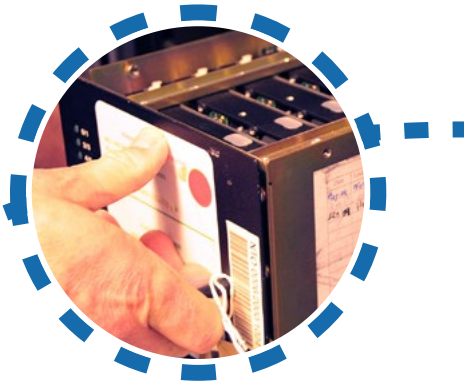
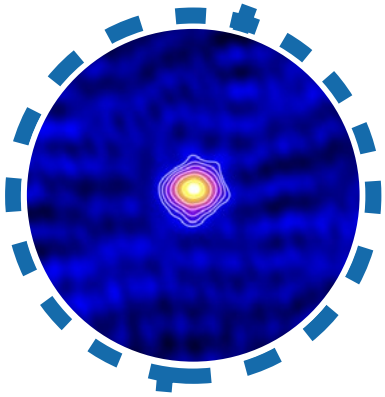
JIVE

Joint Institute for VLBI ERIC





2018 ANNUAL REPORT

ANNUAL REPORT 2018

The Joint Institute for VLBI ERIC (JIVE) 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 2018, JIVE had six members:

The Netherlands, represented by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) and the Netherlands Institute for Radio Astronomy (ASTRON)

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

Latvia, represented by the Latvijas Izglītības un zinātnes ministrija (IZM)

Spain, represented by the Ministerio de Fomento (MF)

Sweden, represented by the Vetenskapsrådet (VR)

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

JIVE was also supported by the following Participating Research Institutes in 2018:

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

It has been an honour to chair the JIVE Council for the last two years and after the next Council meeting in Bologna, Prof. John Conway, from Onsala Space Observatory will become the new chair of the JIVE Council.

When John and I started as PhD students together at Jodrell Bank, large global VLBI experiments were just becoming possible, thanks partly to the adoption of readily available VHS tape as a recording medium. Even so, the logistical challenge of conducting such experiments was huge.

30 years later, we can almost take multi-Gb/s real-time data connections for granted across the globe, and a new spirit of global cooperation in VLBI is being fostered by JIVE, the EVN and radio astronomers around the world.

The JUMPING JIVE project is an important part of this effort, helping to train and support scientists as well as provide technical guidance in commissioning VLBI capabilities in several African nations, for example. Equally important is the inclusive approach JIVE has taken to supporting all scientists across Europe and around the world, enabling them to do VLBI and focus on the scientific output rather than the challenge of the technique.

At the same time JIVE scientists and engineers are pushing the technical capabilities and scientific applications of VLBI, and spreading that expertise to the community at large.

All these aspects have been fully recognised by an in-depth review of JIVE led by Dr Bruno Leibundgut (ESO) with an international panel of scientific and technical experts. This review found that JIVE's performance was 'excellent', that JIVE's support operations were 'extremely successful', and that JIVE's Research & Development achievements were 'outstanding'. The scientific output by JIVE staff was also highlighted.

As JIVE celebrates its 25th year, the new Director, Dr. Francisco (Paco) Colomer, together with all his staff can be rightly proud of the outcomes of this review.

The recommendations of the panel are already central to what Paco and the JIVE management team are working on: attracting new partners, securing future funding, defining the JIVE core programme.

I look forward to watching JIVE continue to thrive as a central driving force behind the development and use of VLBI as a uniquely powerful technique in astronomy and an enormously powerful example of global co-operation in science. The recent image of the 'shadow' of the black hole in M87, in which JIVE played its part, is a landmark demonstration of the power of VLBI not just for scientists but also for the public as a whole.

Simon Garrington

Chairman of the JIVE Council

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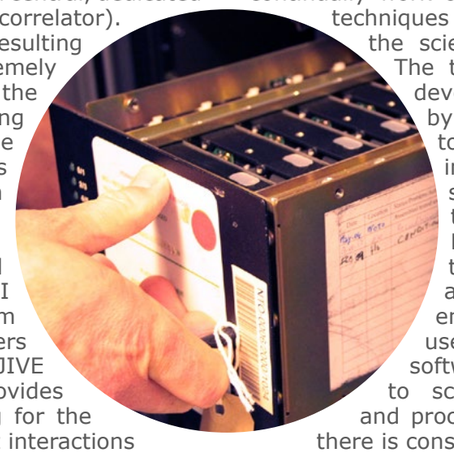
01 INTRODUCTION

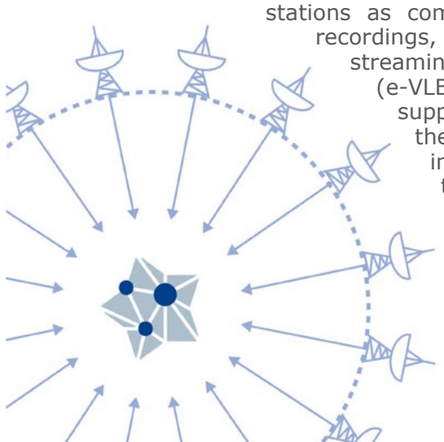
1.1 JIVE MISSION

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 simultaneously 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, and provides support to the end user through subsequent processing and analysis as requested. Calibration data and images from a standard data pipeline are included in the final user product.



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. The team's primary focus is to develop new observing modes by investigating 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 schedule their observations and process their data. In addition, there is considerable expertise at JIVE in deploying VLBI for space applications.

The JIVE staff members also do scientific research themselves in a number of exciting areas, from merging neutron stars to jet-launching regions of planetary nebulae (see *2 Science Highlights*). Such research is considered essential to maintain appropriate expertise and provide an excellent service to EVN stations and users.

JIVE has developed a reputation to foster coordination, innovation and capacity building for European and global VLBI. As an ERIC and the central entity of the EVN, JIVE brings these qualities to multiple European Commission (EC) projects (see *7.2 JIVE projects*).

1.2 JIVE IN 2018

On 21st December 1993 the Joint Institute for VLBI in Europe was created by the European Consortium for VLBI. The directors of five European radio observatories signed the deed to form the Foundation under Dutch law, inspired by the vision of Richard Schilizzi, who became JIVE's first director. Schilizzi had recognised the potential of building a dedicated correlator for the EVN, hosted by the Netherlands Insitute for Radio Astronomy (ASTRON) in Dwingeloo, the Netherlands. Now, 25 years later, JIVE is a European Research Infrastructure Consortium (ERIC) with some important challenges as part of a promising future. For example, the advent of the Square Kilometre Array (SKA) offers new scientific opportunities for VLBI, but brings with it the need for a globally organised VLBI network to complement such an instrument.

Throughout 2018, JIVE and its partners have been involved in a number of innovative projects (see *7.2 JIVE projects*). One of the major projects that JIVE continues to lead is a European Commission (EC) Horizon2020 project known as JUMPING JIVE (Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization of JIVE). The project provides the means for JIVE, as an ERIC, to profile itself with its potential members, the user base and the international radio astronomy community. In practice, it means that JIVE can enhance its effort in outreach, in particular to advocate its relevance for European and global science. The project also offers resources to address some key operational interfaces that will be important in the foreseen globalisation of VLBI. One of the highlights of JUMPING JIVE involves the production of an updated scientific vision for VLBI (and the EVN in particular) – an effort, that while facilitated by JIVE, involves the whole community. JUMPING JIVE also supports the development of tools (e.g. pySCHED for scheduling of global-VLBI observations) and new capabilities for the JIVE correlator (geodetic modes). Moreover, the project helps in building capacity for radio astronomy in Africa. These developments are all crucial for developing the VLBI capabilities of the SKA, where JIVE is leading the definition of "SKA-VLBI" modes and science cases, which will enable the participation of phase-1 SKA telescopes low and mid into global VLBI. The JUMPING JIVE project was successfully reviewed by the EC in November 2018.

LEADING THE DEFINITION OF "SKA-VLBI"

The EC RadioNet project, coordinated by JIVE partner the Max Planck Institute for Radio Astronomy (MPIfR, in Bonn, Germany), provides trans-national access funding as an EC integrating activity, which allows JIVE to deliver user support. Alongside the training, engineering and science networks that RadioNet helps to maintain, many of the RadioNet activities are also of great relevance to JIVE. For example, the EVN benefits from a work package on next generation receivers (BRAND EVN) and JIVE contributes directly to providing new data processing tools, notably for fringe fitting VLBI data in the RadioNet RINGS work package. Another EC funded project involving JIVE, ASTronomy ESFRI and Research Infrastructure Cluster (ASTERICS), pioneers data processing techniques and showcases the use of Jupyter (an open source web application) for data handling in the software package CASA. As part of the ASTERICS project, JIVE collaborated with ASTRON, SURFnet and Optical Positioning Navigation and Timing (OPNT) to allow the Dwingeloo telescope to participate in VLBI observations with the EVN (see *3.4 Time and frequency distribution: SKA and VLBI*).

14th EVN Symposium held in October in Granada, Spain

Trainees at the Kuntunse telescope in Ghana

This year has also seen the approval of two new EC H2020 projects due to begin in 2019. The first, the European Science Cluster of Astronomy and Particle physics ESFRI research infrastructures (ESCAPE), will develop tools, services and platforms for the European Open Science Cloud (EOSC) – including completing VLBI functionality in CASA, creating a VLBI data reduction pipeline suitable for the EOSC, and making the EVN/JIVE archive accessible through a Virtual Observatory (VO). The second, the ERIC Forum, has been established to identify common challenges affecting ERICs and collectively respond to them. The forum will also contribute to further development of the EC ERIC Regulation, the European Strategy Forum on Research Infrastructures (ESFRI) framework, and European and international research contexts, as well as foster the visibility, impact and sustainability of ERICs. All existing ERICs are members of the Forum.

Aside from these projects, JIVE continues to actively share the excellent ongoing work of the EVN. One of the key endeavours in 2018 was the representation of the EVN at the European Week of Astronomy and Space Science (EWASS 2018). JIVE hosted a special session on the future of the EVN, as well as a booth featuring research highlights from across the network and materials to attract new users to the EVN. Both endeavours were deemed successful exercises to be repeated in the future (see *5.1 Events*). Significant EVN results have been shared throughout the year among a new and growing network of outreach officers and scientists, ensuring all EVN partners have access to important pieces of news. The close of 2018 also brought with it an overhaul of the EVN website. Currently in the first phase of transition, it is hoped that this will provide an attractive platform for new and existing users.

Celebrating 25 years of JIVE!

SUPPORTING RADIO ASTRONOMY IN AFRICA

Of course, JIVE has been directly involved in a number of scientific results throughout the year, covering topics from binary star mergers to planetary nebula formation (see *2 Science Highlights*). As well as this, JIVE has also supported the data collation, correlation and production of many more results using VLBI. This included, astronomers using a global network of radio telescopes (comprised of the EVN, the Very Long Baseline Array (VLBA) and the Green Bank Telescope in the USA) and gravitational lensing to produce one of the sharpest astronomical images ever. By observing how radio emission from a distant source is bent by the gravitational field of a massive object – a lens – located between the source and the Earth, it was possible to determine information about both the distant source and the lens. All the data in this study was correlated at JIVE and the findings contributed to understanding how dark matter is distributed unevenly across a distant galaxy (Spingola, C., McKean, J.P., *et al*. 2018. SHARP - V. Modelling gravitationally-lensed radio arcs imaged with global VLBI observations. MNRAS. DOI: 10.1093/mnras/sty132). In addition, data correlated at JIVE

from observations of a pair of colliding galaxies using the EVN and the VLBA, demonstrated that a suspected supernova explosion was actually a star being pulled apart by a supermassive black hole. This rare stellar death, known as a tidal disruption event (TDE), occurs when the powerful gravity of a supermassive black hole rips apart a star that has wandered too close to the massive monster. The findings contribute to a better understanding of the environment in which galaxies developed billions of years ago (Mattila, S., Pérez-Torres, M., *et al*. 2018. A dust enshrouded tidal disruption event with a resolved radio jet in a galaxy merger. Science. DOI: 10.1126/science.aao4669).

1.3 PERSONNEL

Notably, 2018 began with a change of Director for JIVE. After 10 years of leading the team Prof. Huib van Langevelde took the decision to step down and the Council appointed Dr. Francisco (Paco) Colomer as Director. Colomer had joined JIVE earlier in 2017, from the National Geographic Institute (IGN) in Spain, as the Policy Officer and Project Manager for the JUMPING JIVE project. Van Langevelde will continue as a Senior Scientist at JIVE and has adopted new teaching responsibilities at Leiden University.

