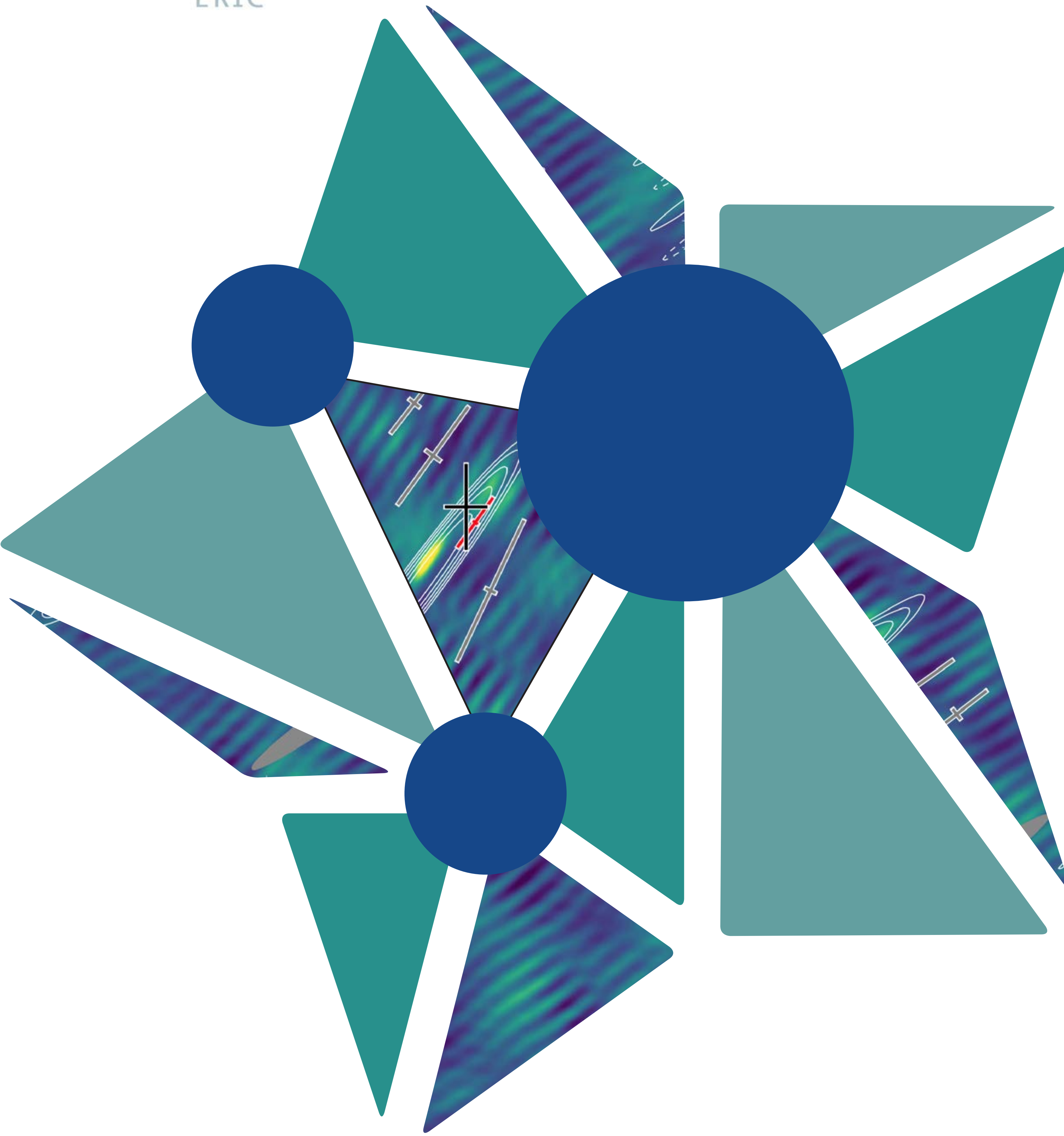
JIVE
Joint Institute for VLBI
ERIC



ANNUAL REPORT 2016

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The Joint Institute for VLBI ERIC was established by a decision of the European Commission in December 2014, and assumed the activities and responsibilities of the JIVE Foundation, which was established in December 1993. JIVE's mandate is to support the operations and users of the European VLBI Network (EVN), in the widest sense.

In 2016, JIVE had 5 members:

The Netherlands, represented by the Netherlands Organisation for Scientific Research (NWO) and the Netherlands Institute for Radio Astronomy (ASTRON)

France, represented by the Centre National de la Recherche Scientifique (CNRS)

Spain, represented by the National Geographic Institute (IGN)

Sweden, represented by Swedish Research Council (VR)

The United Kingdom, represented by the Science & Technology Facilities Council (STFC)

JIVE was also supported by the following Participating Research Institutes in 2016:

National Astronomical Observatories of China (NAOC), China

Max Planck Institute for Radio Astronomy (MPIfR), Germany

Italian National Institute of Astrophysics (INAF), Italy

National Research Foundation (NRF), South Africa

Foreword

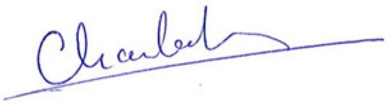
JIV-ERIC retains the core mission of the JIVE foundation that preceded it: to process the data of the EVN telescopes and support the astronomers who want to study their favourite objects. Enabling users to get their data in a timely fashion, while ensuring that they can wholeheartedly trust the data quality, has been key to the success of JIVE, qualifying it as an excellent European Research Infrastructure provider. Again, in 2016 we had the opportunity to see how diverse and wide-spread the user community is at a very interesting EVN symposium in St Petersburg.

Beyond its base operations, JIVE has been able to implement expedient quality control and hands-on support for all European astronomers by means of the Transnational Access programme to the EVN, which featured prominently in the EC-funded RadioNet programmes. In 2016 this support was temporarily – as we now know – interrupted and JIVE faced a fundamental decision: to focus on the funded work only, or to live up to its core mission and continue the full user support that the community expects. JIVE decided to do the latter, albeit with somewhat reduced staffing. The build-up of a processing backlog did show how critical the funding for operations is, nevertheless any impact on the user community was considered to be minimal.

It is gratifying to see that through a focus on proposal writing the situation for 2017 is going to be much better, with an access programme funded in a new RadioNet project. Moreover, with the launch of the JUMPING JIVE programme, the JIVE partners will have an opportunity to address this operational issue more fundamentally; we must come to a situation where, at a minimum, the same organisations that contribute to the EVN data, also commit to efficient data processing and open user support. It is possible that the EC should also have a continued role in making the service available to all European countries where there is traditionally less interest in radio astronomy.

The past year was also marked by preparations for Latvia to become a member of JIV-ERIC, which was approved by the JIV-ERIC Council in November and is effective from the beginning of 2017. This is an essential step that will strengthen links with the Latvian radio astronomy community. It is also an important milestone towards increasing the number of partners for the benefit of all of JIVE and the entire European community. We are looking forward to welcoming Latvia in JIV-ERIC in 2017.

All of this, of course, is to be seen in the context of the developments in radio astronomy at large. Through the aforementioned programmes, as well as additional projects, JIVE is making ties with the SKA and other major research initiatives. JIVE's technical expertise in user software, digital techniques and space applications make it a valuable partner in many radio astronomy projects. With the ERIC status, the new project grants and some exciting, innovative VLBI science applications – like those you will find in this report – I think JIVE is blessed with very bright prospects for the future.



Chairman of the JIV-ERIC Council

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1 Introduction

1.1 JIVE Mission

The Joint Institute for VLBI ERIC (JIVE) was established to support, progress and promote the use of Very Long Baseline Interferometry (VLBI). VLBI is a technique in which radio telescopes hundreds to thousands of kilometres apart observe the same radio source in the sky. The observations from the telescopes are presented as digital signals, which are then combined at a central, dedicated data processor (the correlator). Astronomers can use the resulting data to produce an extremely high resolution image of the radio sky. Alongside making images, the technique can be used to measure positions of bright radio sources with very high accuracy.

In Europe VLBI is organised through the European VLBI Network (EVN), a consortium that also includes members from other continents. JIVE hosts the correlator that provides the central data processing for the EVN and also supports most interactions with the astronomers who use the facility. The EVN is open to any astronomer who can write a competitive observation proposal.

JIVE receives the data from the telescope stations, as computer hard disk recordings or by direct streaming over fibre links (e-VLBI). The JIVE support team verifies the data quality, interacts with the staff at the telescopes if necessary, and provides support to the end user through subsequent processing and analysis if requested (see Chapter 4). Calibration data and images from a standard data pipeline are included in the final user product.

JIVE staff and summer students interacting during the summer of 2016

In order to keep the EVN and JIVE at the forefront of scientific research, JIVE harbours a team of scientists and engineers, who continually work on the development of new techniques and software to further the scientific capabilities of VLBI (Chapter 3). The team's primary focus is to investigate new methods to record and transport data, in order to enhance the sensitivity and flexibility of the research infrastructure. Novel data processing techniques and platforms are also explored, and JIVE engineers work on various user interfaces, such as the software that astronomers use to process their data. In addition, there is considerable expertise at JIVE in deploying VLBI for space applications.

Of course, the JIVE staff members also do scientific research themselves in a number of exciting areas, from active galactic nuclei at cosmological distances to star formation in the Galaxy (Chapter 2).

