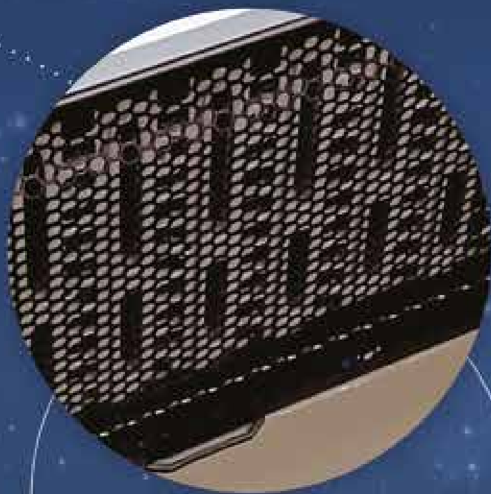
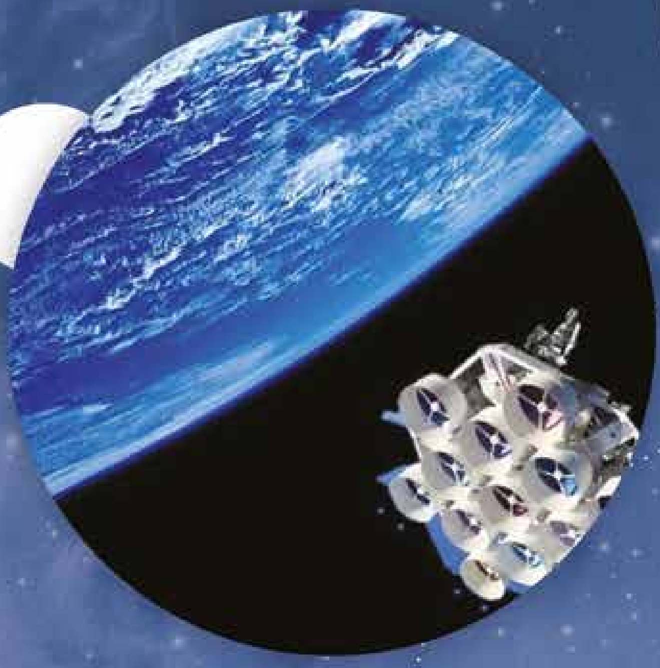
JIVE

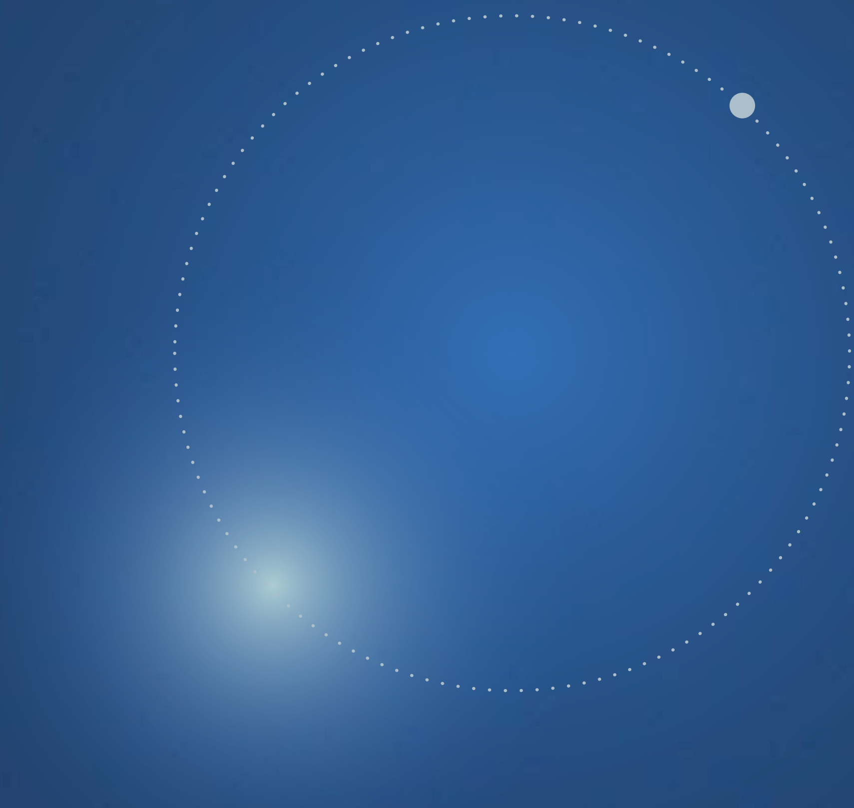
Joint Institute for VLBI ERIC





2022

ANNUAL REPORT



ANNUAL REPORT 2022

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 2022, JIVE had seven members:

— The French Republic: National Centre for Scientific Research (CNRS)
— The Kingdom of the Netherlands: Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) and the Netherlands Institute for Radio Astronomy (ASTRON)
— The Kingdom of Sweden: Swedish Research Council (VR)
— The Republic of Latvia: Ministry of Education and Science of the Republic of Latvia
— The Kingdom of Spain: Instituto Geográfico Nacional (IGN)
— The Kingdom of the United Kingdom of Britain and North Ireland: Science and Technology Facilities Council (STFC)
— The Republic of Italy: National Institute for Astrophysics (INAF)

JIVE was also supported by the following Participating Research Institutes in 2022:

— China: National Astronomical Observatories of China (NAOC)
— South Africa: National Research Foundation (NRF)
— Germany: Max Planck Institute for Radio Astronomy (MPIfR)

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FOREWORD

It is a pleasure to open the 2022 JIVE Annual report. 2022 has been a challenging but very rewarding year. The effects of the COVID-19 pandemic continued to be felt, but JIVE maintained fully successful operations. Towards the end of the year travel and in-person international meetings were again allowed after almost three years of restrictions; it was finally possible to hold the JIVE Council in Dwingeloo in autumn, and JIVE could host the European Radio Interferometry School (ERIS).

Unfortunately the Russian invasion of Ukraine has been a shock for us all, and has severely challenged the VLBI community, and its unique spirit of friendship and collaboration. Operations involving the Quasar antennas were regrettably stopped, with negative implications on the EVN observing array. We all hope that this terrible conflict will soon end, and that the scientific collaboration which underpins the EVN can fully resume.

In the autumn of 2022 the project RADIOBLOCKS was approved by the EC. This is an extremely important achievement, which will ensure coordination and cooperation among several European partners in the technological developments required throughout the European radio astronomical infrastructures to ensure front-rank scientific delivery in the near future.

The amazing scientific results achieved by the EVN, and made possible either by the JIVE scientific and operational staff and resources, cover a broad range of topics. Noteworthy is the localisation of a Fast Radio Burst (FRB) in a nearby spiral galaxy, the closest counterpart found so far. JIVE again played a major role in another major result obtained with EHT, with the imaging of the black hole shadow at the centre of our Galaxy. The image is remarkably similar in form to that of M87, obtained a few years ago, but is associated with a black hole thousands of times less massive. Imaging SgrA* has been much more challenging than M87, and the result shows the potential and strength of the collaboration.

JIVE continued to play an essential part in supporting new telescopes to join the EVN. Most remarkable in 2022 has been the engagement in ensuring VLBI operations with the upgraded GMRT in India, whose first fringes with the EVN were detected at the JIVE correlator. The users' support and training of new generations of radio astronomers remains a key mission of JIVE, and the success of the ERIS school held in person in Dwingeloo, clearly shows the dedication and engagement of the JIVE staff in this role.

At the end of 2022 the appointment of Dr. Francisco Colomer as JIVE Director finished, and part of the year the JIVE Council has been engaged in identifying the new Director of JIVE. We wish to thank Paco Colomer for successfully leading JIVE over the past five years. JIVE has grown a lot under his leadership, strengthening its role in Europe, its ties with the EVN and its major engagement in broadening the EVN array. We congratulate the new Director, Dr. Agnieszka (Aga) Słowikowska, to whom the Council ensures support and faithful collaboration. Aga was previously the Deputy Director at the Torun radio observatory in Poland, one of the long-standing EVN partners.

I would like to underline that the success of the EVN and JIVE operations relies on the dedication of the personnel at JIVE and at each of the participating EVN telescopes. On behalf of the JIVE Council and its representatives I wish to thank all the JIVE staff for their commitment and competence, and for generously working in the interest of the whole VLBI community. I personally wish to thank the JIVE partners for their support during my Chairmanship.

Tiziana Venturi
JIVE Council Chairperson

Introduction

01

1.1 JIVE MISSION

The Joint Institute for VLBI ERIC (JIVE) was established to support, progress, and promote Very Long Baseline Interferometry (VLBI) use. VLBI is a technique in which radio telescopes hundreds to thousands of kilometers apart simultaneously observe the same radio source in the sky. The telescope observations 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 the positions of bright radio sources with very high accuracy.

In Europe, VLBI is organised through the European VLBI Network (EVN), a consortium that includes members from other continents. JIVE hosts the correlator that provides the central data processing for the EVN and supports most interactions with the astronomers who use the facility. The EVN is an open-sky facility which accepts observation proposals from anyone.