Francisco Colomer began as the new Director of JIVE in 2018

Wybren Buijs left JIVE in November

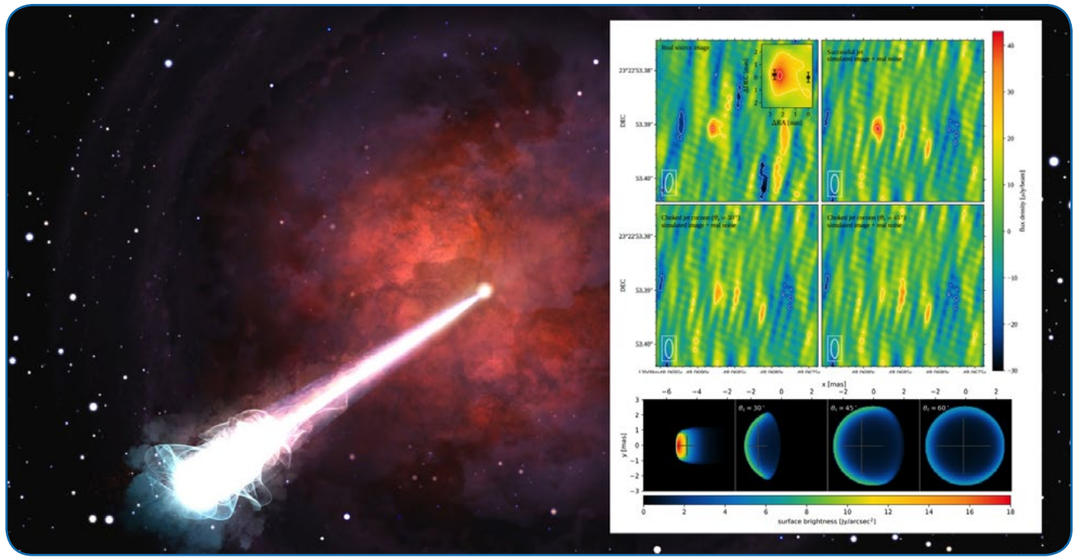
Linux/Network Specialist Wybren Buijs left JIVE in November to take up a position in industry.

Ross Burns left JIVE in December

Support Scientist Dr. Ross Burns left in December to join the Mizusawa VLBI Observatory in Tokoyo, Japan. He will be replaced, in early 2019, by Dr. Dhanya Nair, a postdoc from Max-Planck Institute for Radioastronomy in Bonn.

02 SCIENCE HIGHLIGHTS

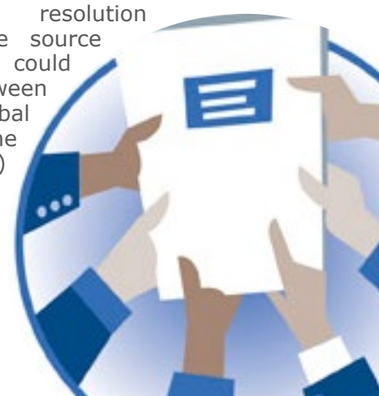
2.1 A STRUCTURED JET FROM A BINARY NEUTRON STAR MERGER



Artist's impression of the jet breaking through the dense gas ejecta produced during the merger of neutron stars, which caused the gravitational waves recorded as GW170817 (Beabudai Design). The inset shows the radio image of the observation, with a zoom on the position of the source (top left); a simulated radio image (top right); a modelled collimated jet (bottom left); and a modelled jet-cocoon with different opening angles (bottom right). At the bottom of the inset the predicted source images for the four models are shown. Ghirlanda *et al.* 2019, Science, Vol. 363, Issue 6430, pp. 968-971.

In August 2017, two neutron stars were observed colliding, producing gravitational waves that were detected by the American LIGO and European Virgo detectors. This binary star merger event, known as GW170817, occurred in a galaxy 130 million lightyears away from Earth and is the first and, currently, only one to have been observed. Astronomers monitored emission from the event from the radio waves to gamma rays for several months. The spectra and the light curve evolution showed signs of at least mildly relativistic expansion in the ejecta that was expelled during the explosion. However, in the absence of very high resolution observations it was not possible to distinguish between certain types of relativistic jets, or a (partially) more isotropic outflow.

High angular resolution measurements of the source size and displacement could discriminate between these scenarios. Global Very Long Baseline Interferometry (VLBI) observations (including the European VLBI Network and e-MERLIN



telescopes) were performed at 207.4 days after the merger, using a network of 32 radio telescopes with the data correlated at JIVE. The team included JIVE co-authors Zsolt Paragi, Benito Marcote, Jay Blanchard, Huib van Langevelde and Leonid Gurvits, and the observations were led by Italian astronomers Giancarlo Ghirlanda and Om Salafia (INAF-Brera).

The apparent source size is constrained to be smaller than 2.5 milliarcseconds at the 90% confidence level. This excludes the isotropic outflow scenario, which would have produced a larger apparent size, indicating that GW170817 produced a structured relativistic jet. These results are in agreement with the earlier published ones using the High Sensitivity Array that showed relativistic motion in the ejecta (Mooley *et al.* 2018), but it reveals more details as well due to the better North-South resolution of the global array.

GW170817 PRODUCED A STRUCTURED RELATIVISTIC JET

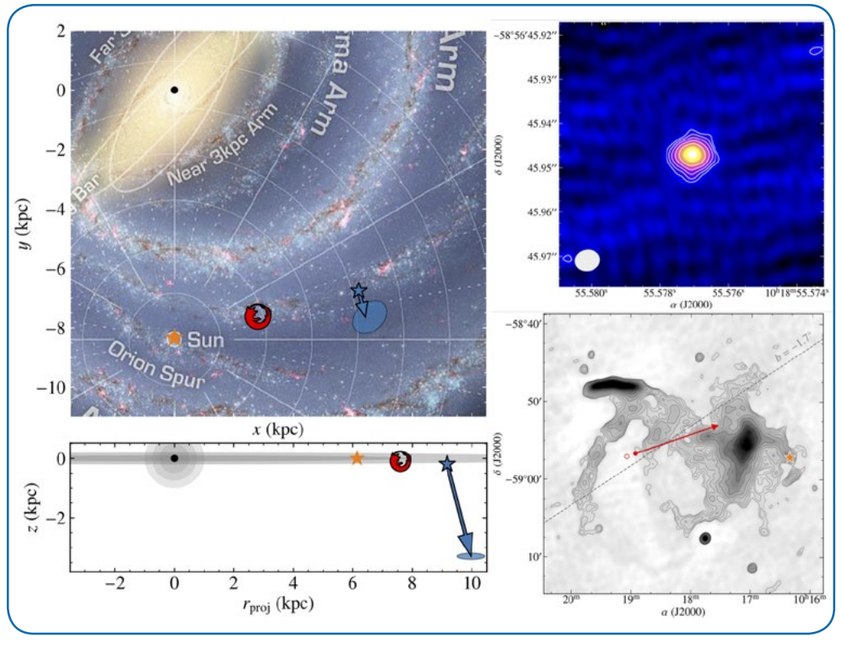
This event appeared much less energetic in the gamma rays than usually seen in other 'short-Gamma Ray Bursts (GRBs)'. This was due to the fact that the relativistic jet was pointing away from the observational line of sight. In coming years many more binary star merger events will be discovered and the team concluded that the obtained results suggest that more that 10% of these should exhibit a successful jet, allowing researchers to unveil the processes that take place during some of the most powerful events in the Universe.

2.2 UNVEILING THE ORIGIN OF A GAMMA-RAY BINARY

Gamma-ray binaries are systems composed of a massive star and a compact object (which is likely a young non-accreting neutron star). The systems exhibit emission from radio to very high energy gamma rays, but have the particularity that most of the energy is emitted as gamma-rays, which implies that extreme processes are involved. However, many questions on gamma-ray binaries remain, as to date, only seven have been detected.

Previously, the gamma-ray binary 1FGL J1018.6–5856 had been poorly explored at radio frequencies. For the first time, a team led by Benito Marcote (JIVE) carried out observations with the Australian Long Baseline Array (LBA) to study the source on milliarcsecond (mas) scales.

1FGL J1018.6–5856 was detected as a compact radio source (with a size of <3 mas or <20 au), confirming that the emission has a non-thermal origin. The emission is consistent with those observed in other gamma-ray binaries.

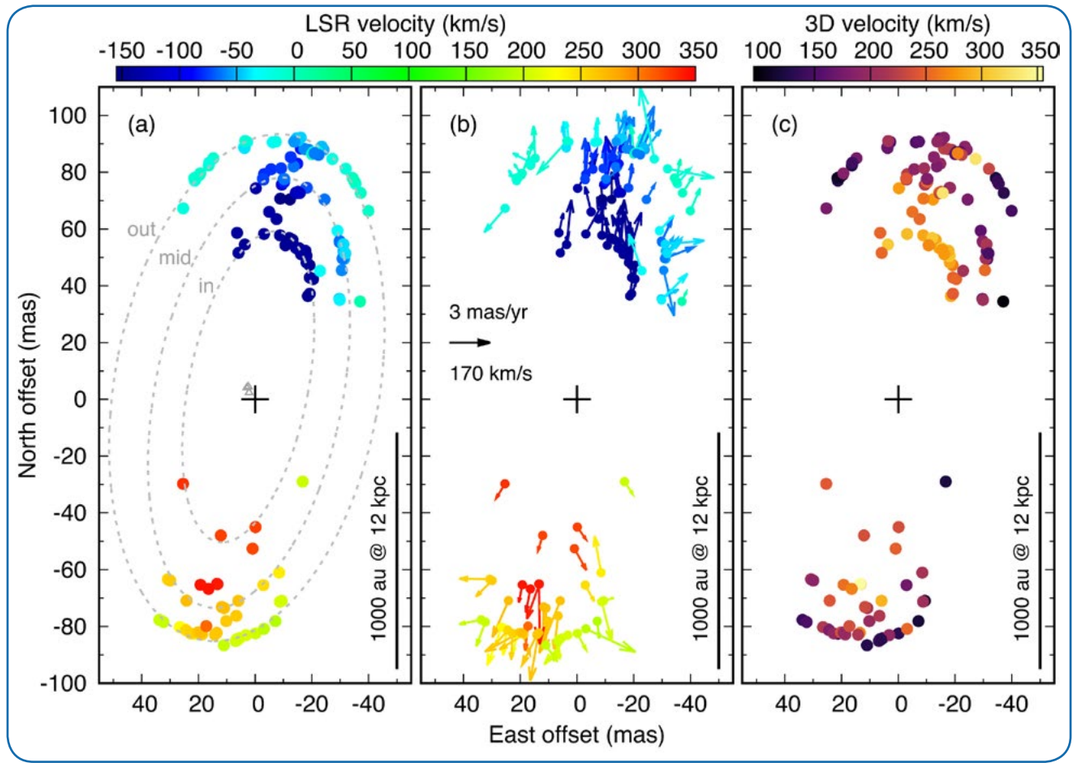


Images of 1FGL J1018.6-5856 and its position within the Galaxy. The figures depict a representation of the Galaxy, the position of SNR G284.3-1.8, and the position and peculiar motion of 1FGL J1018.6-5856 (left); The LBA image (top right); and a wider field, showing the position and motion of 1FGL J1018.6-5856, which is surrounded by the supernova remnant (SNR) G284.3-1.8 (bottom right). (Marcote *et al.* 2018, Astronomy and Astrophysics, 619, A26).

The positions obtained from the Gaia DR2, UCAC4, and LBA data (spanning 20 yrs in total) constrained the 3D motion of the source within the Galaxy and its distance (~6.4 kpc). The gamma-ray binary exhibits a peculiar motion of 45 +30/-9 km s-1, with the system moving away from the Galactic plane.

The obtained motion and distance allowed the team to estimate a mass loss during the core collapse that lead to the creation of the compact object in the system. More importantly, it had previously been thought that this binary system was physically connected with the supernova remnant (SNR) G284.3-1.8, however with the information on age, distance and peculiar motion this theory has now been disproved.

2.3 CLUES TO THE EJECTION MECHANISM OF THE FASTEST WATER FOUNTAIN



The Spatial distribution (a), internal proper motions (b), and absolute values (c) of the three-dimensional velocities of the 22 GHz H2O maser features around IRAS 18113−2503. Features in each lobe are found in distinct arcs, separated both spatially and in velocity (Orosz *et al.* 2019, MNRAS, Vol. 482, Issue 1, L40).

Planetary nebula formation has remained a mystery ever since the days of its discovery by Charles Messier in 1764. Specifically, the transformation process from their precursors - generally spherical asymptotic giant branch stars - into a variety of point symmetric, multi- or bipolar, and occasionally spherical objects, remains unexplained. It is generally accepted that such shapes must be driven by some collimated outflow process, however the launching mechanism of such ejections has never been revealed by observation, owing to the short timescale of the transition between the post-AGB and PN phases, lasting only a few tens of years; a mere instance in the lifetimes of stars.