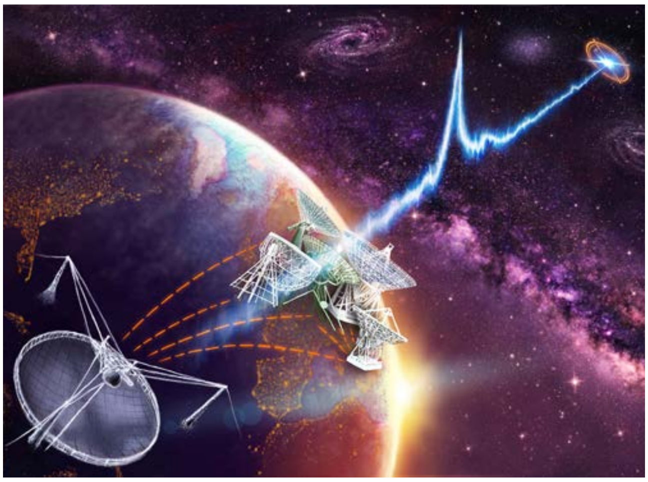
Finally, JIVE has a role in the EVN as the central entity in dealing with EC projects (listed on page 24); as an ERIC, JIVE has a responsibility to catalyse innovation and capacity building for European VLBI.

1.2 JIVE in 2016

An important milestone for JIVE was the admission of Latvia as a member of the ERIC. The Latvians made great progress retrofitting their antenna in Irbene near Ventspils, and subsequently joined the EVN in 2016. In the same instance they also proved to be ready to take an exemplary next step and join JIVE before the end of the year. This brings the number of full members of JIVE to six countries, with four additional organisations supporting JIVE through bilateral arrangements.

Despite becoming an ERIC in 2015, JIVE faced a number of challenges in 2016, which impacted its finances and some of its core services. A number of EC 7th framework projects ended – most notably the Transnational Access program to the EVN, which is part of the RadioNet project. Consequently, priorities had to be adjusted and writing new grant applications was all important in the first quarter of the year. In the end, 2016 concluded very positively, as it became clear that the new RadioNet proposal was to be funded, along with an initiative called "JUMPING JIVE" (Joining up Users for the Maximising the Profile, the Innovation and the Necessary Globalisation of JIVE) that will

During a press event at the Latvian Ministry of Education and Science, Ms Diana Laipniece, deputy director of the Department of Innovation, presents the Latvian commitment to membership of JIV-ERIC



Artist impression of the EVN telescopes participating in the observations of the repeating Fast Radio Burst.

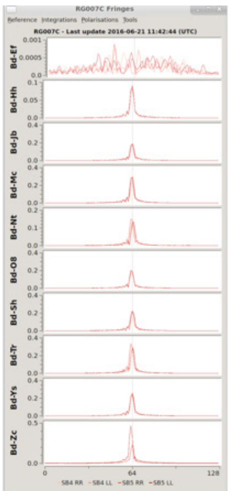
profile JIVE as an attractive future partner for European countries that have an interest in radio astronomy and institutes involved in VLBI world-wide.

The drop in subsidy for the EVN access programme in 2016 resulted in a bottleneck for the data processing and user services. The JIVE staff continued to accept the full load of EVN observing proposals, but as a result of adhering to the normal standards for data quality control, a backlog started to develop. It was decided to keep a basic staffing number for the support group, which in fact meant that JIVE had to reduce some of its financial reserves.

The research and development group at JIVE had new assignments from the ASTERICS project, and also made progress on user software implementations through the BlackHoleCam project. Moreover, JIVE worked on the design of the SKA telescope as an associated member of the Dutch SKA-NL programme. In this context, JIVE is a visible contributor to the definition of the SKA signal and data transport infrastructure.

Research and development linked to the EVN focussed on progressively increasing the bandwidth of VLBI observations. After recorded 2 Gbps modes were advertised, e-VLBI at increased bandwidth was also tested. During the testing campaigns, it also proved to be possible to get e-VLBI results from the KVAZAR stations in Russia. The past investments in the connectivity related research and development have also resulted in the deployment of so-called FlexBuff systems. This allows stations to buffer the data and stream it to the correlator after the observations, alleviating the need for shipping disks.

Scientifically, JIVE staff were involved in some very high-profile astrophysics projects. The effort to outfit the JIVE SFXC correlator platform with capabilities to de-disperse pulsar signals anywhere in the primary beam of the VLBI telescopes paid off when it



The JIVE team during real time observations with two KVAZAR stations could be applied to the repeating Fast Radio Burst source FRB121102. In 2016 it was established that this, and probably all FRBs, are of extragalactic nature, as a red-shifted dwarf galaxy was discovered to be host of this enigmatic source. By the end of 2016, several papers and press releases were prepared by the large, international team for publication in early 2017 (page 13). Overall, from both a technical and scientific angle, there is an increasing interest in studying transient phenomena with VLBI. JIVE staff are pursuing another technique, known as astrometry, notably to measure the position of masers associated with young stars. The scientific highlights also contain extremely high-resolution RadioAstron results, which have displayed remarkable brightness at the longest baselines (page 11).

1.3 Training and Outreach

The most notable VLBI event for JIVE staff was unquestionably the EVN symposium in St. Petersburg. The VLBI community enjoyed the Russian hospitality and the grandeur of the city in the XVIII century building that housed the first headquarters of the Russian Academy of Sciences. The meeting was a great success.

Conference photo of the participants in the 13th EVN Symposium in front of a sculpture of the founder of the Russian Academy of Sciences M.V. Lomonosov. Vasilevsky Island, St.Petersburg.

1.4 Personnel

In early 2016 two support scientists left JIVE to take up positions elsewhere. Minnie Mao had made a very enthusiastic contribution to JIVE but had an opportunity to pursue a Marie Curie position at Jodrell Bank.

After four years of support and very productive scientific collaborations, Gabriele Surcis accepted a post at the telescope on his home island Sardinia.

A farewell to Minnie Mao

A farewell to Gabriele Surcis

In 2016 our chief operator Hans Tenkink retired, which was celebrated in October. However, due to special circumstances he did agree to temporarily fill in for a few months after his retirement.

Hans Tenkink at his retirement party

Another notable event was the departure of ASTRON director Mike Garrett, who had been on the JIVE council for ten years after having, of course, served as JIVE director himself.

Mike Garrett's past and future support to VLBI was highlighted at his departure from ASTRON.

2 Science highlights

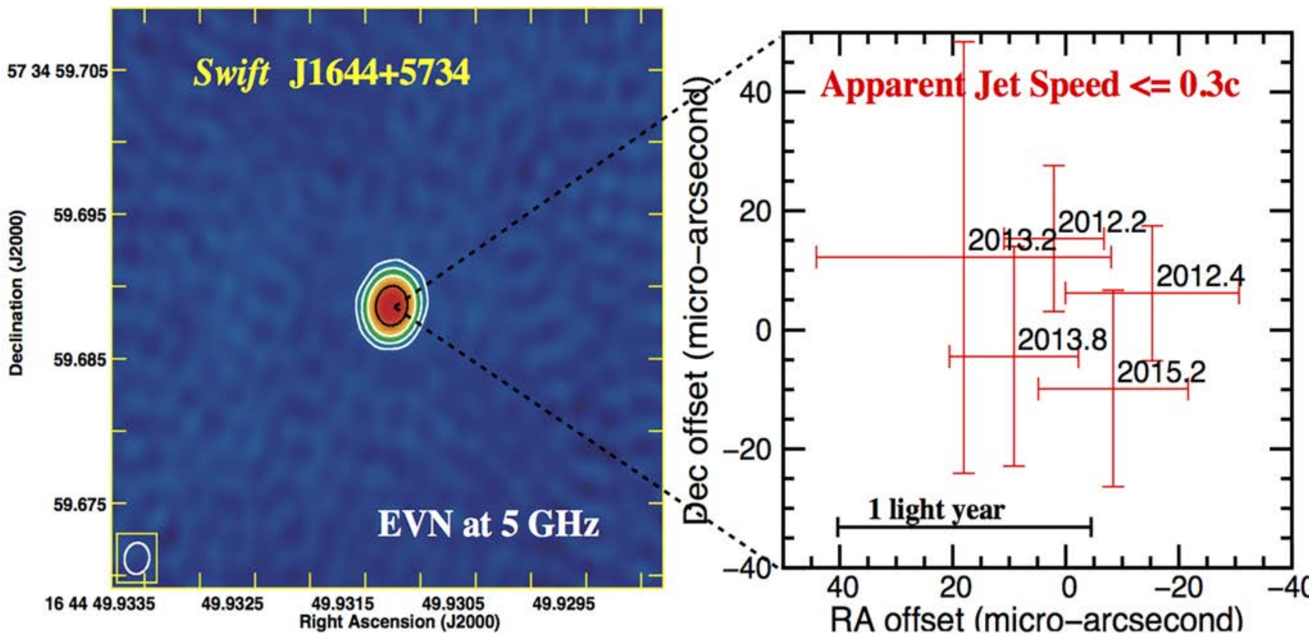
2.1 Tidal disruption events

Previously unseen supermassive black holes have been revealed as stars entering the tidal disruption radius of the black hole are torn apart. Such tidal disruption events present an opportunity for us to study the formation of astrophysical jets as they are ejected from the supermassive black hole.

The violent disruption of stars will occur when a star moves close to a supermassive black hole. About half of the gas forming the star is then attracted to the black hole, forming or feeding a disc around it, and the released gravitational energy is emitted across a wide range of the electromagnetic spectrum. Under certain physical conditions, part of the matter around the black hole is ejected in highly collimated beams, at rates approaching the speed of light. These so-called relativistic jets then produce strong radio emission. The first witnessed tidal disruption event that formed a relativistic jet was Swift J1644+57, which was initially identified by its luminous X-ray flare in 2011.