JIVE receives the data from the telescope stations as computer hard disk recordings, offline download, 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. The final user product includes calibration data and images from a standard data pipeline.

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 observing modes by investigating new methods to record and transport data to enhance the research infrastructure’s sensitivity and flexibility. Novel data processing techniques and platforms are also explored. JIVE engineers work on various user interfaces, such as the software astronomers use to schedule their observations and process their data. In addition, JIVE has considerable expertise in deploying VLBI for space applications.

The JIVE staff members also perform scientific research in several exciting areas, from active galactic nuclei at cosmological distances to star evolution in the Galaxy, which is essential to maintain appropriate expertise and provide excellent service to EVN stations and users.

JIVE has developed a reputation for fostering coordination, innovation and capacity building for European and global VLBI. As a central entity in the EVN and through its status as an ERIC, JIVE can share these qualities with multiple institutes and European Commission (EC) projects.

1.2 JIVE IN 2022

One of the main events of 2022 was the relaxation of the COVID-19 pandemic-related restrictions in the Netherlands. With no formal rules agreed upon for coming back to the office and a continually changing situation, the process of returning to the office was flexibly applied in negotiation with individual staff members.

By the end of 2022, many staff had adopted a routine. However, it was clear that a new balance was needed between ’working from home’ and ’working from the office’. JIVE currently follows the guidance from the Dutch government to allow more flexible working patterns, and discussions continue, both within and outside of JIVE, on hybrid working practices.

2022 was an excellent year for VLBI science. JIVE facilitated several great EVN results, furthering our understanding of Fast Radio Bursts (FRBs). Surprisingly, Kirsten *et al.* (2022) localised a repeating FRB to a globular cluster in M81, challenging the indications from previous findings that FRBs are connected to young stellar populations. The same FRB was studied by Nimmo et al. (2022) at extremely high time resolution, which provided additional clues to the origin of this source. JIVE scientists have also been leading research with other instruments, resulting in publications in high-profile journals. Murthy et al. (2022) demonstrated that low-power jets could deplete the innermost regions of a galaxy of cold molecular gas, suppressing star formation. The JIVE EHT group continued working on results obtained with the Event Horizon Telescope, which included the widely publicised first image of the massive black hole, Sagittarius A*, at the centre of the Milky Way.

JIVE organised, jointly with ASTRON, the European Radio Interferometry School (ERIS), which attracted seventy-two students from across the world. This highly successful series of schools, supported by the OPTICON-RadioNet Pilot program, train the next generation of radio astronomers. In addition, JIVE organised the Users' Meeting at the EVN Symposium in Cork. Both were opportunities for in-person meetings and networking following a long period of travel restrictions. However, in 2022 JIVE was also able to coordinate the first-ever online EVN users training session to support first-time network users.

The Technical Operations/R&D staff concluded the work on the ESCAPE project, resulting in a coherent set of tools: a JupyterCASA kernel published in the Open Source software and Services Repository, enabling Jupyter-notebook based radio (VLBI) data reduction using CASA, and making the data in the EVN Archive findable and downloadable using virtual Observatory queries and protocols. A science platform built on JupyterHub combines all of these to provide easy federated access for users to compute, network, and storage resources at JIVE, significantly lowering the entry barrier for EVN data processing.

At the beginning of the year, a one PetaByte storage element, funded jointly by four EVN stations, was added to the pool at JIVE. Expanding the group with a new hire resulted in more frequent maintenance, and monitoring could begin. Work on the ORP-PILOT Joint Activity 2.2 (Time domain, multi-frequency, multi-facility access) progressed, demonstrating the technical possibility of providing deeper integration between modern, optical astronomy targeted platforms such as Las Cumbres' Target and Observation Manager system and, initially, the VLBI specific scheduling software package SCHED. Furthermore, several improvements to the VLBI support in the Common Astronomy Software Applications software package (CASA) were worked on and, a high point was that a CASA VLBI paper was published, coordinated with the National Radio Astronomy Observatory (NRAO). This served as a companion to the CASA reference paper and described the result of those past efforts and verification through an in-depth comparison of the results of the Astronomical Imaging Processing Software (AIPS) vs CASA-based calibration workflows. The publication concludes that the workflows are equal for all practical purposes.