Masers (maser amplification through stimulated emission of radiation) are clouds of dense molecular gas producing non-thermal molecular line emission. Since their molecular emission has a known transition frequency their line of sight motions (red-/blue-shift) in addition to their proper motions derived from multi-epoch VLBI observations, reveals 3D motions within dense environments only accessible at radio wavelengths. This makes maser VLBI the perfect tool for probing the jet-launching regions of aspiring planetary nebulae.

UNIQUE CAPABILITIES OF VLBI OBSERVATIONS

Using this approach, Orosz *et al.* (including Ross Burns from JIVE) discovered nested bowshocks of highly supersonic shock-tracing water masers in IRAS 18113−2503, a star transitioning from the asymptotic giant branch to a planetary nebula. Their results indicate the strongest evidence to date that the ejection process leading to the variety of planetary nebula morphologies may be episodic, with a ~10 year periodicity in the case of IRAS 18113−2503. The results also revealed the fastest moving masers to locate closer to the star than their slower counterparts - indicating exponential deceleration effective within the scale of the circumstellar envelope. In the article, published in MNRAS letters, the authors hypothesise that the most natural explanation for the episodic ejections are a periodic mass exchange in a close binary of ~10 au. The work is an elegant demonstration of the unique capabilities of VLBI observations in approaching fundamental, age-old mysteries in the skies above.

03 RESEARCH AND DEVELOPMENT

3.1 DATA RECORDING AND TRANSPORT

Two European VLBI Network (EVN) stations, Sardinia and Irbene, contributed FlexBuffs (the EVN-developed Commercial Off-The-Shelf (COTS) based high-capacity data recorders) to JIVE in 2018. In addition, several stations upgraded the existing hardware with higher-capacity hard disks, and in some cases, stations contributed disks to populate partially filled units. As a result, it became necessary to reinforce the floor in the JIVE correlator room, in order to cope with the extra load of the new EVN software correlator (SFXC) cluster and the racks with an increasing number of storage units.

The Westerbork Synthesis Radio Telescope (WSRT) link to JIVE was upgraded from 2 times 1 Gbps to a 10 Gbps Coarse Wavelength Division Multiplexing (CWDM), directly connecting the WSRT Fila10G to the JIVE correlator.

EVN DATA TRANSPORT WORKED SMOOTHLY AND RELIABLY

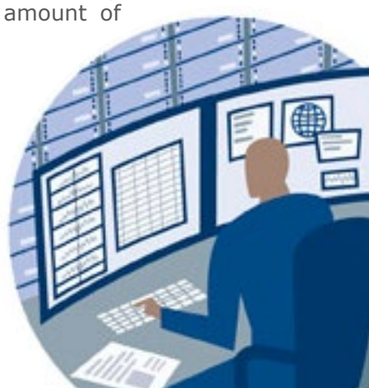
As part of the Netherlands Organisation for Scientific Research (NWO)-Dome project, aimed at enabling VLBI observations between the EVN and the Karoo Array Telescope 7 (KAT7)/MeerKAT arrays in South Africa, two Mark6 recording units plus expansion chassis were purchased and installed at JIVE.

EVN data transport in the form of real-time e-VLBI and automated and manual e-shipping worked smoothly and reliably throughout the year.

3.2 SOFTWARE CORRELATION

Upgrades to the SFXC software correlator, developed and maintained at JIVE, continued throughout the year. For geodetic purposes a conversion of SFXC output to Mk4 format was implemented, which is the native data format in the geodetic data processing suite called HOPS (Haystack Observatory Postprocessing Suite). Support for multiple data streams per station (based on the soon-to-be-released VLBI Experiment Definition 2 (VEX2) standard experiment description) was also built in.

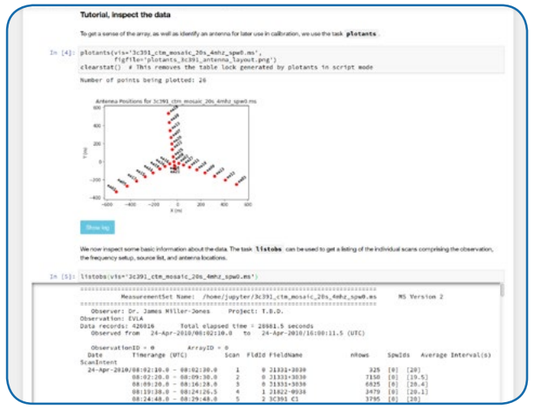
With a number of Australian colleagues, a JIVE engineer participated in a Graphics Processing Unit (GPU) hackathon, organised in the city of Perth, Australia. This was aimed at implementing various computing challenges on GPU hardware, helped by a number of GPU experts. A basic VLBI GPU correlator was actually created, but although it became clear that it is possible to speed up VLBI correlation somewhat using GPUs, the gain is rather modest, at the cost of a considerable amount of re-engineering.



3.3 USER SOFTWARE

The Common Astronomy Software Applications (CASA) suite is widely used to process radio astronomical data. However, VLBI has continued to rely on legacy code because fringe fitting was not a part of CASA. A VLBI fringe fitter, written at JIVE, was finally included in CASA release 5.3 – making this the first CASA release ever capable of handling VLBI data. Enhancements and additional functionality were implemented, tested and submitted for inclusion in future releases. Much effort went into developing a Python prototype for dispersive fringe fitting, for the RadioNet Radio Interferometry Next Generation Software (RINGS) work package. This was tested successfully on P-band EVN data. A method for Fast Fourier Transform (FFT) fringe fitting with spectral window gaps was extensively researched and described in a memo. Phase cal tone extraction was also prototyped and tested on data from the Korean VLBI Network.

During the afternoon of 11th October, a CASA workshop was organised for participants of the EVN symposium. Combined with the presentation at the symposium this exposed approximately 100 people to the new tools, of which about 60 were actively involved in the workshop. The aim of the workshop was to get people up to speed with the new CASA tasks, which was a big success. Several participants managed to complete the entire tutorial, and constructive feedback was received for further developments.

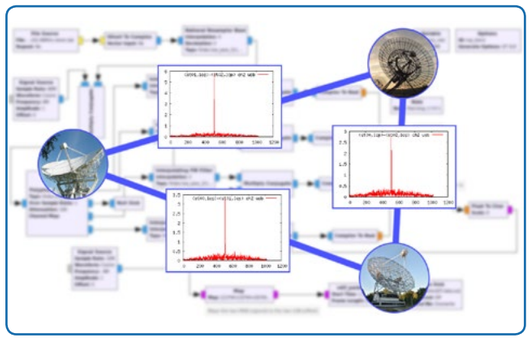


Screenshot of online demo of the Jupyter-CASA kernel on http://jupyter.jive.eu

Remote data processing progressed with a much improved version of the Jupyter-CASA kernel. Support for CASA 5.3 and 5.4 was added. An online tutorial was created, located at http://jupyter.jive.eu. Users connecting to the service can access a Jupyter notebook in which they can reduce an entire VLA dataset from start to finish.

Re-factoring of the scheduling software (SCHED), used by many VLBI networks around the world, continued. The use of digital baseband converters (DBBC) is now supported by pySCHED, and many updates and improvements were made following feedback from the JIVE support scientists.

3.4 TIME AND FREQUENCY DISTRIBUTION: SKA AND VLBI



The return of the Dwingeloo Radio Telescope to VLBI with fringes between Dwingeloo, Westerbork Synthesis Radio Telescope and Jodrell Bank MK2.

The Signal and Data Transport (SaDT) consortium, for which JIVE has provided the Synchronisation and Timing (SAT) architect, reached the Critical Design Review (CDR) stage by submitting detailed designs for the SaDT design and Coordinated Universal Time (UTC) distribution of the Square Kilometre Array (SKA). The CDR was successfully passed, although the official announcement will only appear in early 2019.

For the Astronomy ESFRI and Research Infrastructure Cluster (ASTERICS) project, JIVE collaborated with the Netherlands Institute for Radio Astronomy (ASTRON), SURFnet and Optical Positioning, Navigation and Timing (OPNT) to connect the H-maser reference located at the WSRT to the Dwingeloo telescope via a link WSRT—Groningen—Dwingeloo, together with a direct dark-fiber link for calibration. The aim is to use this reference signal, transported via public fiber, as a local clock, allowing the Dwingeloo telescope to participate in VLBI observations with the EVN. Extensive use was made of the White Rabbit equipment, an open-source technology initiated by the European Organisation for Nuclear Research (CERN) that has been further developed and sustained by a large engineering community.

RETURN OF THE DWINGELOO TELESCOPE TO VLBI

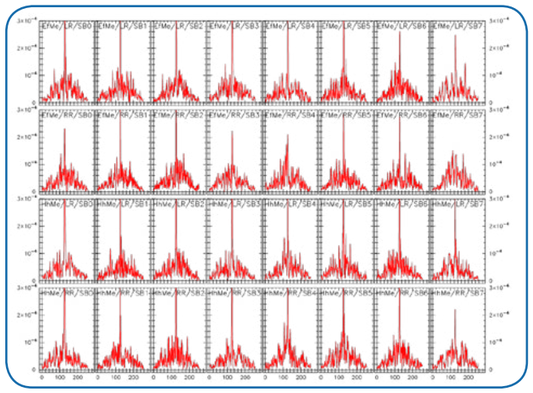
As a first step, a VLBI session with Dwingeloo, the WSRT and the MK2 at Jodrell Bank yielded fringes to the Dwingeloo telescope for the first time in about 40 years. For this test a local Rubidium clock was used, not yet the WSRT maser; this will be attempted in the beginning of 2019. Eventually, the H-maser signal will also be transported from Groningen to the Low-Frequency ARray (LOFAR) in the East of the Netherlands.

3.5 VLBI WITH SOUTH AFRICA

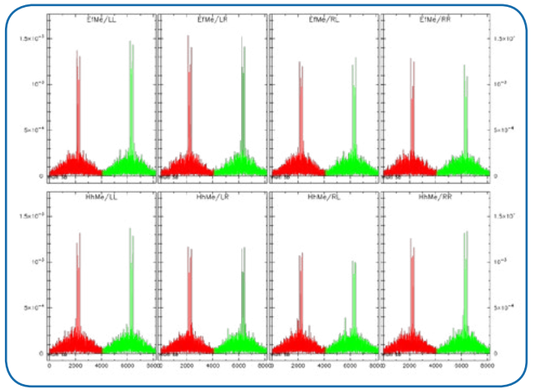
Supported by funding from NWO and the South African National Research Foundation (NRF), a collaboration was initiated several years ago between JIVE and the South African Radio Astronomy Observatory (SARAO). Its aim was to enable VLBI between the EVN and the prototype KAT7 array, followed by MeerKAT and, eventually, the SKA.

Ultimately the decision was made to skip attempts to use KAT7 for VLBI, and instead to concentrate on MeerKAT. As MeerKAT's sampling rate and data formats are not yet VLBI compatible, software was developed by JIVE staff to extract and resample 2 x 32 MHz, overlapping with the 8 x 8 MHz bands observed by the EVN stations, and reformat it to the VLBI Data Interchange Format (VDIF).

In February 2018, the recently inaugurated MeerKAT array co-observed with one of the EVN's Network Monitoring Experiments (NME). Beamformer spectra and single dish voltage time series were captured from the MeerKAT system by SARAO staff.



Fringes between single MeerKAT dish and the EVN telescopes Hartebeesthoek and Effelsberg



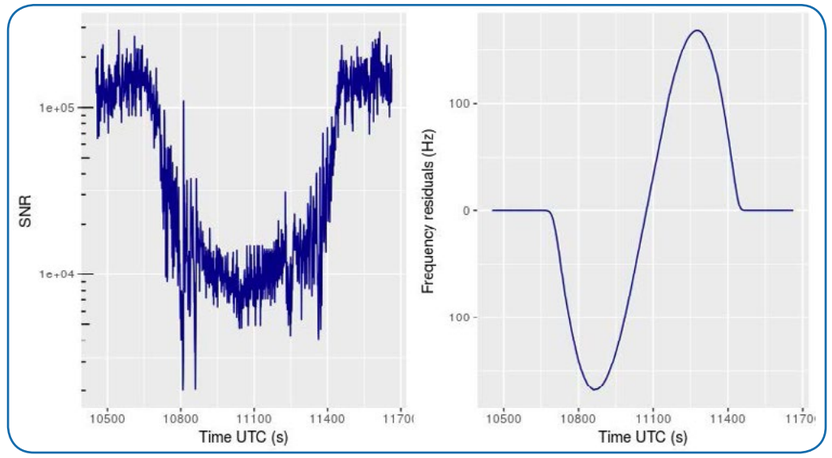
Fringes in two subbands between beamformed MeerKAT and the EVN telescopes Hartebeesthoek and Effelsberg

The pictures show fringes between the beamformed output of 16 MeerKat dishes in two bands and between one single MeerKAT dish (Me), m011v, and the EVN stations Effelsberg, Germany (Ef) and Hartebeesthoek, South Africa (Hh) in all eight EVN bands. They appear in Left-Right(LR) and Right-Right (RR) polarization because the MeerKAT receivers are linear while VLBI telescopes observe in circular.