The new-born relativistic jet was monitored with the very long baseline interferometry (VLBI) technique, using the European VLBI Network (EVN). The group involved Jun Yang (PI, Onsala Space Observatory, Sweden), and JIVE collaborators Bob Campbell, Leonid Gurvits and Zsolt Paragi (among others).

VLBI is known to be capable of detecting



EVN 5 GHz image (color scale) and the results of top-level relative astrometry: the data reveal a very compact jet with no apparent motion. Yang, Paragi, van der Horst et al. (2016), MNRAS, 462, L66

tiny displacements in relativistic jets at great distances from Earth. During the Swift J1644+57 observations the team used a faint background source in the vicinity of the target, and achieved extreme astrometric accuracy of about 10 microarcseconds. Even with this incredible accuracy, there was no motion detected in the jet. This indicates that the newly-formed relativistic ejecta decelerate quickly as they interact with the interstellar medium in the galaxy. Furthermore, a very small jet viewing angle – inferred from earlier studies – may contribute to the apparent compactness and absence of proper motion. These results provide the first direct constraints on newly launched jets in tidal disruption events.

2.2 Hunting for the 'Hottest' Sources in the Universe

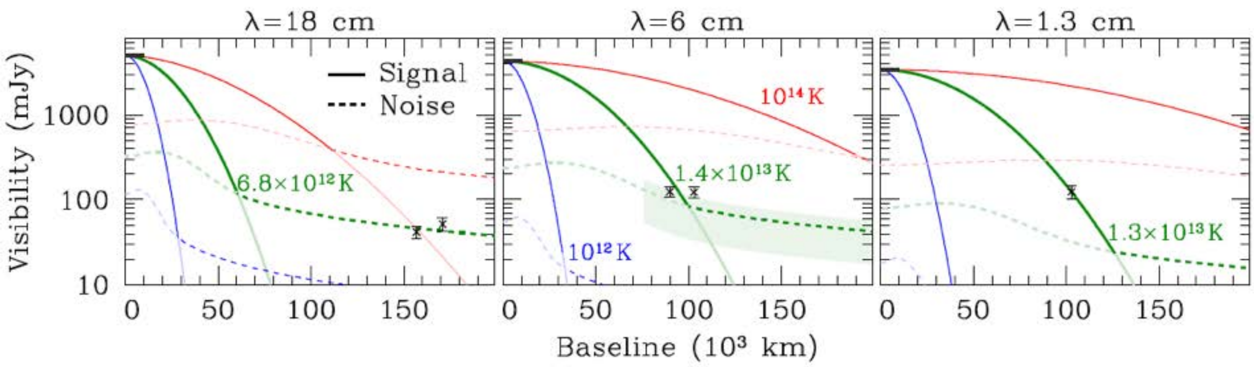
RadioAstron, the second dedicated Space VLBI (SVLBI) mission has been operating in orbit since July 2011. It is led by the Russian Academy of Sciences together with Roscosmos, and involves virtually all VLBI observatories around the world – a truly global VLBI facility. With the projected baseline between Earth-based and space-borne antennas measured in hundreds of thousands of kilometres, the facility is uniquely able to detect extremely high brightness temperatures in celestial radio sources, in particular – Active Galactic Nuclei (AGN), potentially exceeding the conventional theoretical limit of the inverse Compton cooling at about $10^{11.5}$ K. Indeed, due to its baseline length, RadioAstron should be able to measure brightness temperatures several orders of magnitude higher than this.

Artist's impression of the space-borne radio telescope RadioAstron onboard the "Spektr-R" spacecraft (courtesy of NPO Lavochkin and Astro Space Center, Lebedev Physical Institute).

However, are there sources that bright? Previous studies with various Earth-based VLBI arrays and the Japanese-led SVLBI mission VSOP hinted on the possible existence of such exceedingly 'hot' sources. If confirmed, their existence would pose serious problems for the current understanding of the phenomenon of AGN radio emission. The RadioAstron mission approaches such conundrums with focused studies of specific extragalactic objects and the AGN Survey.

An international team involving JIVE scientist, Leonid Gurvits, investigated one of the most 'charismatic' quasars, 3C 273, as a part of the RadioAstron's Early Science Programme – together with the largest Earth-based radio telescopes Arecibo (6 and 18 cm wavelengths), Effelsberg (6 cm), Green Bank (1.3 and 18 cm) and phased JVLA (1.3 cm). In 2012 and 2013 the programme provided consistently high estimates of brightness temperatures in excess of 10^{13} K. Refractive substructure does affect estimates of the brightness temperature at longer RadioAstron observing wavelengths of 6 and 18 cm, but not at the shortest wavelength of 1.3 cm. Consequently, because of these RadioAstron observations, the brightness temperatures in AGN contradicts the conventional theoretical models, making them even more fascinating.

The on-going RadioAstron AGN Survey offers a broader view of the enigmatic properties of extremely bright cores in active galactic nuclei. The Survey sample involves more than 250 extragalactic radio sources, and observations were completed in June 2016. Preliminary results do indicate that while there are no sources with stunning brightness temperatures of 10^{15} – 10^{16} K, which RadioAstron is technically able to detect, some sources (a dozen or so) are as bright as 3C273 or even several times brighter. Thus, the need to reconcile observational findings and theoretical predications becomes ever more topical. The in-depth analysis of the RadioAstron AGN Survey data is on-going, and its results will be presented to the community in the coming years.



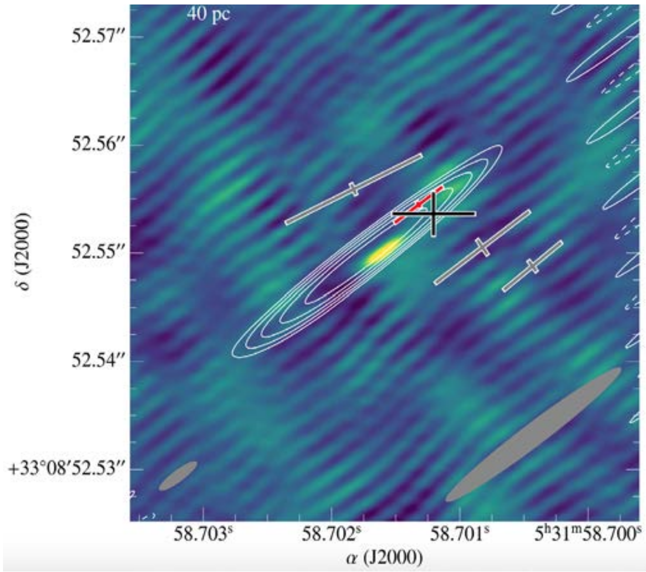
Visibility amplitude obtained in SVLBI observations of 3C 273 versus baseline length for circular Gaussian brightness distribution models. The effect of refractive substructure might dominate the detected signal at higher brightness temperatures and longer baselines at 18 and 6 cm wavlengths, but not at 1.3 cm (Johnson et al. 2016, ApJ 820, L10).

2.3 Fast Radio Bursts (FRBs)

Fast radio bursts are very short duration (a few milliseconds), dispersed radio signals of unknown origin. The first FRB was reported by Lorimer et al. in 2007. The high dispersion measure indicated that FRBs are most likely extragalactic in origin. If true, these signals could be used to probe the distribution of baryonic matter in the Universe, fundamental to cosmological models. The, so far reported, single-dish detections with Parkes Observatory, Arecibo Observatory and the Green Bank Telescope could not provide the accurate positions needed to identify a counterpart.

The only way to reliably measure the position of an FRB is direct, interferometric detection of a burst. At JIVE we have worked in the past few years to develop a technique to localize ms-duration signals with the EVN. The discovery of repeated bursts from FRB 121102 provided an excellent opportunity to do this. We carried out five epochs of EVN e-VLBI ToO observations from February to May 2016 at 18cm, with parallel recording of the data at JIVE and with the pulsar backend in Arecibo (PI Jason Hessels, Astron; JIVE team members, Bob Campbell, Aard Keimpema, Benito Marcote, Zsolt Paragi, and Huib van Langevelde). We did not detect activity in the field.