JIVE's multidisciplinary collaborations in space applications continued to generate interest, facilitating the creation of novel uses of VLBI and expanding its traditional community of users and researchers. The efforts towards near-field VLBI applications have accelerated in preparation for the ESA's JUICE mission, which is set to explore the Jovian system and its icy moons with a JIVE-led experiment that will provide high-precision measurements of the spacecraft's position and velocity using VLBI observations. The crucial role of JIVE in space innovations culminated with the organisation of the Space-VLBI Workshop in Dwingeloo, where the community met to discuss the future of high-resolution radio interferometry

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Figure 1.1: JIVE Gender Equality plan

in space as a natural extension of advanced existing and prospective Earth-based facilities.

The growth in the overall EVN observing and correlation load continued to expand in 2022, setting new records for the number of network hours (1121, 7.3% higher than the previous record from 2021) and the number of user observations (152, 17.8% higher than the previous record from 2019). Correlation included a new record for the largest set of FITS files from a single observation at 17.9 TB. Fourteen first-time PIs received support, including from non-EVN countries such as Ireland, Belgium, and Israel (exactly one-third of the PIs with observations in 2022 were first-time PIs).

JIVE organised test observations for telescopes that could potentially join in future EVN sessions, including two more tests of the 500m FAST telescope (China), and the first three tests including uGMRT with other EVN antennas, with fringes seen in correlation at JIVE.

In 2022, JIVE published its Gender Equality Plan (GEP) as part of its commitment to promoting gender equality within its workforce and advocating for its importance in the broader context of equality, diversity and inclusion in research infrastructures. The GEP is a tool for sustainable change towards a fairer, safer, and more transparent work environment. It includes an analysis of the current state of actions in place, results of a gender equality survey amongst JIVE employees, and an action plan to address issues highlighted by those assessments. The GEP will be regularly updated based on repeated audits to ensure its continued relevance and effectiveness. The whole plan can be accessed online at: https://www.jive.eu/resources/gender-equality-plan.

1.3 PERSONNEL

JIVE is organised into four departments (Science Operations, User Support, Technical Operations and R&D, Space Science and Innovative Applications) plus a Coordination and Support Office that assists and facilitates the running of JIVE.

In 2022 Prof. Leonid Gurvits retired as the Head of Space Science & Innovative Applications Group at JIVE. Gurvits has had an extremely successful career in radio astronomy and space science and has pioneered many projects and collaborations while at JIVE. He continues to share his expertise as 'Senior Astronomer Emeritus' and Dr. Giuseppe Cimo will adopt the position of Interim Head of the Space Science and Innovative Applications Group.

At the end of the year, the Communications Officer, Dr Jorge Rivero González, left JIVE to take up a position as Head of Communications and Outreach at the Institute of Space Sciences in Spain. His position will be filled in due course.

Support scientists Dr Olga Bayandina and Dr Dhanya Nair left JIVE to pursue new roles: Dr Dhanya Nair moved to the University of Concepcion in Chile, while Dr Olga Bayandina moved to the Osservatorio di Brera in Italy.

Dr Shivani Bhandari, a JIVE postdoc financed by the AstroFlash project to work on fast radio burst VLBI studies, has received a prestigious NWO VENI fellowship. ASTRON became her primary host, but she retained the JIVE affiliation and her office in our corridors to continue the daily work with JIVE colleagues.

It was great to be part of Prof. Leonid I. Gurvits' retirement event this week at JIVE in Dwingeloo, NL - on behalf of all his friends and colleagues at Jodrell Bank Centre for Astrophysics (JBCA), we presented Leonid with a specially polished and engraved piece of the original 1957 Lovell Telescope surface (photo courtesy of Giuseppe Cimo, JIVE).

Dr Junghwan Oh joined the Science Operations group. His scientific interests include polarization and jet physics within AGN, and he brings valuable experience in mm-VLBI.

Dr Mas Said, adopted a postdoctoral researcher position as part of the Space Science and Innovative Applications Group.

Wybren Buijs was welcomed back to JIVE in a new role as Linux and Network Specialist in the Technical Operations and Research and Development group.

Notably, 2022 ended with a change of the JIVE

Director. After five years of leading the team, Dr. Francisco Colomer stepped down, to take on the role at the Ministry of Science and Innovation of Spain, as Coordinator for the Spanish Presidency of the Council of the European Union.

The JIVE Council appointed Dr Agnieszka (Aga) Słowikowska as a new director, to start on January 1st, 2023.

Aga Słowikowska was Associate Professor at the Institute of Astronomy, Faculty of Physics, Astronomy and Informatics, NCU (Poland).

For the last three years, she has been the Deputy Director for Research Infrastructure at the Institute of Astronomy NCU.

Among many international responsibilities, she is a member of the European VLBI Network Consortium Board of Directors and is the Board Chair of the Opticon RadioNet Pilot project.