Finding VLBI fringes using a single 13.5 m MeerKAT dish on an 8000+ km baseline clearly demonstrates the excellent quality of the dish and receiver system.

04 SPACE AND PLANETARY SCIENCE

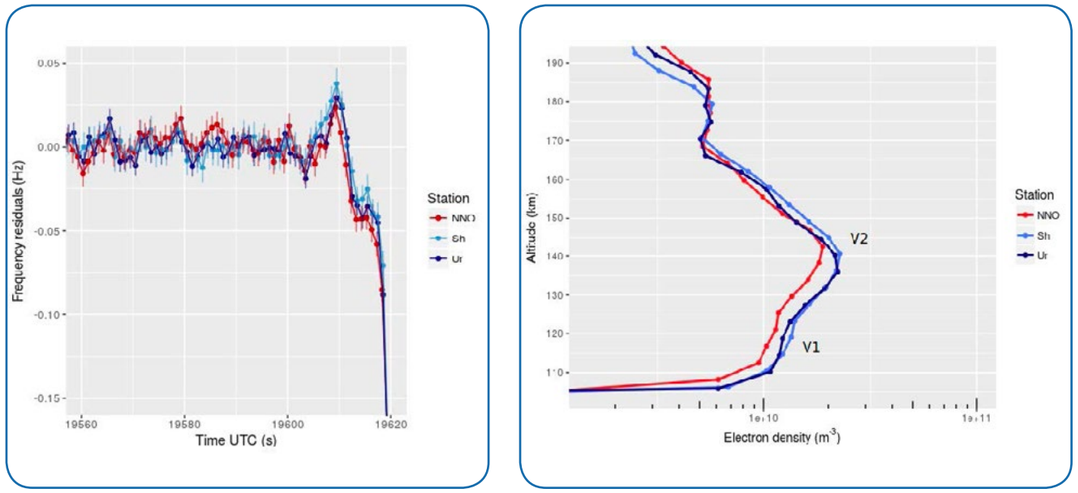
4.1 OBSERVATIONS OF SPACECRAFT AS NEAR-FIELD VLBI TARGET



Central panel: the S/N throughout the radio occultation detection of Venus Express by the Tianma 65-m radio telescope (China) on 2014.03.23, showing no loss of detection during the whole occultation. Right panel: shows the frequency residuals, which show from 10650 to 11100 s (ingress) followed by the egress from 11100 to 11450 s. The Tianma telescope was able to detect the signal while the planetary disk was completely occulting Venus Express.

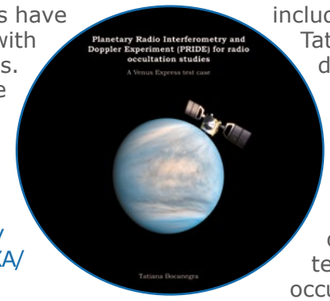
The Planetary radio Astronomy and Doppler Experiment (PRIDE) developed at JIVE and aimed at multi-disciplinary enhancement of the science output of planetary and space science missions is accepted as one of the eleven experiments of the European Space Agency's (ESA) Jupiter Icy Satellites Explorer (JUICE) mission. It is scheduled for lift-off in May 2022. PRIDE will address and enhance science tasks of the JUICE mission by providing measurements for improvement of the Jovian system ephemerides as well as measuring parameters of the propagation medium penetrated by the spacecraft radio transmission. In 2018, the JIVE group and its partners from other organisations continued the PRIDE development by applying this technique in several scientific domains.

As a new application of the PRIDE technique, Tatiana Bocanegra-Bahamón and co-authors (Bocanegra-Bahamón *et al.* 2019, A&A, arXiv:1903.01582) demonstrated the might of the method in studies of planetary atmospheres in radio occultations. In this work they investigated propagation of the ESA's Venus Express orbiter radio emission in various geometries (ingress, egress, total eclipse) as well as radio communication configurations (open and closed loops). The investigation demonstrated the potential of the PRIDE methodology in measuring parameters of the planetary atmosphere at altitudes and pleasures unreachable by other available techniques. The



Frequency residuals retrieved from open-loop data from Ur and Sh compared to the residuals from closed-loop data from ESTRACK New Norcia station during occultation ingress in the session of 2012.04.27. Left panel: the spacecraft signal starts getting refracted by Venus' ionosphere at around 19605 s. Left panel: the electron density profile, where the secondary V1 layer and main V2 layer of Venus' ionosphere are identified (Bocanegra-Bahamón *et al.* 2019, arXiv:1903.01582).

VEX radio occultation experiments have been conducted in 2012–2014 with the EVN and Global VLBI arrays. The results of these studies were included in the PhD dissertation by Tatiana Bocanegra, the thesis will be defended in March 2019.



PhD dissertation cover by T.M. Bocanegra-Bahamón with a schematic representation of a radio occultation experiment with Venus Express (artist's impression, courtesy ESA) and Venus (image courtesy JAXA/ ISAS/DARTS/Damia Bouic)

The PRIDE observations of Venus Express radio occultations, among other things, provided measurements down to about 45 km above the Venus surface, deeper than achieved by other techniques during the same occultation event.

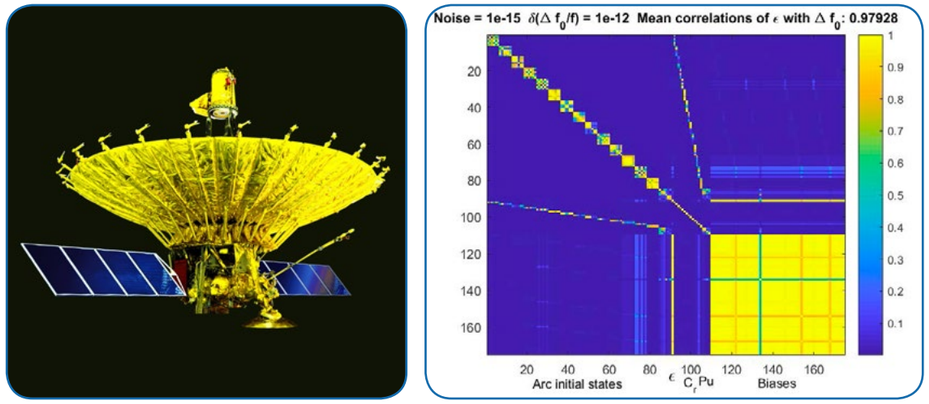
4.2 TOWARD VERIFICATION OF THE EINSTEIN EQUIVALENCE PRINCIPLE WITH AN EARTH-ORBITING SATELLITE

DEEP SYNERGY BETWEEN VLBI AND FUNDAMENTAL PHYSICS

Is gravitational mass, responsible for universal law of gravitation equivalent to the inertial mass, which defines an acceleration of a massive body to which a given force is applied? According to the equivalence principle, which postulated in the general relativity (the so called Einstein Equivalence Principle, EEP), the inertial and gravitational masses are equivalent. However, this principle, which is one of the pillars of modern physics, is not taken for granted by experimental physicists. They try to verify it experimentally. One of the approaches to such the verification is based on measurements of the effect of gravitational redshift. The Space VLBI mission RadioAstron offered a unique opportunity to conduct such an experiment owing to the presence of an active Hydrogen-maser oscillator on board the mission's spacecraft Spektr-R. The experiment, described in the paper by Litvinov *et al.* 2018 (Phys. Letters A 382, 2192–2198) involved G. Cimó, L.I. Gurvits, G. Molera Calvés and S.V. Pogrebenko of JIVE. The preliminary evaluation of the experiment indicates that the total amount of data obtained in the period from 2011 through 2017 would allow researchers to reach the highest to date

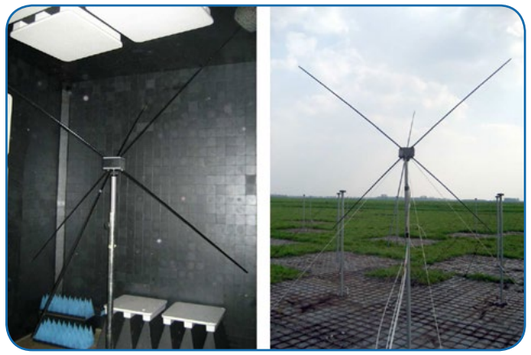
verification of the EEP. Meanwhile, an MSc project conducted by Giovanni Granato at the Department of Astrodynamics and Space Missions of the Delft University of Technology under supervision by D. Dirkx and L.I. Gurvits, addressed statistical properties of the RadioAstron gravitational redshift experiment. His finding on the statistical covariance between various measurables of the experiment provided an important input into the overall experimental data evaluation. The MSc thesis will be defended at Delft University of technology in February 2019.

The RadioAstron gravitational redshift experiment demonstrates deep synergy between VLBI and fundamental physics. Various applications of this synergy is discussed in the book 'High performance Clocks with Special Emphasis on Geodesy and Geophysics and Applications to Other Bodies of the Solar System' co-edited by L. Gurvits.



Left panel: Artist's impression of the RadioAstron mission's Spektr-R spacecraft, courtesy Lavochkin Science and Production Association. Right panel: Covariance correlations matrix of more than 100 measurables and experiment parameters analysed in the MSc thesis by G. Granato. The physical parameter of the mass equivalence is denoted in this analysis as variable #91 (marked in the matrix as a straight vertical stroke).

4.3 ULTRA-LONG-WAVELENGTH INTERFEROMETRY IN SPACE



Tests with the prototype tripole antenna. Left panel: Test setup in the ASTRON anechoic chamber. Right panel: Experimental setup of the tripole antenna at the LOFAR station CS011.

Opening up the last unexplored electromagnetic spectrum domain at wavelengths longer than the ionosphere cut-off (frequencies shorter than ~20 MHz; ultra-long-wavelength, ULW) is standing high on the radio astronomy agenda. Since 2007, JIVE collaborated on this topic with partners in the Netherlands (ASTRON, Radboud University) and China (National Astronomical Observatories and National Space Science Center of the Chinese Academy of Sciences). In particular, a PhD thesis on development of ULW instrumentation by L. Chen co-supervised by L.I. Gurvits was defended in 2011. Major components of this work are presented in the paper by Chen *et al.*, 2018 (Experimental Astronomy 45, 231-253).

The Chinese Lunar mission Chang'E-4 was launched in 2018. This mission carries ULW instrumentation developed, in part, on the basis of the results presented in the paper by Chen *et al.* 2018. The first radiometric and interferometric experiments with this instrumentation are planned for 2019.

05 OUTREACH AND TRAINING

5.1 EVENTS AND TRAINING

JIVE made a substantial effort both to target new users for the EVN and build links across the broader international astronomy community throughout 2018. The largest undertaking involved hosting a booth at the European Week of Astronomy and Space Science (EWASS). A special session on the future of the EVN was held and a brochure designed to highlight key information for potential EVN users was showcased at a booth shared with e-Merlin and Jodrell Bank. The booth was deemed a success as it created a true "VLBI hub" at the conference and will subsequently be repeated at EWASS 2019.

CLASSES AND EXERCISES WERE MET WITH ENTHUSIASM

Efforts at EWASS formed part of the JUMPING JIVE project, which also supported local radio astronomy training in Ghana together with the Development in Africa with Radio Astronomy (DARA) project. Support scientists Jay Blanchard and Ross Burns took part to guide trainees through a wide variety of topics including technical operations: hardware and software, principles of radio astronomy and interferometry, scheduling and observing VLBI experiments, programming and data reduction, and the science that can be done when combining these techniques. Over the three week course the classes and exercises were met with enthusiasm from the trainees who were keen to further their skills at summer schools and workshops around the world. In addition, JUMPING JIVE contributed to the ASTRON/JIVE traineeship programme, where two visitors from the African VLBI Network spent a week at JIVE to receive an introduction to how the EVN and JIVE operate.

JIVE members at the European Week of Astronomy and Space Science 2018

Dora Klindžić receives a Diploma Cum Laude, University of Zagreb, Croatia

Leonid Gurvits gave seven lectures at middle and high schools in French Guiana, as part of the BepiColombo launch campaign to provide materials and resources on Europe's first mission to Venus. In addition, from 2017 to 2018, Gurvits hosted Dora Klindžić, a student of the Department of Physics of the University of Zagreb (Croatia), at JIVE as an Erasmus trainee on the applications of Planetary Radio Interferometry and Doppler Experiment to studies of the Mars interior and atmosphere. In particular, in collaboration with Tatiana Bocanegra and Leonid Gurvits, she

Leonid Gurvits at a public lecture at a high school, French Guiana, October 2018.

investigated radio occultations of the European Space Agency's (ESA) Mars Express spacecraft observed with EVN in 2012-2016. Later, in September 2018, Dora Klindžić defended her MSc thesis "Planetary Radio Interferometry and Doppler Experiment (PRIDE) Applications to Orbiters and Landers", co-supervised by L. Gurvits and Vernesa Smolčić (University of Zagreb), with the overall distinction Cum Laude.