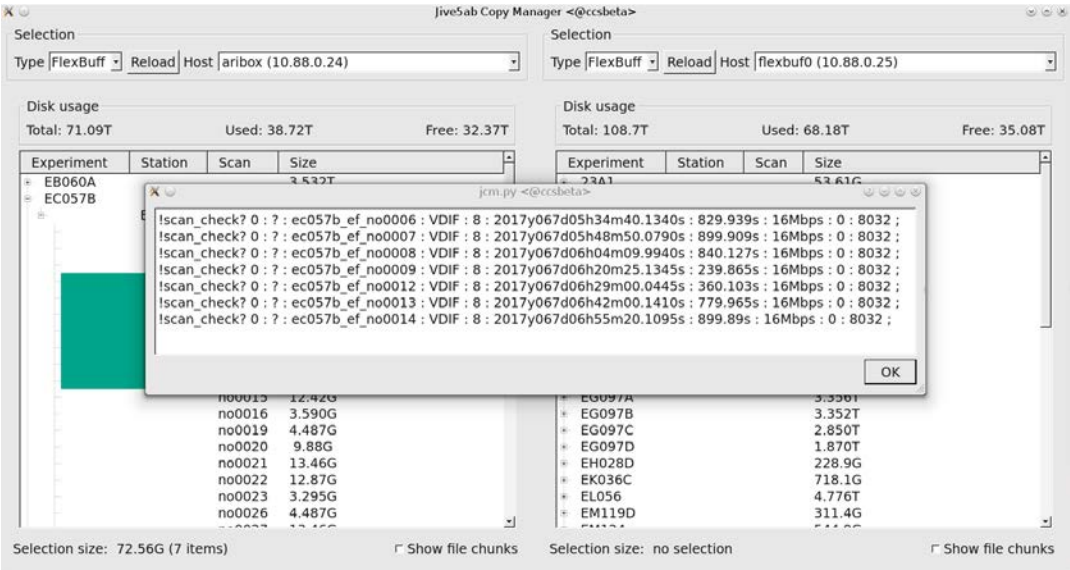
In August 2016, the Karl G. Jansky Very Large Array (VLA) succeeded in detecting activity, and provided the first accurate position of this source. Within about 100 mas the VLA found a weak persistent radio source as well. The EVN data were recorrelated with this new position, and the persistent source was detected on milliarcsecond scales (also confirmed by VLBA). To verify that the bursts and the persistent source are indeed concurrent at higher resolution, the group carried out further EVN+Arecibo observations in September 2016. This resulted in the detection of four bursts, the brightest of which clearly show that the source of the bursts and the persistent radio source are co-located within about 10 mas. The persistent radio source itself is located in a dwarf galaxy at a redshift of z=0.1927.



Individual burst locations (grey: weak bursts; red: the brightest burst ever detected in FRB121102) and the weighted mean burst location (black) with respect to the persistent radio source (contours: 18cm, color scale: 6cm EVN images). Marcote et al. 2017, ApJL, 834, L8

3.1 Data Recording and Transport

During 2016 many more stations followed the example of Onsala and switched to FlexBuff recording, with e-transfer to the correlator. This has the great advantage that it eliminates the need for the physical shipping of disk packs. The FlexBuff system, developed during the EC-funded NEXPReS project, consists of a high-speed, high-capacity COTS data recorder. Effelsberg, Yebes, Hartebeesthoek, Medicina and Noto all purchased units to be deployed at JIVE. In the second half of the year a switch was made from 4 to 8 TB disks, doubling the capacity of the newer units.



Screenshot of the newly developed jive5ab Copy Manager

In order to facilitate the increased use of e-shipping, decisions had to be made about the way to store data. This led to a system that automatically balances the load on the available FlexBuffs during the observing sessions, while limiting the number of individual station recordings per experiment to two per FlexBuff. More than two stations per unit might adversely influence the playback speed during correlation. Many additional fixes and improvements were made to the data transfer software and new software tools were created to efficiently handle the transfer and copying of recorded data.

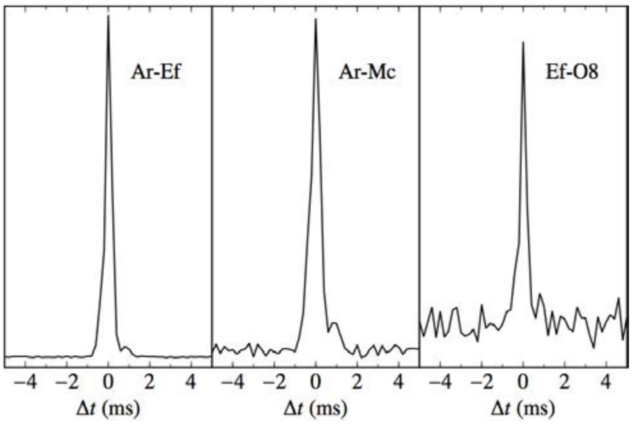
The in-house developed jive5ab program, which is used throughout the EVN (and beyond) for both recorded and real-data transfer, continued to be improved. It is now capable of handling data rates up to 256 Gbps, which should be sufficient for the foreseeable future. Many small and large improvements were implemented, increasing its ease of use and the fully transparent handling of both Mark6 and FlexBuff formats.

3.2 Software Correlation

The unique features of SFXC, the EVN software correlator developed at JIVE, played an important role in the localisation of FRB121102 (see 2.3 Fast Radio Bursts). The use of recorded e-VLBI data, combined with coherent de-dispersion and the ability to output filterbank data which can be processed directly with existing pulsar toolkits, were at the basis of the success of these observations.

During 2016 several new methods were implemented, like baseline-dependent windowing and averaging. Using these methods the size of wide-field VLBI dataset can be reduced dramatically, at the cost of some loss of sensitivity. Furthermore, it can be used to restrict the field of view to a region on the sky in order to prevent strong nearby sources from appearing in the sidelobes of the interferometric beam.

In September 2016, the SFXC hardware was expanded with 4 nodes, each containing 2 8-core CPUs, bringing the total number of cores to 512.



Profile of a burst from FRB121102 on the baselines between Arecibo-Effelsberg, Arecibo-Medicina, and Effelsberg-Onsala. The data was coherently de-dispersed to DM=561.

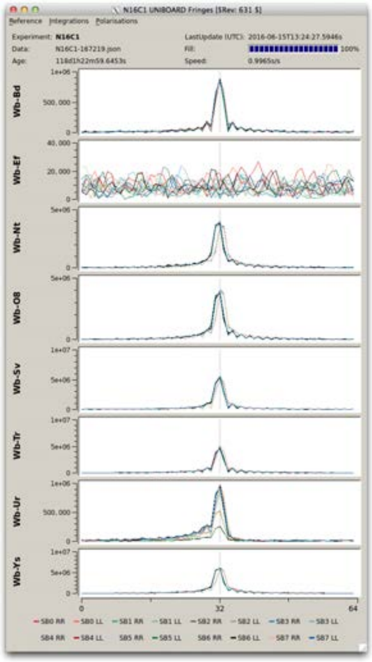
3.3 Hardware Correlation and Digital Engineering

The development of the JIVE UniBoard Correlator, or JUC, continued apace. As the name implies, this correlator makes use of the UniBoard, a powerful FPGA-based computing platform which was developed by JIVE and its partners as part of the RadioNet FP7 project. Although less flexible than the SFXC, the JUC packs a tremendous amount of processing power at very low power consumption, and should be very useful for the real-time processing of large numbers of stations producing data at 4 Gbps – a mode which will be next in line for the EVN.

During the year, several features were added to the firmware to support e-VLBI processing. Besides the 16 and 32 MHz personalities, a new 64 MHz firmware version was developed.

Towards the end of the year, the 32 MHz personality had been debugged and verified, while testing of the 64 Mhz version had just begun.

The JUC was designed to receive data from the stations, packaged in single frequency bins. Unfortunately, during the first real-time test towards the end of 2016, it was found that the hardware at the stations could not quite produce data in this mode. Although this issue is under investigation, it is not clear when a fix will be forthcoming. As a result, the control code had to be rather extensively re-written to deal with mixed-frequency data packets, and e-VLBI tests had to be postponed to 2017.

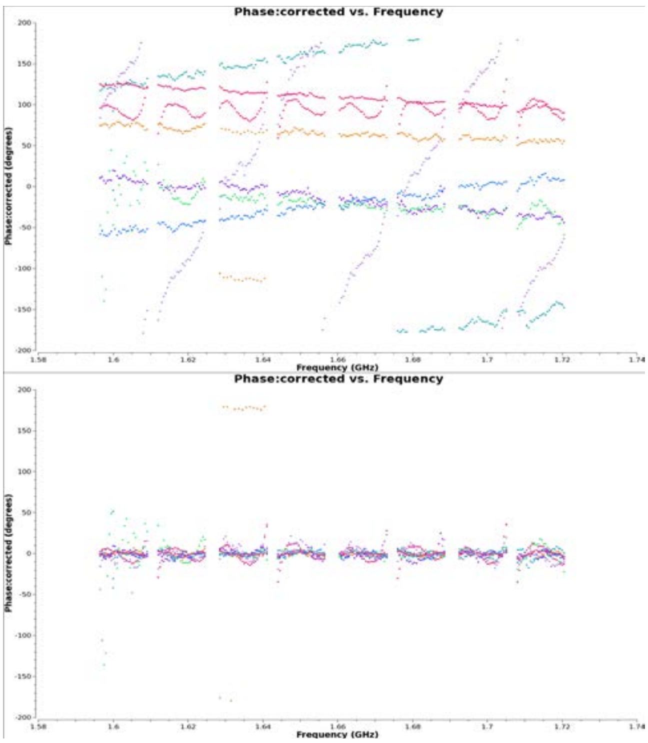


Screenshot of the UniBoard fringeplot monitor. It is run in parallel with the correlator and reads the output of the correlator, filters out the correlation functions on baselines to a reference station and computes the fringes, and plots the results in a graphical user interface.

3.4 User Software

Excellent progress was made with the development of a CASA VLBI fringe fitter, in the context of the BlackHoleCam ERC project. The lack of this functionality has until now been a major obstacle for switching from the time-honored AIPS package to the far more up-to-date, and actively maintained, CASA data processing package.

The existing Python prototype was fine-tuned, and a C++ implementation within the CASA framework begun. Extensive comparisons were made between the CASA and AIPS/HOPS results, to which were added MeqTrees simulations in order to study the impact of the troposphere on fringe fitting. Besides the



Results of prototype Python fringe fitter. Upper panel: phases as function of frequency for a phase reference source after applying the instrumental delay, but before applying residual delay solutions over the entire frequency band. Lower panel: phases after the residual delay is applied. As expected, the phases are successfully flattened across the full width of the frequency range and on all baselines.

actual fringe fitter, a lot of additional code had to be written to make fringe fitting in CASA possible: the translation of AIPS calibration tables into CASA calibration code, the application of the solutions, handling of VLBI amplitude calibration and importing of Tsys and weather information from FITS-IDI files.

