Instituto de Astrofisica de Andalucia-CSIC in Granada (Spain) on behalf of the EVN Consortium Board of Directors. The meeting will take place on October 8-11, 2018 at the main auditorium of the Parque de las Ciencias of Granada, the science museum of the city, within walking distance from the historic areas of Granada.

This biennial meeting is the main forum for discussion of the latest very long baseline interferometric scientific results and technical and technological developments within the EVN member countries. At this meeting there will also be a chance for user input into the future Science Vision for the EVN.

Topics to be discussed include:

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

Moreover, **the meeting will also focus 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

Confirmed invited speakers include:

- Anna Bartkiewicz (Stellar evolution and stellar masers)
- Marica Branchesi (Multi messenger astronomy)
- Heino Falcke (The Event Horizon Telescope)
- Cristina Garcia-Miro (Very-high sensitivity VLBI with SKA)
- Jose-Luis Gomez (Powerful AGN science)
- Jose-Carlos Guirado (Synergies with high-resolution IR-optical interferometry)
- Benito Marcote (Fast radio bursts)
- Monica Orienti (Synergies between VLBI and CTA)
- Maria Rioja (Techniques and applications of high accuracy astrometry)

The next **relevant dates** regarding the Symposium are:

- Deadline for registration: **October 1st, 2018**
- Meeting starts: **October 8th, 2018**

A CASA-VLBI tutorial will be organised by JIVE for the late afternoon of October 11th, 2018 (15:30 h to 18:30 h). Separate registration is required for interested participants.

The **conference fee (390€)** includes admission to all scientific sessions, conference materials, welcome reception, coffee breaks and lunches during the meeting (Monday to Thursday), and conference dinner.

The weather and the city environment in Granada is typically excellent for the period selected for the conference. A number of social activities have been organized, including (among others) a welcome reception at Nazari Palace "Cuarto Real de Santo Domingo" (October 7th, evening), a visit to the historic Alhambra Palaces and Gardens (October 9th, evening), a visit to the IRAM 30m millimeter radiotelescope (October 10th, afternoon; if weather allows), and the conference dinner in the historic rooms of Santa Paula Palace (October 10th, evening).

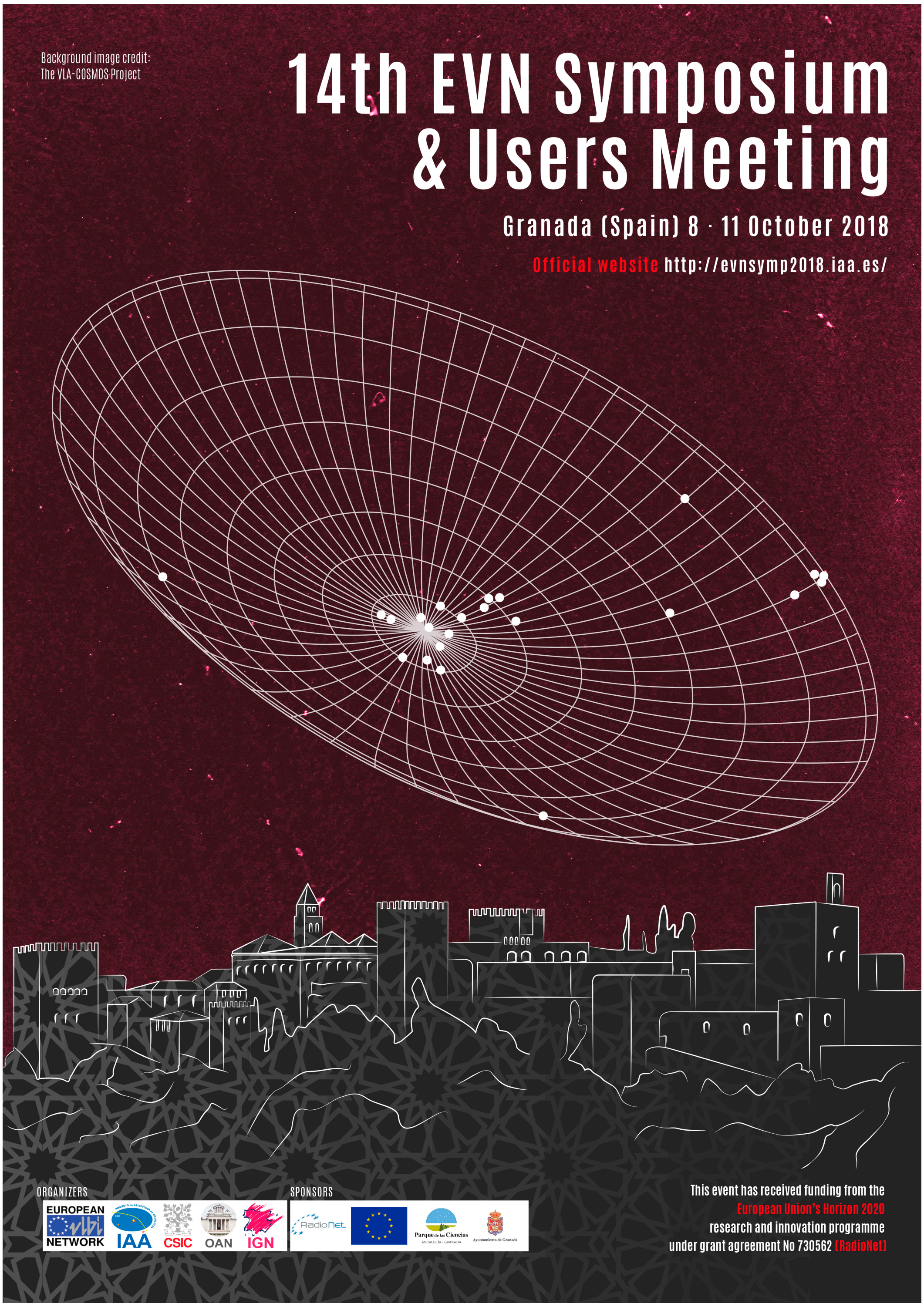
Further information regarding the meeting and details about committees, the venue, accommodation, and travelling to Granada is available on the conference web site at:

http://EVNSymp2018.iaa.es

Contact: EVN2018@iaa.es

Ivan Agudo on behalf of the SOC and the LOC

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



P.S.: **A copy of the EVN Symposium 2018 advertisement poster** (see above) can be found here. Thanks for helping us to advertise the meeting by printing, and placing in your bulletin board.

The 7th International VLBI Technology Workshop

The Seventh International VLBI Technology Workshop will be hosted by NARIT, the National Astronomical Research Institute of Thailand. It will take place from November 12 to 15, 2018, at Aonang Villa Resort, Krabi, Thailand. The details can be found here.

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.

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 aims to encompass all areas of hardware and software development relevant to VLBI.

The Seventh workshop in this series will feature (but not be limited to) traditional VLBI topics, such as receivers, backends, recording equipment, and e-transport. One day will be dedicated to correlators, for which we will also invite a number of experts from non-VLBI fields.