INCREASING THE PROFILE OF JIVE MEMBERS

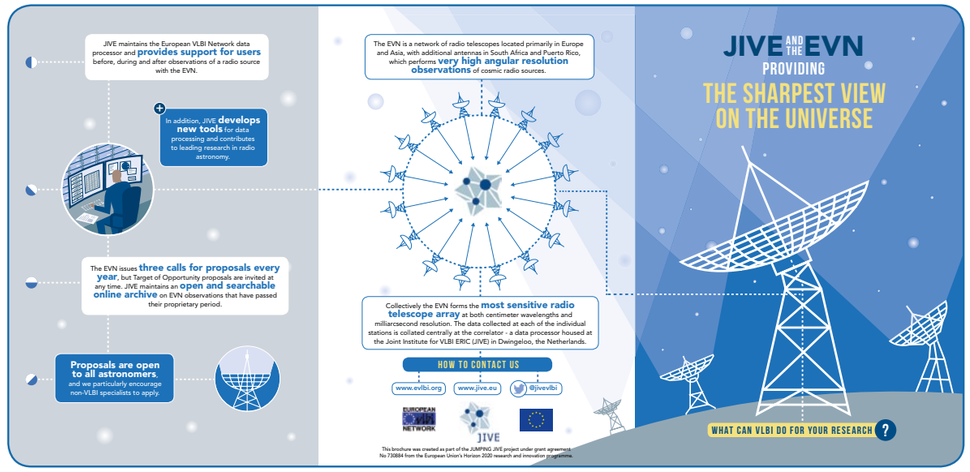
Science Communication Officer, Dr. Gina Maffey, represented JIVE at Communicating Astronomy with the Public 2018 (CAP2018) in Japan. While the conference covered all aspects of astronomy communication, there was a definite interest in the particular challenges faced in radio astronomy. As many of these challenges are shared internationally by institutes there is an informal forum developing in which to discuss such issues.

Closer to home, JIVE and ASTRON hosted the Young European Radio Astronomy Conference 2018 (YERAC2018) in Dwingeloo, the Netherlands. The conference was warmly received by all involved, and participants were offered a workshop on science communication and a number of social activities alongside the more traditional science presentations. ASTRON and JIVE also partnered to offer science communication talks at Bessensap (a day for researchers, science communicators and journalists), ASTROfest (an event for ASTRON and JIVE early career researchers) and as part of the Summer Student programme. Once again, JIVE supported ASTRON in hosting Girlsday (where local female students are invited to visit ASTRON and JIVE), and the Open Day as part of the Dutch Weekend of Science.

Participants at the Young European Radio Astronomy Conference 2018

5.2 RESOURCES

JIVE continued to provide core resources for the EVN – including English press releases, which are distributed across the EVN to serve as a template for local institutes to share key scientific results. The EVN website was maintained and, crucially, updated at the end of 2018. This redesign is ongoing and is targeted at ensuring that new and returning EVN users are able to quickly and simply access the information needed to submit an observation proposal.



Brochure design showcased at the European Week of Astronomy and Space Science 2018

The redesign of the website compliments the creation of a brochure, showcased at EWASS, which provides an overview on how to submit a proposal to use the EVN and is available for all EVN institutes to use. At the end of 2018, a booth following the same design as the brochure was made as a deliverable of the JUMPING JIVE project. This will be used at events throughout 2019, notably EWASS.

At the beginning of 2018, two articles were published on the Nature Careers website, which explored the role of astronomy in Africa through the stories of two students who have been supported by the JUMPING JIVE project. The stories had a significant impact on the profile of the students in their respective counties and indicated the value of such training programmes.

JIVE now has a growing collection of branded materials, which serve to increase the profile of JIVE members in attendance at events across the astronomy community.

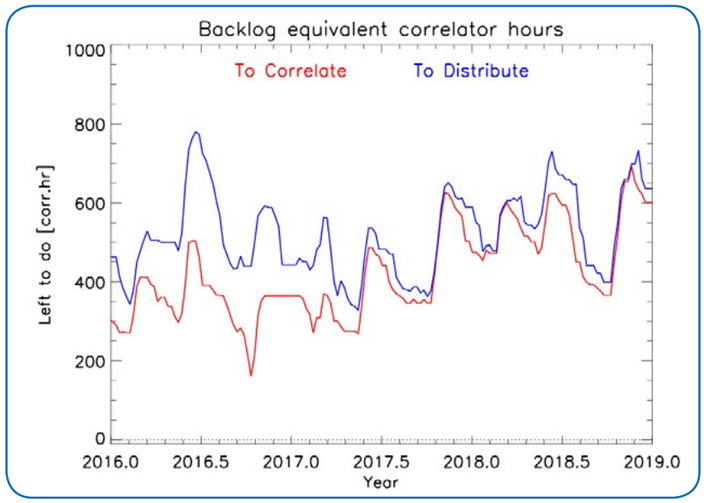
06 OPERATIONS

6.1 CORRELATION

At the core of JIVE's service is the processing of EVN data; the table below summarizes experiments that were correlated, distributed, or released in 2018. For a detailed list of the user experiments, see *8.5 Correlator Activity.*

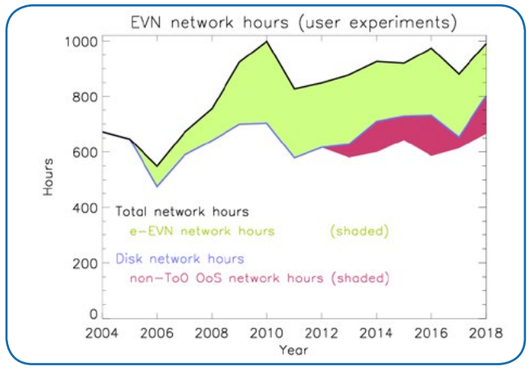
Table: Summary of projects correlated, distributed, or released in 2018. Here, 'network hours' sum the total duration of experiments, and 'correlator hours' are simply network hours multiplied by any multiple correlation passes required.

	User Experiments			Test and Network Monitoring		
	N	Ntwk_hr	Corr_hr	N	Ntwk_hr	Corr_hr
Correlated	79	664.5	802.5	35	111	111
Distributed	85	695.5	854.5	36	109	109
Released	84	648.5	764.5	31	93	93
e-EVN experiments	32	118	188			
e-EVN ToOs	12	79	79			

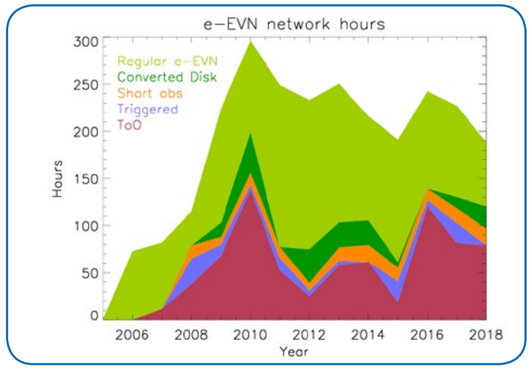


The size of the correlator queue at different stages in the processing cycle. The red line shows the number of correlator hours that remain to be correlated. The blue line shows the number of correlator hours in experiments whose data remain to be distributed to the PI.

The EVN offers a variety of observing modes that provide users with extra flexibility, but add some complexity to the operations. The top figure shows the evolution of the annual EVN network hours. The bottom figure focuses on e-EVN experiments, showing the breakdown into individual proposal categories.



Annual EVN network hours, with 'traditional' disk-based observations, e-EVN hours, and the relatively new category of scheduled disk-based out-of-session hours distinguished by colour.



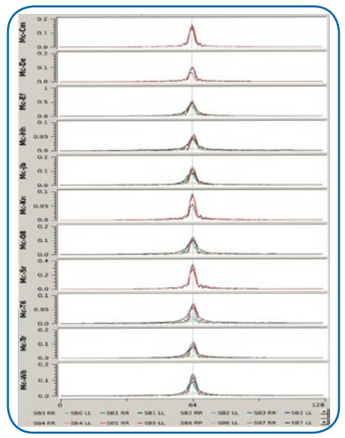
Division of total e-EVN network hours into proposal categories, from the bottom to the top: target-of-opportunity, triggered, short observations, converted from disk, and regular.

2018 continued to see new ground broken in various experiments:

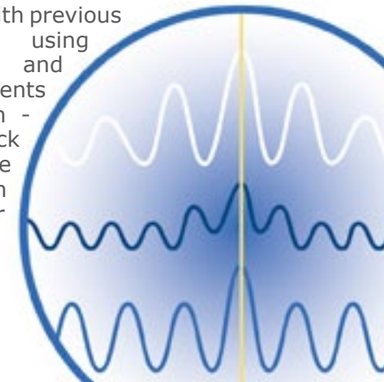
- First user e-EVN experiments including e-MERLIN out-stations in September. Three out-stations participated at 512 Mbps to fit, together with a Jodrell Bank antenna at 1 Gbps, within the current network bandwidth limitation from the UK of 3000 Mbps. SFXC was able to keep up with the mixed-bandwidth correlation in real-time (each out-station uses 64 MHz channels which in this experiment needed to be split into 16 MHz channels to match the other stations).

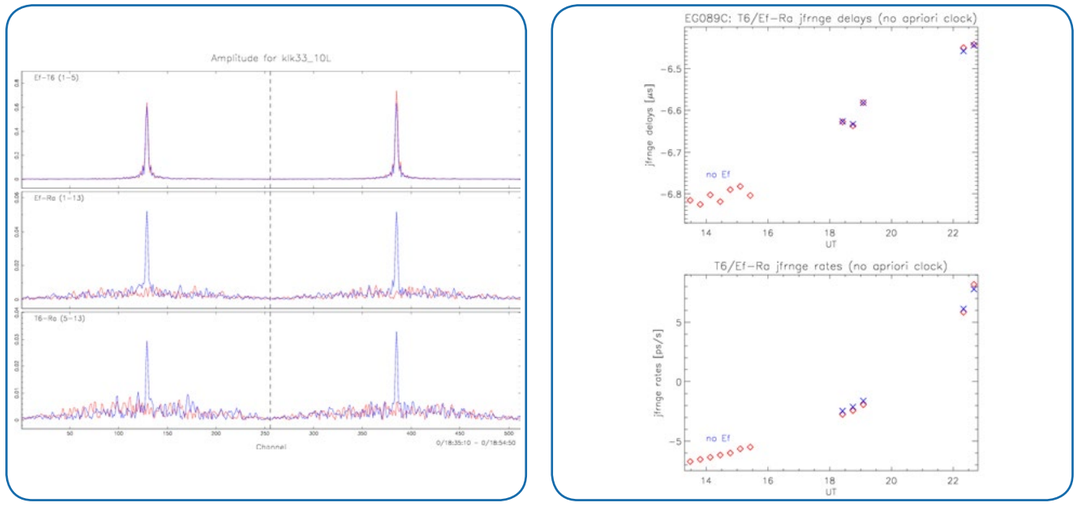
GROUND BROKEN IN VARIOUS EXPERIMENTS

- First successful participation of the Sardinia Radio Telescope in e-EVN user experiments, also in September.
- There were 12 e-EVN ToO observations (arising from 6 proposals), covering targets ranging from following the structural evolution of the E-M counterpart to a gravitational wave events, tracing the expansion of gamma-ray bursts (2 different ones), investigating a possible association between a gamma-ray burst and fast-radio bursters, seeking jet components in a gamma-ray detected nova, to an unusual transient in the nuclear region of a narrow-line Seyfert 1 galaxy.
- GG084A was the first joint Global + LBA observation at 6cm.
- First fringes from a RadioAstron user experiment using the normal production system; the ephemeris was good enough to keep residual delays and rates within standard clock-search windows over the course of the experiment, and not require estimation of an acceleration term. This is consistent with previous 'off-line' tests using test observations and scans of experiments correlated in Bonn - suggesting that lack of fringes via the normal production system in other



Real-time fringe display during the September e-EVN observation, showing e-EVN fringes to three e-MERLIN out-stations (Cm, De, Kn) and Sardinia (Sr), all in baselines to the Medicina telescope.





[i] Fringe plots for the triangle Effelsberg – Tianma - RadioAstron from the experiment EG089C (6 cm). [ii] Plot of residual delay and delay rates on baselines to RadioAstron for all scans of EG089C.

user experiments may have been target-related rather than production-system-related.

- The 'E-series' firmware for the DBBC, which enabled 2 Gbps observing via tunable 32MHz channels, had been deployed for user experiments since session 3/2015, but a new version of this showed amplitude variations across channels, most notably in session 1/2018. However, a quick succession of tests showed that the behaviour could persist even for a station reverting back to earlier version, but was not necessarily entirely reproducible. The EVN Council Board of Directors (CBD) decided in May to revert to the non-E-series firmware, at the expense of 2 Gbps bit-rates. This change was carried out, which required JIVE to make last-minute revisions to the schedules for ~85% of the session 2/2018 user experiments. The rest of 2018 remained at 1 Gbps while new firmware was being developed and tested to re-attain higher bit-rates.