3.5 Contributing to SKA design

Last year the work of the SAT architect in the SaDT consortium was the main contribution of JIVE to the SKA effort. Much work went into the performance requirements for the SKA time and frequency system and its interface to the rest of the telescope. Besides that, the design of a system for the distribution of UTC timing at ns accuracy throughout the SKA, based on White Rabbit technology, was finalised.

4 Operations

4.1 Correlation

The core of JIVE's service is the processing of EVN data; the table below summarizes experiments that were correlated, distributed, or released in 2016. For a detailed list of the user experiments, see 6.5 Correlator Activity.

	User Experiments			Test and Network Monitoring		
	N	Ntwk_hr	Corr_hr	N	Ntwk_hr	Corr_hr
Correlated	90	752.75	696.5	20	71	77
Distributed	97	844	1045	23	81	87
Released	94	835	1047	25	86.5	92.5
e-EVN experiments	39	242.5	258.5			
e-EVN ToOs	19	121	135			

Summary of projects correlated, distributed or released in 2016. Here, 'network hours' sum the total duration of experiments, and 'correlator hours' are network hours multiplied by any multiple correlation passes required.

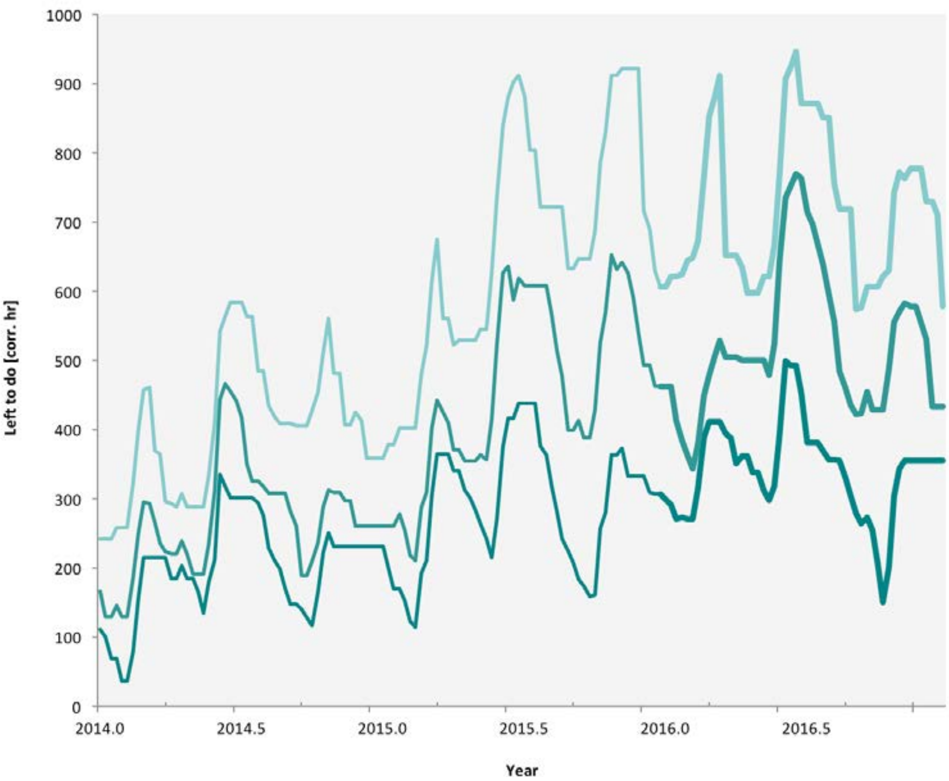


Figure 1. The size of the correlator queue at different stages in the processing cycle. The bottom line shows the number of correlator hours that remain to be correlated. The middle line shows the number of correlator hours in experiments whose data remain to be distributed to the PI. The top line plots the number of correlator hours associated with recording media that have yet to be released back to the pool.

The EVN offers a variety of observing modes that provide users with extra flexibility, but add some complexity to the operations. Figure 2 shows the evolution of the annual EVN

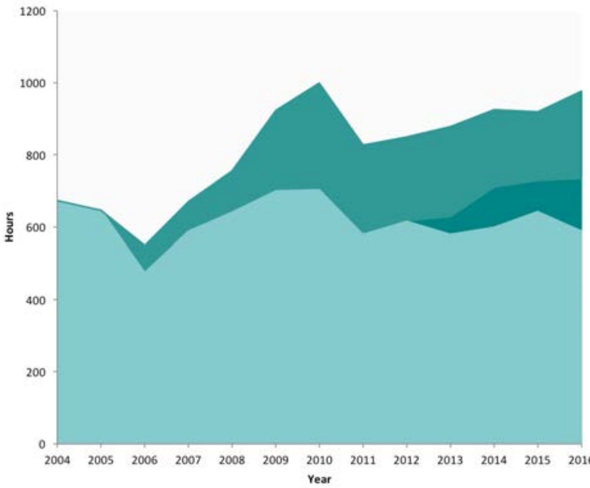


Figure 2. Annual EVN network hours, with 'traditional' disk-based observations in grey (bottom section), e-EVN hours in light blue (top section), and the relatively new scheduled disk-based out-of-session hours in dark blue (middle section). 2016 saw the second highest number of total network hours ever, and the most disk-based out-of-session hours.

network hours. Figure 3 focuses on e-EVN experiments, and shows how they break-down into individual proposal categories.

In 2016, there were user experiments that took advantage of new features of the EVN software correlator at JIVE (SFXC) and new observing possibilities with the EVN, especially for e-EVN experiments:

- Ten e-EVN experiments recorded onto FlexBuffs at JIVE, simultaneously to the real-time correlation: eight target-of-opportunity observations aiming to localize fast radio bursts, one looking for pulsed emission in a gamma-ray binary, and one maser observation requiring both continuum line passes. At one point, the sum of recorded e-EVN data was 101 TB.

- User e-EVN experiments were run at 2 Gbps for some stations in June, October, and November. By the November e-EVN day, the 2 Gbps stations were Effelsberg, Medicina, Noto, Onsala, Yebes, Hartebeesthoek, and Irbene, with a total across the array of 17 Gbps streaming into JIVE for real-time correlation (the other stations were run at 1Gbps, covering the upper half of the subbands, which poses no issues for SFXC).

- There was a first e-VLBI from KVAZAR stations at 512 Mbps in June (Zelenchukskaya, Badary).

- EG088 was the first joint EVN + Australian LBA experiment under the new policy of encouraging linked proposals to both arrays. LBA data was translated to Mark5B format and e-shipped to JIVE. This was also the first experiment in which different sets of subbands from a station had significantly different clocks, arising from the use of two separate back-ends to attain the 1 Gbps data rate at ATCA.

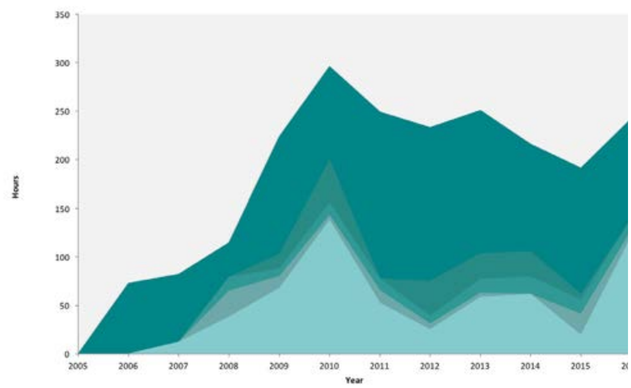


Figure 3. Division of e-EVN network hours into proposal categories, from the bottom to the top: target-of-opportunity, triggered, short observations, converted from disk, and regular. 2016 saw the second highest number of target-of-opportunity hours ever (121 hrs), which can occur in either the scheduled e-EVN days or out-of-session.

4.2 EVN Support

The Kunming telescope in Yunnan (southwest China) participated in three bands in session 3/2016, producing fringes for the first time in an EVN context at 6cm and 5cm (they had previously participated in some 3.6 cm observations).

Discussions with SKA SA continued on arranging test observations at 5 or 6 cm, with the Nkutunse telescope just to the north of Accra, Ghana. First observations are anticipated during the session 1/2017.

The Kunming 40m telescope

JIVE coordinated and correlated a series of tests of the DBBC polyphaser filter bank (PFB) personality: four at 2 Gbps and four at 4 Gbps. So far, only a limited number (4-5) of stations have participated because of the LO compatibility requirements implicit in using the PFB personality, which does not feature tunable BBCs. Test observations with Torun continued into 2016 comparing the now operational remote H-maser and a remote optical-lattice clock for frequency control.

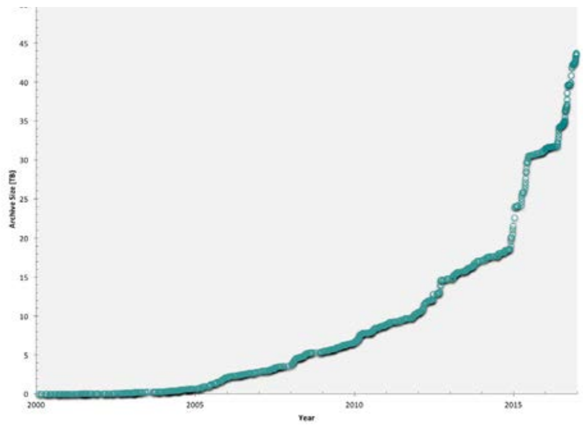
The process of e-shipping, in which JIVE pulls data from the telescopes to FlexBuffs at JIVE, saw its first operational use in 2016. This avoids the need to ship disk-packs, and provides the opportunity for finer control over freeing up space for future observations. JIVE is developing tools to harness this increased flexibility (rather than being inundated by it).