Detailed per-station/frequency-band summaries of the effects of this firmware problem were presented at the Users' Meeting during the EVN Symposium in Granada, and targeted summaries were sent to PIs of possibly affected observations, along a description of their re-queuing options.

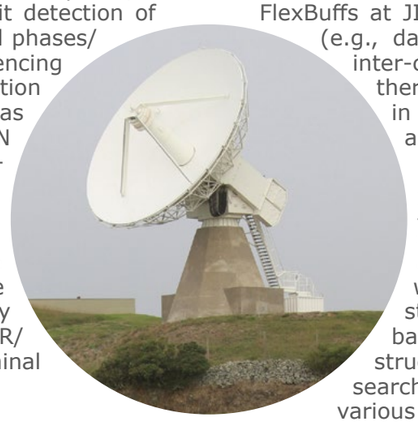
6.2 EVN SUPPORT

Participants on an ASTRON/JIVE traineeship with support scientists Jay Blanchard and Ross Burns.

The Kuntunse telescope in Ghana participated in its second 6cm Network Monitoring Experiment in session 1/2018 (N18C1), and obtained fringes in the ftp fringe-test segments – an improvement over the original fringes from 2017.

During 2018, JIVE received visitors from the African VLBI Network and Support Scientists Jay Blanchard and Ross Burns taught at a two-week Development in Africa with Radio Astronomy (DARA) training event, in conjunction with JUMPING JIVE WP9, in Ghana in late April (see *5.1 Events and Training*).

In session 1/2018, good e-MERLIN out-station fringes were seen at 1.3 cm, completing the bands having overlap with the EVN. During 2018, data quality continued to improve, such that it was possible to permit detection of model-based effects. Residual phases/delays from phase-referencing observations led to the realization that the tropospheric model was being applied in the e-MERLIN correlation (and thus doubly-applied after the EVN correlation) – it is now turned off for e-MERLIN correlation when out-stations participate in EVN observations, and the effect in earlier data can largely be compensated via CLCOR/ATMO in AIPS using a nominal zenith delay of 220 cm.



The RAEGE Santa Maria telescope

Fringes from the RAEGE Santa Maria telescope (Azores) were found in a single-baseline test using a geodetic S/X set-up in February. Test observations were conducted for the new 7mm receivers at Effelsberg and Tianma, with fringes seen to both.

By the end of 2018, the majority of EVN stations used the FlexBuff system to record data and e-shipping to transfer the data to JIVE. Those yet to make this transition include the KVAZAR stations, Chinese stations, and Torun, although some activity in the direction of FlexBuff operations is underway at these stations as well. There has been 'unbudgeted' use of FlexBuffs at JIVE for special circumstances (e.g., data from the Australian LBA, inter-correlator transfers); so far there has been enough slack in the FlexBuffs at JIVE to accommodate such instances.

Under the aegis of JUMPING JIVE WP5, central database structures for station feedback and amplitude calibration, which hitherto have been stored purely in an experiment-based fashion. The new SQL structures permit stations to search across all experiments by various quantities and create their own custom plots and tables. The new structures are presented using a web-based Grafana graphical interface. Station feedback has been back-loaded through 2002, and amplitude calibration through 2006.

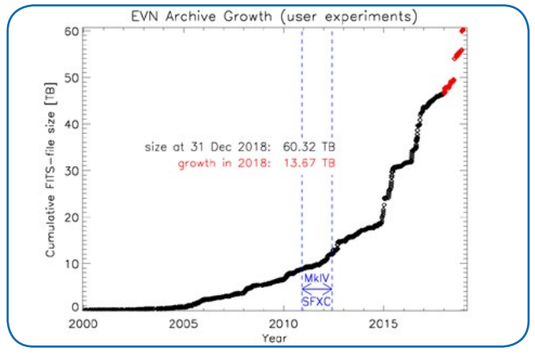
JIVE has also installed a mattermost server to handle real-time communication with stations during e-VLBI, ftp fringe-tests, and the like. mattermost was found to overcome some recently arising limitations with skype and slack - all EVN stations retain access and conversation history is preserved.

6.3 USER SUPPORT

JIVE provides support in all stages of a user's EVN observation, from proposal definition to data analysis. There were five first-time PIs in 2018 observations, including three students. A list of visitors to JIVE can be found in section 8.4. JIVE continued to provide PIs with experiment-specific scheduling templates to track the evolving configurations of equipment at EVN stations. About 85% of the schedules for session 2/2018 had to be re-made at JIVE after the PIs had already submitted them, in order to enact the reversion back to non-E-series DBBC firmware as directed by the CBD.

The script that provides primary-beam corrections into the FITS files has received its first application by users in their own observations. It fits Gaussians to beam maps provided by stations; most of the large stations (who typically taper their sensitivity to the outer reaches of their antennas) have provided such maps, smaller stations that have not receive nominal-diameter models.

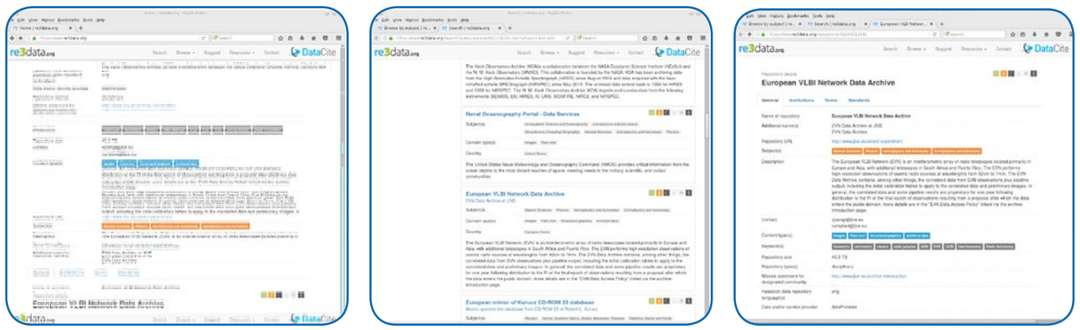
The EVN Archive is another vital user service, providing open access following the expiry of the proprietary period (one year, but six months for ToO projects). The total size of user-experiment



Growth of user experiments in the EVN Archive. Experiments archived in 2018 are plotted in red. Vertical grey lines show the transition period between the MkIV and SFXC correlators.

FITS files in the Archive at the end of 2018 was 60.32 TB, an increase of 29% in the year.

We arranged to have the EVN Archive listed in re3data.org, a registry of research data repositories, searchable by discipline, country (European Union for the EVN Archive), or content type. There are currently 24 repositories listed under astrophysics. Bypassing the search hierarchies provided, the direct URL for the EVN Archive listing is: https://www.re3data.org/repository/r3d100012641



Left panel: Top page of the re3data.org registry of research data repositories.
Central panel: Description of the EVN Archive within the astrophysics discipline listing.
Right panel: The EVN Archive's own page within re3data.org.

07 FINANCES

7.1 JIVE FINANCIAL REPORT 2018

Balance [after allocation of results]

ASSETS	2018 in €	2017 in €
Tangible fixed Assets		
Tangible fixed Assets	153,027	231,734
Total of Tangible fixed Assets	153,027	231,734
Current Assets		
Work in process	0	0
Receivables	986,209	844,974
Cash at bank	3,752,993	2,169,131
Total of Current Assets	4,739,202	3,014,105
Total Assets	**4,892,229**	**3,245,839**

LIABILITIES	In €	In €
Capital		
General reserve	1,270,450	1,335,197
Designated funds	299,678	299,678
Total capital	1,570,128	1,634,875
Other Liabilities		
Short term debts	3,322,101	1,610,964
Total Other Liabilities	3,322,101	1,610,964
Total Liabilities	**4,892,229**	**3,245,839**

Statement of profit and loss

REVENUES	2018 BUDGET in €	2018 ACTUAL in €	2018 DIFFERENCE in €	2017 ACTUAL in €
Income				
Contributions/subsidies third parties	2,583,796	2,400,450	-183,346	2,662,987
Interest	0	0	0	0
Other	204,812	262,806	57,994	178,506
Total Income	2,788,608	2,663,257	-125,351	2,841,493
Total Revenues	**2,788,608**	**2,663,257**	**-125,351**	**2,841,493**

EXPENDITURES	in €	in €	in €	in €
Operations				
Grants/Expenditures	2,778,293	2,728,004	-50,290	2,424,168
Total Operations	2,778,293	2,728,004	-50,290	2,424,168
Total Expenditures	**2,778,293**	**2,728,004**	**-50,290**	**2,424,168**
RESULT	**10,315**	**-67,747**	**-75,062**	**417,325**

7.2 JIVE PROJECTS

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 contributes to the 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.
JUMPING JIVE	01.12.16 - 31.01.21	JIVE coordinates the Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization of JIVE (JUMPING JIVE) project. JUMPING JIVE aims to take VLBI into the next decade, with JIVE and the EVN as globally recognized centres of excellence in radio astronomy.
AENEAS	01.01.17 - 31.12.19	AENEAS (Advanced European Network of E-infrastructures for Astronomy with the SKA) is an EC funded study to develop a concept and design for a federated data science centre for the SKA.
RadioNet4	01.01.17 - 31.12.20	RadioNet supports the collaboration of major radio astronomy facilities in Europe. JIVE is involved in the RINGS workpackage and receives trans-national access funds.

08 TABLES AND METRICS

8.1 JIVE COUNCIL

Representatives of Members

Prof. Simon Garrington – Jodrell Bank Centre for Astrophysics, Manchester, UK (Chair)

Prof. John Conway – representing the EVN Board of Directors, Onsala Space Observatory, Onsala, Sweden (Vice chair)

Dr. Valdis Avotins – Ventspils International Radio Astronomy Center, Ventspils, Latvia

Dr. Patrick Charlot – Laboratoire d'Astrophysique de Bordeaux, Pessac, France

Prof. Leif Eriksson – Vetenskapsrådet / Swedish Research Council, Stockholm, Sweden (from 01 Dec)

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

Prof. Carole Jackson – ASTRON, Dwingeloo, the Netherlands

Ms. Inga Jekabsone – Ministry of Education and Science of the Republic of Latvia, Riga, Latvia

Dr. José Antonio López Fernández – Instituto Geográfico Nacional, Madrid, Spain

Dr. Guy Perrin – National Centre for Scientific Research, Paris, France

Dr. Catarina Sahlberg – Vetenskapsrådet / Swedish Research Council, Stockholm, Sweden (until 31 Nov)

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

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

Representatives of Associated Research Institutes

Dr. Fernando Camilo – National Research Foundation, South African Radio Astronomy Observatory, Cape Town, South Africa

Prof. Zhinqiang Shen – NAOC, Shanghai Astronomical Observatory, Shanghai, China

Dr. Tiziana Venturi – INAF-IRA, Bologna, Italy

Prof. Anton Zensus – MPIfR, Bonn, Germany

8.2 JIVE PERSONNEL

Dr. Jay Blanchard	Support Scientist
Miss. Tatiana Bocanegra Bahamon	PhD Student
Mr. Paul Boven	Network/Linux Specialist
Mr. Wybren Buijs	Linux-/Network Specialist (until 1 November 2018)
Dr. Ross Burns	Support Scientist (until 1 December 2018)
Dr. Bob Campbell*	Head of Science Operations
Dr. Giuseppe Cimò	Space VLBI Scientist
Dr. Francisco Colomer Sanmartín*	Director
Drs. Bob Eldering	Software Engineer
Prof. Leonid Gurvits*	Head of Space Science & Innovative Applications Group
Mr. Bert Harms	Chief Operator
Dr. Katharina Immer	Support Scientist
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. Gina Maffey	Science Communication Officer
Dr. Benito Marcote Martin	Support Scientist
Dr. Zsolt Paragi*	Head of User Support
Mr. Luis Henry Quiroga-Nuñez	PhD Student
Dr. Des Small	Scientific Software Engineer
Dr. Arpad Szomoru*	Head of Technical Operations and R&D
Dr. Ilse van Bemmel	Project Scientist
Drs. Aukelien van den Poll	Project Assistant
Prof. Huib Jan van Langevelde*	Senior Scientist
Drs. Harro Verkouter	Senior Software Engineer

* - JIVE MT member

8.3 EDUCATIONAL RESPONSIBILITIES

MSc project supervision

Giovanni Granato - by L. Gurvits and D. Dirkx, TU Delft (completion in 2018)

Dora Klindžić - by Vernesa Smolčić and L.I. Gurvits, University of Zagreb (completion in 2018)

Ardjan Sturm - by K. Immer & H.J. van Langevelde, Leiden University

Keith Tirimba – by L.H.Quiroga Nuñez & H.J. van Langevelde, Leiden University

Benjamin van Ommen - by S. Schouws, M. Brentjens & H.J. van Langevelde, Leiden University