4.3 User Support

JIVE provides support in all stages of a user's EVN observation, from proposal definition to data analysis. There were 13 first-time PIs in 2016 observations, including 6 students. A list of visitors to JIVE can be found in section 6.4.

JIVE maintains many of the interfaces through which the EVN users interact with the VLBI facility. JIVE continued to provide PIs with experiment-specific scheduling templates to track the evolving configurations of equipment at EVN stations. The new procedure for depositing schedules (PIs send their scheduling files to JIVE for running through the schedule program and populating the server from which stations download them) continued, with no instances in which a wrong schedule version was observed. JIVE also provided assistance with making schedule files for mm-VLBI (GMVA) experiments, so that they reflected the field-system preferences.

The EVN Archive is another vital user service, providing open access to practically all data older than one year. The total size of user-experiment FITS files in the Archive at the end of 2016 was 43.34 TB, an increase of 39% over the year. The figure below shows the growth of the Archive with time.



Growth of user experiments in the EVN Archive. Experiments archived in 2016 are plotted in dark blue. Vertical grey lines show the transition period between the MkIV and SFXC correlators.

5.1 JIVE Financial Report 2016

Balance [after allocation of results]

ASSETS	2016 in €	2015 in €
Tangible fixed Assets		
Tangible fixed Assets	69 831	77 831
Total of Tangible fixed Assets	69 831	77 831
Current Assets		
Receivables	822 411	1 055 679
Cash at bank	2 498 396	1 150 686
Total of Current Assets	3 320 807	2 206 365
Total Assets	**3 390 638**	**2 284 196**
	========	========

LIABILITIES	In €	In €
Capital		
General reserve	807 767	936 117
Designated funds	409 783	511 415
Total capital	1 217 550	1 447 532
Other Liabilities		
Short term debts	2 173 088	836 664
Total Other Liabilities	2 173 088	836 664
Total Liabilities	**3 390 638**	**2 284 196**
	========	========

Statement of profit and loss

	2016 BUDGET	2016 ACTUAL	2015 ACTUAL
R E V E N U E S	**in €**	**in €**	**in €**
Income			
Contributions/subsidies third parties	1 710 066	1 809 747	2 644 675
Interest	0	0	27
Other	201 490	235 762	168 095
Total Income	1 911 556	2 045 510	2 812 798
Total Revenues	**1 911 556**	**2 045 510**	**2 812 798**
	========	========	========

E X P E N D I T U R E S	**in €**	**in €**	**in €**
Operations			
Expenditures	2 069 058	2 275 492	2 676 681
Total Expenditures	**2 069 058**	**2 275 492**	**2 676 681**
	========	========	========
R E S U L T	**-157 502**	**-229 982**	**136 117**

5.2 JIVE Projects

The table lists the projects that JIVE was active in during the reporting period.

Project & Work Packages	Dates	JIVE role
SKA-NL (NWO)	01.09.14 - 31.12.18	JIVE is an associated partner of the Dutch effort to support the engineering contribution for the SKA, contributing in the area of Signal and Data Transport and VLBI with SKA-MID.
BlackHoleCam (EC)	01.10.14 - 30.09.20	BlackHoleCam is an ERC synergy project to enable sub-mm VLBI in which JIVE is contributing to the areas of real-time data verification and user software.
ASTERICS (EC)	01.05.15 - 01.09.19	ASTERICS is a collaboration to provide common tools and interfaces for ESFRI-listed astronomy projects.
├ *Cleopatra*		JIVE is a major contributor to research on time-distribution and data-transport methods and provides the work package leader (Arpad Szomoru).
└ *Obelics*		JIVE is a partner in some of the user data processing development projects.

6 Tables and Metrics

6.1 JIVE Council

Representatives of Members

Dr. Patrick Charlot – Laboratoire d'Astrophysique de Bordeaux, France (Chair)

Prof. Simon Garrington – Jodrell Bank Centre for Astrophysics, Manchester, UK (Vice-chair)

Prof. John Conway – Onsala Space Observatory, Onsala, Sweden

Prof. Michael Garrett – ASTRON, Dwingeloo, the Netherlands

Prof. Jesus Gómez González – Instituto Geográfico Nacional, Madrid, Spain

Mrs. Monica Groba Lopez – Instituto Geográfico Nacional, Madrid, Spain

Dr. Denis Mourard (until 31-12-2016) – National Centre for Scientific Research, Paris, France

Dr. Guy Perrin (from 1-1-2017) – National Centre for Scientific Research, Paris, France

Dr. Catarina Sahlberg – Vetenskapsrådet (VR) / Swedish Research Council, Stockholm, Sweden

Dr. Ronald Stark – NWO, Den Haag, the Netherlands

Dr. Colin Vincent – Science and Technology Facilities Council, Swindon, UK

Dr. Marco de Vos – ASTRON, Dwingeloo, the Netherlands

Representatives of Associated Research Institutes

Prof. Ludwig Combrinck – National Research Foundation, Pretoria, South Africa

Prof. Xiaoyu Hong – NAOC, Shanghai Astronomical Observatory, Shanghai, China

Mrs. Vinny Pillay – South African Embassy, Brussels, Belgium

Dr. Grazia Umana – INAF-ORA, Bologna, Italy

Dr. René Vermeulen – representing the EVN Board of Directors, ASTRON, the Netherlands

Prof. Anton Zensus – MPIfR, Bonn, Germany

6.2 JIVE Personnel

Dr. Jay Blanchard	Support Scientist (from 1 May 2016)
Mr. Paul Boven	Network/Linux Specialist
Mr. Wybren Buijs	Linux-/Network Specialist
Dr. Ross Burns	Support Scientist (from 1 May 2016)
Dr. Bob Campbell*	Head of Science Operations
Dr. Giuseppe Cimo	Space VLBI Scientist
Dr. Dominic Dirkx	Researcher (until 1 February 2016)
Drs. Bob Eldering	Software Engineer
Prof. Leonid Gurvits*	Head of Space Science & Innovative Applications Group
Dr. Jonathan Hargreaves	Digital Engineer
Mr. Bert Harms	Chief Operator
Dr. Ing. Aard Keimpema	Scientific Software Engineer
Dr. Ir. Mark Kettenis	Software Project Scientist
Mrs. Yvonne Kool-Boeser	Senior Secretary
Mr. Martin Leeuwinga	Hardware Support Engineer
Dr. Minnie Mao	Support Scientist (until 13 April 2016)
Dr. Benito Marcote Martin	Support Scientist (from 11 January 2016)
Dr. Zsolt Paragi*	Head of User Support
Dr. Sergei Pogrebenko	Senior System Scientist (until 1 October 2016)
Dr. Des Small	Scientific Software Engineer
Dr. Gabriele Surcis	Support Scientist (until 15 March 2016)
Dr. Arpad Szomoru*	Head Technical Operations and R&D
Mr. Hans Tenkink	Chief Operator (until 3 November 2016)
Dr. Ilse van Bemmel	Project Scientist
Drs. Aukelien van den Poll	Project Assistant
Prof. Huib Jan van Langevelde*	Director
Drs. Harro Verkouter	Senior Software Engineer

* - JIVE MT member

6.3 Educational Responsibilities

MSc project supervision

Giovanni Granato - by Dominic Dirkx and Leonid Gurvits, TU Delft (completion in 2017)

PhD project supervision

Tatiana Bocanegra Bahamon – by Leonid Gurvits, TU Delft (completion in 2017)

Luis Henry Quiroga Nuñez – by Huib van Langevelde, Leiden University (completion in 2019)

Secondary affiliations:

Tatiana Bocanegra Bahamon – affiliated with Shanghai Astronomical Observatory, Shanghai, and Department of Astrodynamics and Space Missions, Delft University of Technology, the Netherlands

Leonid Gurvits – affiliated with Department of Astrodynamics and Space Missions, Delft University of Technology, the Netherlands

Huib Jan van Langevelde – affiliated with Sterrewacht Leiden, Leiden University, the Netherlands

Luis Henry Quiroga Nuñez – affiliated with Sterrewacht Leiden, Leiden University, the Netherlands

6.4 Visitors to JIVE

Name	Institute	Period	Host
J. Pelamatti	Delft University of Technology, the netherlands	01/09/15 – 01/03/16	Gurvits
G. Molera	Aalto University, Finland	31/01/16 – 02/02/16	Gurvits
D. Litvinov	Sternberg Astronomical Institute, Russia	31/01/16 – 03/02/16	Gurvits
C. Lonsdale	MIT Haystack Observatory, USA	10/02/16	Van Langevelde
L.H. Quiroga Nunez	Leiden University, the netherlands	01/03/16 – 03/03/16	Van Langevelde
B. Edmonts	Centro de Astrobiología, Spain	21/03/16 – 25/03/16	Mao

Name	Institute	Period	Host
L. Haehner	European School of Bergen, the Netherlands	28/03/16 – 31/03/16	Van Bemmel
S. Frey	FÖMI, Hungary	11/04/16 – 22/04/16	Paragi
K. Gabanyi	FÖMI, Hungary	11/04/16 – 22/04/16	Paragi
R. Coppejans	Radboud University, the Netherlands	17/04/16 – 21/04/16	Paragi
D. van Rossum	Radboud University, the Netherlands	17/05/16	Van Bemmel
M. Atemkeng	Rhodes University, South Africa	27/05/16 – 22/07/16	Paragi
N. Gizani	Hellenic Open University, Greece	12/06/16 – 25/06/16	Paragi
F. Broekgaarden	University of Amsterdam, the Netherlands	13/06/16 – 27/08/16	Van Bemmel
Y. Huang	Carleton College, USA	17/06/16 – 10/09/16	Keimpema
I. Polderman	Radboud University, the Netherlands	14/07/16	Van Bemmel
A. Akoto-Danso	Rhodes University, South Africa	20/07/16 – 31/08/16	Paragi
S. Makhatini	Rhodes University, South Africa	23/07/16 – 31/08/16	Paragi
M. Mao	Jodrell Bank Observatory, UK	11/08/16 – 22/08/16	Paragi
M. Cruz	Leiden University, the Netherlands	14/09/16	Van Langevelde
I. Rüse	Embassy of the Republic of Latvia to the Netherlands	26/09/16	Van Langevelde
D. Duev	Caltech, USA	06/10/16 – 12/10/16	Gurvits
S. Noesel	MPIfR Bonn, Gemany	07/11/16 – 11/11/16	Cimo
L. Chen	NAOC/CAS, China	17/12/16 – 18/12/16	Gurvits

6.5 Correlator Activity

User experiments with correlation, distribution, or release activity in 2016

	Observation Date/ Session	Principal Investigator	User Experiments
EA055B	171015	Argo	Tracking the evolution of the new radio source NGC660
EA057A	161015	Anderson	Testing the feasibility of EVN phase-referencing observations to GPS satellites
EA057B	050316	Anderson	Testing the feasibility of EVN phase-referencing observations to GPS satellites
EB056	080615	Biggs	Determining the mass distribution in the lensing galaxy of CLASS B0850+054
EB059	210916	Blanchard	Radio core of TDE source IGR J12580+0134
EC052F	120116	Cseh	Do most high-redshift radio-loud quasars have a steep spectrum?
EC054C	130116	Cao	First-epoch VLBI observations of four z>4 blazars with the EVN
EC054D	030216	Cao	First-epoch VLBI observations of four z>4 blazars with the EVN
EC057A	140616	Cutini	Morphological changes after a bright optical/gamma-ray flare in S51803+78
EG073B	231015	Goddi	How do O-type forming stars accrete their mass?
EG078D,E	Session 2/2016	Garrett	No place left to hide -- AGN among the faint radio source population
EG082G	020216	Gawronski	Project RISARD -- part III
EG082H	160316	Gawronski	Project RISARD -- part III
EG082I	100516	Gawronski	Project RISARD -- part III
EG082J	210616	Gawronski	Project RISARD -- part III
EG091A	150316	Ghirlanda	Modeling the emission of the brightest Swift GRBs from the radio to the X-ray
EG092A	040316	Guirado	Radio emission in ultra-cool dwarfs: the nearby planetary system VHS1256-1257
EG092B	270516	Guirado	Radio emission in ultra-cool dwarfs: the nearby planetary system VHS1256-1257
EH028D	191015	Hu	Parallax measurement to 1.6 GHz OH masers in the OH/IR star OH138.0+7.4
EH032A,B	Session 3/2015	Heald	Observations of the core of the giant radio galaxy J145049+100649
EJ016A,B	Session 1/2016	Jackson	SKA science now: the gravitationally-lensed radio quiet quasar HS0810+2554
EK035	060615	Koay	Inclination dependencies of optical-UV broad emission line profiles in quasars
EK036A	181015	Kirsten	Long overdue -- measuring the parallax and proper motion of the Crab
EK037	080616	Kim	New strong H2O maser in Cepheus A-HW3div: signature of a new YSO outflow?
EM117A-D	Session 1/2016	Moscadelli	A 3-D view of high-mass star formation: gas kinematics and magnetic fields

JIVE

	Observation Date/ Session	Principal Investigator	User Experiments
EM117E-L	Session 2/2016	Moscadelli	A 3-D view of high-mass star formation: gas kinematics and magnetic fields
EM118A	150915	Mao	Heart of a spiral DRAGN
EM118B	061015	Mao	Heart of a spiral DRAGN
EM119A-D	Session 1/2016	Mao	Heart of a spiral DRAGN
EM121A	210616	Marcote	The possible connection of a compact radio source and an unidentified TeV source
EM125A	111016	Marcote	Unveiling the radio counterpart of the possible gamma-ray binary HESS J1832-093
EM125B	151116	Marcote	Unveiling the radio counterpart of the possible gamma-ray binary HESS J1832-093
EO014	061216	Olech	Position and structure of 6.7 GHz methanol emission in a new periodic maser
EP087I	261015	Perez-Torres	Arp299: the show goes on
EP092B	140615	Perez-Torres	Probing the double-degenerate scenario in Type Ia SNe with the EVN
ER038	011115	Roberts	pc-scale structures of the cores of X-shaped radio sources
ER040	170615	Rampadarath	Possible parsec-scale jet motion in the Seyfert galaxy M51
ES072N	Session 3/2015	Surcis	6.7 GHz methanol maser polarization towards massive proto-stars II
ES074B	120616	Surcis	Monitoring of the magnetic field and the outflow expansion in W75N-VLA2
ES079A	260216	Szymczak	Periodic methanol maser in G107.298+5.639
ES079B	050616	Szymczak	Periodic methanol maser in G107.298+5.639
ES081A	121016	Saikia	Spin dependence of jet power in super-massive black holes
EW017A	Session 3/2015	Wu	The radio structure of ultra-high-energy synchrotron peak BL Lacs
EY023	161015	Yang	Searching for the jet activity associated with Seyfert type change in Mrk590
EY024A	030216	Yang	Searching for the correlation between jets and the most powerful winds
EY024B	080316	Yang	Searching for the correlation between jets and the most powerful winds
EZ025	300516	Zhang	Geometry and kinematics of the colliding-wind binary WR 146
GA035A	281014	Alakoz	Imaging micro-structures of OH and H20 masers with ultimate angular resolution
GA035B	290115	Alakoz	Imaging micro-structures of OH and H20 masers with ultimate angular resolution
GA036	310515	Asadi	Gravitational milli-lensing as a probe of dark halo sub-structure.
GB075C	290515	Boccardi	Ultra-high resolution imaging of the archetypal radio galaxy Cygnus A
GF019A	Session 1/2016	Fenech	High-resolution, multi-frequency mapping of the compact sources in M82
GM073A	301015	McKean	Testing galaxy formation on the smallest scales with VLBI
GM073B	220216	McKean	Testing galaxy formation on the smallest scales with VLBI

	Observation Date/ Session	Principal Investigator	User Experiments
GN002B	130615	Nyland	Tracing the evolution of fast jet-driven outflows
GN002C	151015	Nyland	Tracing the evolution of fast jet-driven outflows
GP053E	040315	Perez-Torres	Deep VLBI observations of the star-bursting regions in Arp299
GP053F-H	Session 2/2015	Perez-Torres	Deep VLBI observations of the star-bursting regions in Arp299
GR035	281213	Rosenblatt	Towards understanding the origin of Phobos
RG007B	150316	Ghirlanda	Unveiling the progenitor nature and environment of the bright GRB151027
RG007C	210616	Ghirlanda	Unveiling the progenitor nature and environment of the bright GRB151027
RG007D	161116	Ghirlanda	Unveiling the progenitor nature and environment of the bright GRB151027
RG008A	160316	Giroletti	Pinpointing the variable radio source in the candidate host galaxy of FRB 150418
RG008B	100516	Giroletti	Pinpointing the variable radio source in the candidate host galaxy of FRB 150418
RG008C,D	Session 2/2016	Giroletti	Pinpointing the variable radio source in the candidate host galaxy of FRB 150418
RP024A	010216	Paragi	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RP024B	100216	Paragi	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RP024C	110216	Paragi	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RP024D	240516	Paragi	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RP024E	250516	Paragi	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RP026A	190916	Hessels	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RP026B	200916	Hessels	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RP026C	210916	Hessels	Pinpointing the position of the unique repeating fast radio burst FRB 121102
RS002	120416	Sanna	6.7 GHz methanol masers and the first-ever detected burst in a high-mass YSO
RSC03	210916	Cui	Searching for a phase-referencing source for the EVN observations of AR Sco
RSF08	181015	Frey	A candidate super-massive black hole binary
RSH01	110516	Herrero	The compact emission in the ultra-steep spectrum radio galaxy J033644-205849
RSP13	100516	Perez-Torres	Dust-enshrouded supernova candidate in the nearby luminous IR galaxy NGC3310
RST03	110516	Tudose	Calibrator search around Cyg X-1
RSY04	161116	Yang	e-EVN short observations of J1114+3241 at 5 GHz
RT013A-C	Session 2/2016	Tudose	The radio/X-ray coupling in Cyg X-1 over a full orbit

6.6 JIVE Publications

Journal Article

Tao An, Yu-Zhu Cui, **Zsolt Paragi**, et al (including **Leonid I. Gurvits**): VLBI observations of flared optical quasar CGRaBS J0809+5341, 2016, Publications of the Astronomical Society of Japan, 68, id.77