PhD project supervision

Tatiana Bocanegra-Bahamón – by L.I. Gurvits and L.L.A. Vermeersen, TU Delft (completion in 2019)

Luis Henry Quiroga-Nuñez – by H.J. van Langevelde, Leiden University (completion in 2019)

EC Erasmus Traineeship

Dora Klindžić (Zagreb University, Croatia) - by L.I. Gurvits (October 2017 - April 2018)

Lecturing

Space-borne astrophysics (graduate course), Department of Astronomy, Moscow Lomonsosov State University - by L.I. Gurvits (spring semester 2018)

Praktische Sterrenkunde (1st year Bachelor course), Leiden University, by H.J. van Langevelde (spring 2018)

Secondary affiliations:

Giuseppe Cimò – affiliated with ASTRON, the Netherlands

Francisco Colomer-Sanmartin - affiliated with Instituto Geográfico Nacional, Madrid, Spain

Leonid Gurvits – affiliated with the 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

8.4 VISITORS TO JIVE

Name	Institute	Period	Host
D. Klindzic	University Zagreb, Croatia	09/10/17 - 04/05/18	Gurvits
C. Garcia Miro	SKA Organisation Manchester, UK	22/01/18 - 25/01/18	Paragi

Name	Institute	Period	Host
Z. Xu	Shanghai Astronomical Observatory, CAS, China	28/01/18 - 09/02/18	Hargreaves
R. Zhu	Shanghai Astronomical Observatory, CAS, China	28/01/18 - 09/02/18	Hargreaves
S. Guo	Shanghai Astronomical Observatory, CAS, China	28/01/18 - 09/02/18	Hargreaves
J. Gan	Shanghai Astronomical Observatory, CAS, China	28/01/18 - 09/02/18	Hargreaves
P. Charlot	Observatoire de Bordeaux, France	01/03/18 - 02/03/18	Campbell
I. Natarajan	Rhodes University / SKA South Africa	01/03/18 - 04/03/18	Paragi
R. Deane	Rhodes University / SKA South Africa	01/03/18 - 04/03/18	Paragi
I. Natarajan	Rhodes University / SKA South Africa	07/03/18 - 23/03/18	Paragi
G. Molera	Finnish GeoSpace Institute, Finaland	08/03/18 - 09/03/18	Gurvits
U.L. Pen	Canadian Institute for Theoretical Astrophysics, University of Toronto, Canada	19/03/18	Colomer
S. Frey	Konkoly Observatory, Hungary	19/03/18 - 29/03/18	Campbell
K. Perger	ELTE University, Hungary	19/03/18 - 29/03/18	Campbell
M. Janssen	Radboud Universiteit Nijmegen, the Netherlands	27/03/18	Van Bemmel
I. Natarajan	Rhodes University / SKA South Africa	28/03/18 - 20/04/18	Paragi
I. Stewart	Sterrewacht Leiden, the Netherlands	12/04/18	Van Bemmel
J. Chibueze	SKA South Africa	30/04/18 - 03/05/18	Paragi
G. Ghirlanda	INAF / Brera Astronomical Observatory, Italy	14/05/18 - 18/05/18	Paragi
O. Salafia	INAF / Brera Astronomical Observatory, Italy	14/05/18 - 18/05/18	Paragi
B. Asabere	Ghana Radio Astronomical Observatory, Ghana	18/05/18 - 25/05/18	Blanchard
E. Manful	University of Hertfordshire, UK	18/05/18 - 25/05/18	Blanchard
D. Quinatoa	National Polytechnic School, Ecuador	01/06/18 - 13/08/18	Burns
A. Plavin	Astro Space Center/Lebedev Physical Institute, Russia	18/06/18 - 24/08/18	Paragi
K. Rygl	Italian ALMA Regional Centre INAF-IRA, Italy	04/07/18 - 06/07/18	Van Bemmel
O. Bayandina	Astro Space Center, Russia	15/07/18 - 28/07/18	Burns
M. Olech	Nicolaus Copernicus University, Poland	26/07/18 - 10/08/18	Burns
S. Gulyaev	Auckland University of Technology, New Zealand	06/08/18 - 18/08/18	Gurvits
H. Zhang	NAOC-FAST, China	14/08/18 - 17/08/18	Gurvits
R. Chen	NAOC-FAST, China	14/08/18 - 01/09/18	Gurvits
C. Garcia Miro	SKA Organisation Manchester, UK	16/08/18 - 22/08/18	Paragi
J. Steinbergs	VIRAC, Latvia	20/08/18 - 07/09/18	Szomoru
P. Saika	New York University, Abu Dhabi	27/08/18 - 08/09/18	Paragi

Name	Institute	Period	Host
X. Hong	ShAnghai Astronomical Observatory, China	02/09/18 - 04/09/18	Gurvits
I. Mutie	Technical University of Kenya, Kenya	03/09/18 - 13/09/18	Colomer
T. Hezareh	MPIfR/CRAF, Germany	10/09/18 - 11/09/18	Colomer
G. Granato	Delft University of Technology, the Netherlands	24/09/18 - 29/09/18	Gurvits
V. Beskin	Lebedev Physical Institute, Russia	22/10/18 - 24/10/18	Gurvits
V. Labushkina	Lebedev Physical Institute, Russia	22/10/18 - 24/10/18	Gurvits
R. Sarniak	Torun University, Poland	07/11/18 - 22/11/18	Immer
A. Sanchez-Monge	University de Cologne, Germany	04/12/18 - 06/12/18	Immer
A. Plavin	Astro Space Center/Lebedev Physical Institute, Russia	09/11/18 - 11/11/18	Paragi

8.5 CORRELATOR ACTIVITY

User experiments with correlation, distribution, or release activity in 2018.

Project code	Observation Date/ Session	Principal Investigator	User Experiments
EA058B	s.3/2017	Argo	Tracking the evolution of the central radio source in NGC660
EA062A	161018	Atri	A parallax measurement for the black hole XRB MAXI J1820+070
EA062B	041218	Atri	A parallax measurement for the black hole XRB MAXI J1820+070
EB060B-C	s.2/2017	Bach	A second active nucleus in Cygnus A?
EB063A-C	s.3/2018	Burns	OH, EGOs - Part II
EC057C	s.1/2018	Cutini	Morphological changes after a bright optical-gamma-ray flare in S51803+78
EC061A-B	s.3/2017	Cao	Looking for radio counterparts of two newly-discovered radio-weak BL Lacs
EC062A-B	s.3/2017	Caccianiga	A VLBI survey of high redshift blazar candidates
EG073C	s.2/2017	Goddi	How do O-type forming stars accrete their mass?
EG078F-B	s.3/2017	Garrett	No place left to hide - AGN among the faint radio source population
EG089C	s.1/2016	Gurvits	Second-epoch Space VLBI visit into core-jet laboratories in the distant
EG093A-B	s.2/2017	Gawronski	Search for massive substellar companions around main sequence A-type stars
EG096E	160118	Gawronski	AR Ursae Majoris - a second identified persistent radio polar
EG098A-B	s.2/2017	Gabanyi	G8+1 in the sky
EG099A-B	s.3/2017	Guirado	Kinematics and radio emission of the multiple stellar system HD160934
EG102A	141217	Gabanyi	Towards solving the puzzle of high-z radio sources: extending the VLBI sample
EG102B	160118	Gabanyi	Towards solving the puzzle of high-z radio sources: extending the VLBI sample

Project code	Observation Date/ Session	Principal Investigator	User Experiments
EG102C	100418	Gabanyi	Towards solving the puzzle of high-z radio sources: extending the VLBI sample
EG102D	170518	Gabanyi	Towards solving the puzzle of high-z radio sources: extending the VLBI sample
EG102E	190618	Gabanyi	Towards solving the puzzle of high-z radio sources: extending the VLBI sample
EG105	201118	Gawronski	Search for radio emission from the binary system LHS 1610
EJ019A-D	s.2/2017	Janson	Closing the orbits on four young, low-mass benchmark binaries
EL058E	170118	Lobanov	Periodic activity in pulsating white dwarf binary AR Scorpii
EM117M-N	s.1/2018	Moscadelli	A 3-D View of high-mass star formation: gas Kinematics and Magnetic Fields
EM127A-B	s.1/2017	Maan	Probing the off-pulse emission from pulsars B0525+21 and B2045-16
EM127C-D	s.2/2017	Maan	Probing the off-pulse emission from pulsars B0525+21 and B2045-16
EM128B	s.2/2017	Moldon	Mapping the orbit of PSR J2032+4127 with EVN astrometry
EM128C	s.3/2017	Moldon	Mapping the orbit of PSR J2032+4127 with EVN astrometry
EM129	s.2/2017	Marcote	Exploring the puzzling origin of the radio nebula G70.7+1.2
EM130A-B	s.3/2017	Marcote	In quest of the origin of the Fast Radio Burst FRB 150418
EM132A	s.1/2018	Marcote	Unveiling the origin of the radio emission in the gamma-ray binary LS I +61 303
EM132B	s.2/2018	Marcote	Unveiling the origin of the radio emission in the gamma-ray binary LS I +61 303
EP103C-D	s.2/2017	Hessels/Paragi	Proper Motion and Variability of FRB121102
EP103E-F	s.3/2017	Hessels/Paragi	Proper Motion and Variability of FRB121102
EP104A-B	s.2/2017	Perger	Is there a blazar hiding in the core of the radio galaxy 3C 411?
EP107A-B	s.3/2017	Baan/Polatidis	OH gas in Megamaser Galaxies: IC860 Zw049.057
ER045B	s.2/2017	Romero-Canizales	Characterising the core-jet components in the nearby TDE ASASSN-14li
ES083	s.3/2017	Szymczak	Hydroxyl masers associated with the methanol periodic source G107.29+5.63
ES084A	s.3/2017	Surcis	A detailed study of the H2O 'gigamaser', and of its polarization, in TXS2226-184
ES085A-B	s.1/2018	Sarniak	Probing environment of protostars I. Second epoch observation of 6.7 GHz masers
ES087	s.3/2017	Shu	Ecliptic plane calibrators for nanoradian absolute astrometry
ES088A	141217	Schulz	The parsec-scale view of the last Westerbork HI absorption survey
ES088B	070218	Schulz	The parsec-scale view of the last Westerbork HI absorption survey
ES088C	201118	Schulz	The parsec-scale view of the last Westerbork HI absorption survey
ES089	s.1/2018	Sarniak	Probing the gas kinematic and velocity gradients at milliarcsecond scales
EW019	s.2/2017	Wu	EVN and MERLIN observations of OH megamaser galaxy IRAS10173+0828
EY027	280318	Yang	Imaging the pc-scale radio structure of Eddington accreting source PDS 456
EY029	s.3/2017	Yang	Is there violent jet activity at the early stage of black hole growth?
EY031	180918	Yang	Imaging compact knots at a later stage in Nova V392 Per

Project code	Observation Date/ Session	Principal Investigator	User Experiments
GG084A	s.1/2018	Ghirlanda	Do binary neutron star mergers always produce a jet?
GG084B	s.2/2018	Ghirlanda	Do binary neutron star mergers always produce a jet?
GK052	010218	Kim	Ultra-Deep Polarization Imaging of the Twin-Jet Structure in M87
GR040	s.2/2017	Romero-Canizales	The nature of the radio emission in PGC043234, the ASASSN-14li's host
GS039	s.2/2017	Savolainen	Proper motion of the newly discovered helical filaments in the M87 pcscale jet
GV022B	s.2/2017	Varenius	Continued monitoring of compact SNe/SNRs/AGNs in the starburst galaxy Arp 220
GV023	s.3/2017	Varenius	Global 3.6cm VLBI observations of SNe/SNRs/AGNs in the starburst galaxy Arp 220
RE005	s.2/2017	Etoka	The evolution of the ongoing long-lasting flare in omicron Ceti
RG009A	270318	Ghirlanda	Unveiling the structure of the outflow of GW170817
RG009B	100418	Ghirlanda	Unveiling the structure of the outflow of GW170817
RG009C	170518	Ghirlanda	Unveiling the structure of the outflow of GW170817
RG009D	190618	Ghirlanda	Unveiling the structure of the outflow of GW170817
RM015	180918	Marcote	The fading of a possible long Gamma-Ray Burst in a Fast Radio Burst-like environment
RP030A	170118	Perez-Torres	Probing the expansion of the very nearby GRB 171205A with the EVN
RP030B	040218	Perez-Torres	Probing the expansion of the very nearby GRB 171205A with the EVN
RP030D	171018	Perez-Torres	Probing the expansion of the very nearby GRB 171205A with the EVN
RP030E	051218	Perez-Torres	Probing the expansion of the very nearby GRB 171205A with the EVN
RR011	110418	Romero	Resolving ASASSN-17jz: a rare nuclear transient
RSD04	151217	Ding	Identify in-beam calibrators for VLBI astrometry on PSR J1939+2134
RSF09	270318	Frey	Zooming in on an optical and X-ray dual AGN candidate in a galaxy merger with the EVN
RSF09B	211118	Frey	Zooming in on an optical and X-ray dual AGN candidate in a galaxy merger with the EVN
RSG09	060218	Gabanyi	A candidate triple AGN
RSG10	190618	Garrett	Potential calibrators in the field centred on KIC 9832227
RSG11	190918	Gabanyi	An assumed radio galaxy at z=5.72
RSM01	141117	Marecki	J084408+462744, the core of a newly discovered giant radio galaxy
RSM02	100418	Marecki	The dubious hotspot in J1427+2632
RSY07	041218	Yang	A change-accretion Seyfert galaxy: 1ES 1927+654
RY006	200618	Yang	Searching for compact knots in the γ-ray detected Nova V392 Per
RY007A	180918	Yang	Accurate determination of the size of the GRB afterglow in AT2018cow
RY007B-C	s.3/2018	Yang	Accurate determination of the size of the GRB afterglow in AT2018cow