A. Bartkiewicz, M. Szymczak, **H. J. van Langevelde**: European VLBI Network imaging of 6.7 GHz methanol masers, 2016, Astronomy and Astrophysics, 587, A104

S. Bauer, H. Hussmann, J. Oberst, et al. (including **D. Dirkx)**: Demonstration of orbit determination for the Lunar Reconnaissance Orbiter using one-way laser ranging data, 2016, Planetary and Space Science, 129, 32-46

S. Bauer, H. Hussmann, J. Oberst, et al. (including **D. Dirkx**): Analysis of one-way laser ranging data to LRO, time transfer and clock characterization, 2016, Icarus, 283, 38-54

Rocco Coppejans, Dávid Cseh, Sjoert van Velzen, et al. (including **Zsolt Paragi**, **Leonid I. Gurvits**): What are the megahertz peaked-spectrum sources?, 2016, Monthly Notices of the Royal Astronomical Society, 459, 2455-2471

Rocco Coppejans, Sándor Frey, Dávid Cseh, et al. (including **Zsolt Paragi**, **Leonid I. Gurvits**): On the nature of bright compact radio sources at z > 4.5, 2016, Monthly Notices of the Royal Astronomical Society, 463, 3260-3275

D. Dirkx, V. Lainey, **L. I. Gurvits**, et al.: Dynamical modelling of the Galilean moons for the JUICE mission, 2016, Planetary and Space Science, 134, 82-95

D. Dirkx, R. Noomen, P. N. A. M. Visser, et al. (including **L. I. Gurvits**): Space-time dynamics estimation from space mission tracking data, 2016, Astronomy and Astrophysics, 587, A156

D. A. Duev, S. V. Pogrebenko, **G. Cimó**, et al. (including **G. Molera Calvés**, **L. I. Gurvits**, **M. M. Kettenis**): Planetary Radio Interferometry and Doppler Experiment (PRIDE) technique: A test case of the Mars Express Phobos fly-by, 2016, Astronomy and Astrophysics, 593, A34

B.H.C. Emonts, M.D. Lehnert, M. Villar-Martín, et al. (including **M.Y. Mao**): Molecular gas in the halo fuels the growth of a massive cluster galaxy at high redshift, 2016, Science, 354, 1128-1130

Sándor Frey, **Zsolt Paragi**, Krisztina Éva Gabányi, et al.: Four hot DOGs in the microwave, 2016, Monthly Notices of the Royal Astronomical Society, 455, 2058-2065

K. É. Gabányi, T. An, S. Frey, et al. (including **Z. Paragi**): Four Dual AGN Candidates Observed with the VLBA, 2016, The Astrophysical Journal, 826, id.106

J. N. Girard, P. Zarka, C. Tasse, et al. (including **I. van Bemmel**): Imaging Jupiter's radiation belts down to 127 MHz with LOFAR, 2016, Astronomy and Astrophysics, 587, A3

M. Giroletti, **B. Marcote**, M. A. Garrett, et al. (including **Z. Paragi**): FRB 150418: clues to its nature from European VLBI Network and e-MERLIN observations, 2016, Astronomy and Astrophysics, 593, L16

Tomoya Hirota, Masahiro N. Machida, Yuko Matsushita, et al. (including **Ross A. Burns**): ALMA Band 8 Continuum Emission from Orion Source I, 2016, The Astrophysical Journal, 833, id. 238

N. Jackson, A. Tagore, A. Deller, et al. (including **I. van Bemmel**): LBCS: The LOFAR

Long-Baseline Calibrator Survey, 2016, Astronomy and Astrophysics, 595, A86

Michael D. Johnson, Yuri Y. Kovalev, Carl R. Gwinn, et al. (including **Leonid I. Gurvits**): Extreme Brightness Temperatures and Refractive Substructure in 3C273 with RadioAstron, 2016, The Astrophysical Journal Letters, 820, L10

Y. Y. Kovalev, N. S. Kardashev, K. I. Kellermann, et al. (including **L. I. Gurvits**): RadioAstron Observations of the Quasar 3C273: A Challenge to the Brightness Temperature Limit, 2016, The Astrophysical Journal Letters, 820, L9

E. K. Mahony, R. Morganti, I. Prandoni, et al. (including **I. M. van Bemmel**): The Lockman Hole project: LOFAR observations and spectral index properties of low-frequency radio sources, 2016, Monthly Notices of the Royal Astronomical Society, 463, 2997-3020

J. P. McKean, L. E. H. Godfrey, S. Vegetti, et al. (including **I. van Bemmel**): LOFAR imaging of Cygnus A - direct detection of a turnover in the hotspot radio spectra, 2016, Monthly Notices of the Royal Astronomical Society, 463, 3143-3150

B. C. Root, P. Novák, **D. Dirkx**, et al.: On a spectral method for forward gravity field modelling, 2016, Journal of Geodynamics 97, 22-30

S. M. Straal, K. É. Gabányi, J. van Leeuwen, et al. (including **Z. Paragi)**: HESS J1943+213: A Non-classical High-frequency-peaked BL Lac Object, 2016, The Astrophysical Journal, 822, id. 117

W. L. Williams, R. J. van Weeren, H. J. A. Röttgering, et al. (including **I. M. van Bemmel**): LOFAR 150-MHz observations of the Boötes field: catalogue and source counts, 2016, Monthly Notices of the Royal Astronomical Society, 460, 2385-2412

J. Yang, **Z. Paragi**, A. J. van der Horst, et al. (including **L. I. Gurvits**, **R. M. Campbell**): No apparent superluminal motion in the first-known jetted tidal disruption event Swift J1644+5734, 2016, Monthly Notices of the Royal Astronomical Society, 462, L66-L70

Conference Papers

A.-J. Boonstra, M. Garrett, G. Kruithof, et al. (including **L. Gurvits**): Discovering the Sky at the Longest Wavelengths (DSL), 2016, IEEE Aerospace Conference, (DOI: 10.1109/AERO.2016.7500678)

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7 Acronyms and Abbreviations

AGN	Active Galactic Nuclei
AIPS	Astronomical Image Processing System
ASTERICS	Astronomy ESFRI & Research Infrastructure Cluster
ASTRON	Netherlands Institute for Radio Astronomy
ATCA	Australian Telescope Compact Array
CAS	Canterbury Astronomical Society
CASA	Common Astronomy Software Applications
CNRS	Centre National de la Recherche Scientifique National Center for Scientific Research
COTS	Commercial off-the-shelf
DBBC	Digital Base Band Converter
DM	Dispersion Measure
DRAGN	Double Radio-Source Associated with a Galactic Nucleus
EC	European Commission
ERC	European Research Council
ERIC	European Research Infrastructure Consortium
ESFRI	European Strategy Forum on Research Infrastructures
e-VLBI	electronic Very Long Baseline Interferometry
EVN	European VLBI Network
e-EVN	electronic European VLBI Network
FITS	Flexible Imaging Transport System
FÖMI	Földmérési és Távérzékelési Intézet Institute of Geodesy Cartography and Remote Sensing
FPGA	Field-Programmable Gate Arrays
FRB	Fast Radio Burst
Gbps	Gigabit per second
GHz	Gigahertz
GMVA	The Global mm VLBI Array
GPS	Global Positioning System
HESS	High Energy Stereoscopic System
HOPS	H_2O Southern Galactic Plane Survey
IDI	i-deas Web ACCESS File
IGN	Instituto Geográfico Nacional National Geographic Institute
INAF	Instituto Nazionale di Astrofisica Italian National Institute of Astrophysics
JIVE	Joint Institute for VLBI ERIC
JUC	JIVE UniBoard-based Correlator
JUMPING JIVE	Joining up Users for the Maximising the Profile, the Innovation and the Necessary Globalisation of JIVE
JVLA	Jansky Very Large Array
LBA	Long Baseline Array
LO	Local Oscillator

mas	Milliarcsecond
Mbps	Megabit per second
MHz	Megahertz
MID	Mid frequencies
MIT	Massachussets Institute of Technology
MkIV	Mark Four Correlator
MNRAS	Monthly Notices of the Astronomical Society
MoU	Memorandum of Understanding
MPIfR	Max-Planck-Institut für Radioastronomie
	Max Planck Institute for Radio Astronomy
MT	Management Team
NAOC	National Astronomical Observatories of China
NL	The Netherlands
NRAO	National Radio Astronomy Observatory
NRF	National Research Foundation
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
	Netherlands Organisation for Scientific Research
NEXPReS	Novel Explorations Pushing Robust eVLBI Services
ORA	Osservatorio Di Radio Astronomia
PI	Principle Investigator
PFB	Polyphaser Filter Bank
R&D	Research and Development
RISARD	Radio Interferometric Survey of Active Red Dwarfs
SA	South Africa
SADT	Structured Analysis and Design Technique
SAT	Synchronisation and Timing
SFXC	EVN Software Correlator
SKA	Square Kilometre Array
STFC	Science and Technologies Facilities Research Council
SVLBI	Space Very Long Baseline Interferometry
TB	Terabyte
TDE	Tidal Disruption Event
ToO	Targets of Opportunity
UK	United Kingdom
USA	The United States of America
UTC	Coordinated Universal Time
UV	Ultraviolet
VIRAC	Ventspils International Radio Astronomy Center
VLA	Very Large Array
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry
VR	Vetenskapsrådet
	Swedish Research Council
VSOP	VLBI Space Observatory Programme
WR	White Rabbit
YSO	Young Stellar Objects

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