8.6 JIVE STAFF PUBLICATIONS

Journal Articles

MAGIC Collaboration, V. A. Acciari, S. Ansoldi, *et al.* (including **B. Marcote**): *Constraining very-high-energy and optical emission from FRB 121102 with the MAGIC telescopes*, 2018, Monthly Notices of the Royal Astronomical Society, 481, 2479-2486

J. H. Kim, D. P. Marrone, A. L. Roy, *et al.* (including **J. Blanchard**): *The 1.4 mm Core of Centaurus A: First VLBI Results with the South Pole Telescope*, 2018, The Astrophysical Journal, Volume 861, Issue 2, article id. 129

C. Müller, M. Kadler, R. Ojha, *et al.* (including **J. Blanchard**): *TANAMI: Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry. II. Additional sources*, 2018, Astronomy & Astrophysics, Volume 610, id.A1

G. W. Schoonderbeek, A. Szomoru, A. W. Gunst, *et al.* (including **J. Hargreaves**): *UniBoard², A Generic Scalable High-Performance Computing Platform for Radio Astronomy*, 2018, Journal of Astronomical Instrumentation, Vol. 8, No. 2, 1950003

Y. M. Pihlström, L. O. Sjouwerman, M. J. Claussen, *et al.* (including **H. J. van Langevelde**, **L. H. Quiroga-Nuñez**): *Positional Offsets between SiO Masers in Evolved Stars and their Cross-matched Counterparts*, 2018, The Astrophysical Journal, Volume 868, Issue 1, article id. 72

J. F. Radcliffe, M. A. Garrett, T. W. B. Muxlow, *et al.* (including **A. Keimpema**, **R. M. Campbell**): N*owhere to Hide: Radio-faint AGN in GOODS-N field. I. Initial catalogue and radio properties*, 2018, Astronomy and Astrophysics, 619, A26

B. Marcote, M. Ribó, J. M. Paredes, *et al.*: *Refining the origins of the gamma-ray binary 1FGL J1018.6-5856*, 2018, Astronomy and Astrophysics, 619, A26

A. De Rosa, C. Vignali, B. Husemann, *et al.* (including **Z. Paragi**): *Disclosing the properties of low-redshift dual AGN through XMM-Newton and SDSS spectroscopy*, 2018, Monthly Notices of the Royal Astronomical Society, 480, 1639-1655

B. Nikolic, **D. Small**, **M. Kettenis**: *Minimal re-computation for exploratory data analysis in astronomy*, 2018, Astronomy and Computing, 25, 133-138

R. Schulz, R. Morganti, K. Nyland, *et al.* (including **Z. Paragi**): *Mapping the neutral atomic hydrogen gas outflow in the restarted radio galaxy 3C 236*, 2018, Astronomy and Astrophysics, 617, A38

M. J. Michalowski, D. Xu, J. Stevens, *et al.* (including **Z. Paragi**): *The second-closest gamma-ray burst: sub-luminous GRB 111005A with no supernova in a super-solar metallicity environment*, 2018, Astronomy and Astrophysics, 616, A169

A. de Angelis, V. Tatischeff, I.A. Grenier, *et al.* (including **B. Marcote**): *Science with e-ASTROGAM. A space mission for MeV-GeV gamma-ray astrophysics*, 2018, Journal of High Energy Astrophysics, 19, 1-106

M. Y. Mao, **J. M. Blanchard**, F. Owen, *et al.* (including **Z. Paragi**): *The first VLBI detection of a spiral DRAGN core*, 2018, Monthly Notices of the Royal Astronomical Society, 478, L99-L104

M. Atemkeng, O. Smirnov, C. Tasse, *et al.* (including **A. Keimpema**, **Z. Paragi**): *Baseline-dependent sampling and windowing for radio interferometry: data compression, field-of-interest shaping, and outer field suppression*, 2018, Monthly Notices of the Royal Astronomical Society, 477, 4511-4523

K. Perger, S. Frey, K. É. Gabányi, *et al.* (including **L. I. Gurvits**, **Z. Paragi**): *Constraining the radio jet proper motion of the high-redshift quasar J2134-0419 at z = 4.3*, 2018, Monthly Notices of the Royal Astronomical Society, 477, 1065-1070

T. P. McCarthy, S. P. Ellingsen, M. A. Voronkov, **G. Cimò**: *The relationship between Class I and Class II methanol masers at high angular resolution*, 2018, Monthly Notices of the Royal Astronomical Society, 477, 507-524

G. C. Bower, R. Rao, M. Krips, *et al.* (including **H. J. van Langevelde**, **Z. Paragi**): *A Search for Molecular Gas in the Host Galaxy of FRB 121102*, 2018, The Astronomical Journal, 155, 227

S. Nösel, R. Sharma, M. Massi, *et al.* (including **G. Cimò**): *Hour time-scale QPOs in the X-ray and radio emission of LS I +61°303*, 2018, Monthly Notices of the Royal Astronomical Society, 476, 2516-2521

N. Gupta, R. Srianand, J. S. Farnes, *et al.* (including **Z. Paragi**): *Revealing H I gas in emission and absorption on pc to kpc scales in a galaxy at z ˜ 0.017*, 2018, Monthly Notices of the Royal Astronomical Society, 476, 2432-2445

Z. Li, J. Yang, T. An, *et al.* (including **Z. Paragi**): R*evealing two radio-active galactic nuclei extremely near PSR J0437-4715*, 2018, Monthly Notices of the Royal Astronomical Society, 476, 399-406

A. M. Kutkin, I. N. Pashchenko, M. M. Lisakov, *et al.* (including **L. I. Gurvits**): T*he extreme blazar AO 0235+164 as seen by extensive ground and space radio observations*, 2018, Monthly Notices of the Royal Astronomical Society, 475, 4994-5009

L. Chen, A. Aminaei, **L. I. Gurvits**, *et al.*: *Antenna design and implementation for the future space Ultra-Long wavelength radio telescope*, 2018, Experimental Astronomy, 45, 231-253

S. V. Pilipenko, Y. Y. Kovalev, A. S. Andrianov, *et al.* (including **G. Cimò**, **L. I. Gurvits**): *The high brightness temperature of B0529+483 revealed by RadioAstron and implications for interstellar scattering*, 2018, Monthly Notices of the Royal Astronomical Society, 474, 3523-3534

V. Dehant, **L. I. Gurvits**, M. Kramer, *et al.*: *Editorial to the Topical Collection on High Performance Clocks with Special Emphasis on Geodesy and Geophysics and Applications to Other Bodies of the Solar System*, 2018, Space Science Reviews, 214, 24

B. Lankhaar, W. Vlemmings, G. Surcis, *et al.* (including **H. J. van Langevelde**): *Characterization of methanol as a magnetic field tracer in star-forming regions*, 2018, Nature Astronomy, 2, 145-150

D. Michilli, A. Seymour, J. W. T. Hessels, *et al.* (including **B. Marcote**, **Z. Paragi**): A*n extreme magneto-ionic environment associated with the fast radio burst source FRB 121102*, 2018, Nature, 553, 182-185

Y. W. Wu, N. Matsunaga, **R. A. Burns**, B. Zhang: *SiO maser survey towards off-plane O-rich AGBs around the orbital plane of the Sagittarius stellar stream*, 2018, Monthly Notices of the Royal Astronomical Society, 473, 3325-3350

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09 ACRONYMS AND ABBREVIATIONS

AENEAS	Association for European NanoElectronics ActivitieS
AGB	Asymptotic Giant Branch
AGN	Active Galactic Nuclei
ALMA	Atacama Large Millimeter/submillimetre Array
ASTERICS	Astronomy ESFRI & Research Infrastructure Cluster
ASTRON	Netherlands Institute for Radio Astronomy, the Netherlands
BRAND EVN	BroadBAND EVN
CAP	Communicating Astronomy with the Public
CBD	Council Board of Directors
CASA	Common Astronomy Software Applications
CDR	Critical Design Review
CERN	Conseil européen pour la recherche nucléair European Organisation for Nuclear Research
CM	Centimetre
CNRS	Centre National de la Recherche Scientifique National Center for Scientific Research, France
COTS	Commercial off-the-shelf
CWDM	Course Wavelength Division Multiplexing
DARA	Development in Africa with Radio Astronomy
DBBC	Digital Base Band Converter
EC	European Commission
Ef	Effelsberg station, Germany
e-EVN	electronic European VLBI Network
e-MERLIN	enhanced Multi-Element Radio Linked Interferometer Network
EOSC	European Open Science Cloud
ERIC	European Research Infrastructure Consortium
ESA	European Space Agency
ESCAPE	European Science Cluster of Astronomy and Particle physics ESFRI research infrastructure
ESFRI	European Strategy Foum on Research Infrastructures
ESO	European Southern Observatory
e-VLBI	electronic Very Long Baseline Interferometry
EVN	European VLBI Network
EWASS	European Week of Astronomy and Space Science
FITS	Flexible Imaging Transport System
FRB	Fast Radio Burst
Gb	Gigabit
Gbps	Gigabit per second
GHz	Gigahertz
GPS	Global Positioning System
GPU	Graphical Processing Unit
GRB	Gamma Ray Burst
GW	Gravitational Wave
Hh	Hartebeesthoek station, South Africa
HOPS	Haystack Observatory Processing Suite
IGN	Instituto Geográfico Nacional National Geographic Institute, Spain
INAF	Instituto Nazionale di Astrofisica Italian National Institute of Astrophysics, Italy
IRA	Istituo di Radio Astronomia Institute of Radio Astronomy, Italy
JIVE	Joint Institute for VLBI ERIC
JUICE	JUpiter ICy satellites Explorer
JUMPING JIVE	Joining up Users for the Maximising the Profile, the Innovation and the Necessary Globalisation of JIVE
KAT	Karoo Array Telescope
LBA	Long Baseline Array, Australia
LIGO	Laser Interferometer Gravitational-Wave Observatory
LOFAR	Low Frequency Array
Maser	Maser amplification through simulated emission of radiation
Mbps	Megabit per second
Me	Meerkat dish, South Africa
MHz	Megahertz
MNRAS	Monthly Notices of the Astronomical Society
MPIfR	Max Planck Institute for Radio Astronomy
MT	Management Team
NAOC	National Astronomical Observatories of China
NASA	National Aeronautics and Space Administration
NL	The Netherlands
NME	Network Monitoring Experiment
NRF	National Research Foundation
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek Netherlands Organisation for Scientific Research, the Netherlands
OPNT	Optical Positioning Navigation and Timing
PI	Principle Investigator
PN	Planetary Nebula
PRIDE	Planetary Radio Interferometry and Doppler Experiment
pySCHED	python SCHEDuling software
R&D	Research and Development
RINGS	Radio Interferometry Next Generation Software
SaDT	Signal and Data Transport
SARAO	South Africa Radio Astronomy Observatory
SAT	Synchronisation And Timing
SCHED	VLBI Scheduling software
SFXC	EVN Software Correlator
SKA	Square Kilometre Array
SKA-NL	Square Kilometre Array Netherlands
SNR	SuperNova Remnant

STFC	Science and Technologies Facilities Research Council, United Kingdom
TB	Terabyte
TDE	Tidal Disruption Event
ToO	Target of Opportunity
UK	United Kingdom
ULW	Ultra Long Wavelength
USA	The United States of America
UTC	Coordinated Universal Time
VDIF	VLBI Data Interchange Format
VeA	Ventspils Augstskola
	Ventspils University College, Latvia
VLA	Very Large Array, United States of America
VLBA	Very Long Baseline Array, United States of America
VLBI	Very Long Baseline Interferometry
VO	Virtual Observatory
VR	Vetenskapsrådet
	Swedish Research Council, Sweden
WSRT	Westerbork Radio Telescope, the Netherlands
YERAC	Young European Radio Astronomers Conference
Ys	Yebes observatory, Spain

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