Francisco (Paco) Colomer and Agnieszka (Aga) Słowikowska

KEY FIGURES

7
Member Countries

3
Participating Research Institutes

25
JIVE staff

USER EXPERIMENTS CORRELATED

114
Experiments

999
Network Hours

1111
Correlated Hours

2022

179.47
TB of total size user-experiments files in Archive

87
JIVE Staff Publications

3
EC Projects

3
Online EVN Seminars organised

OVER 600,000
People reached with communication activities

Science Highlights

02

2.1 LOW-LUMINOSITY JET SWEEPS COLD GAS FROM THE NUCLEUS OF A GALAXY

When gas falls into the supermassive black hole (SMBH) at the centre of a galaxy, the black hole turns into an active galactic nucleus (AGN). These AGN and the galaxies that host them are believed to affect each other: the AGN, via different processes starve the galaxy of cold gas – the fuel for star formation and thereby inhibit the growth of the galaxy. In radio-loud AGN, those that are prominent in the radio band, the energy from the SMBH is mainly emitted in the form of collimated jets. Traditionally it was believed that only the most powerful radio AGN have a significant impact on their host galaxies.

An international team of astronomers led by Suma Murthy at JIVE discovered, however, that less powerful, low-luminosity radio AGN can also play a major role in shaping the evolution of their host galaxies. In particular, they studied cold molecular gas, via the CO(1—0) transition using the NOrthern Extended Millimetre Array (NOEMA), in a low-luminosity radio AGN (B2 0258+35), hosted by an early-type galaxy (NGC 1125). Here, they found that the radio jets are single-handedly driving a massive outflow of cold molecular gas that consists of about 75% of the gas present in the central few kiloparsec (kpc) of the galaxy with the outflow velocities extending up to 500 km/s. This outflow will deplete the gas in the central region in a short time span of a few million years.

This study unambiguously demonstrates that even the low-luminosity radio sources that make up the vast majority of the radio AGN population are capable of affecting their host galaxies significantly. These findings also confirm the results of the models of radio jet-ISM interaction which had predicted that low power radio jets also carry sufficient energy to drive such massive outflows. Overall, this study suggests that the models of galaxy evolution should also consider this class of radio sources while incorporating the role of AGN in galaxy evolution.

Murthy et al. 2022, Nature Astronomy, 6, 488

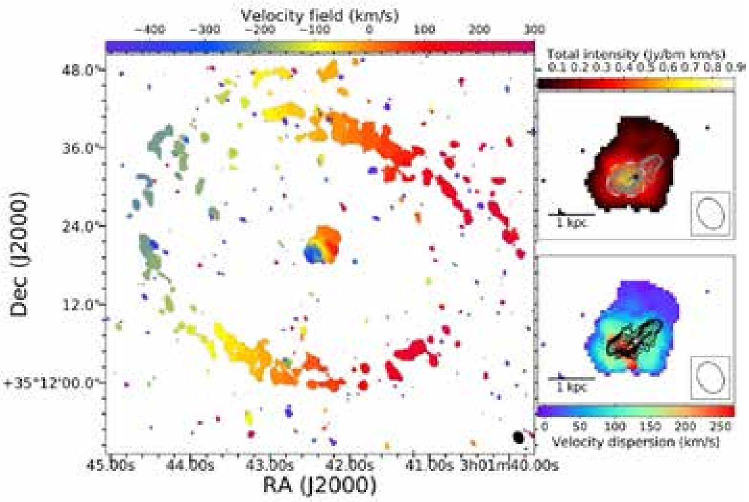


Figure 2.1: The distribution of molecular gas in the central region of NGC 1167. The left panel shows the distribution of velocities of the gas in colour. The large, 10 kpc ring is in regular rotation consistent with the galaxy. The gas structure in the central kpc where the radio jets are is in the form of a massive outflow. The top-right panel shows the radio jets in grey contours and the intensity of the gas in colour, the bottom-right panel shows the dispersion of the gas in colour, with radio jets in black contours. It can be clearly seen that the emission is much brighter (top right panel) and has a high velocity dispersion (bottom-right panel) at the same location where the radio jet shows a sharp bend, indicating that the jets are interacting strongly with the gas.

2.2 RADIO FLASHES FROM AN UNEXPECTED REGION IN SPACE

Fast radio bursts (FRBs) are unpredictable, extremely short flashes of light from space, seen only by radio telescopes. Since their discovery in 2007, FRBs have been a mystery, with each flash lasting only thousandths of a second. Yet, every flash emits as much energy as the Sun does during a whole day. Several hundred flashes occur every day, and they have been recorded in all regions of the sky. Most lie at huge distances from Earth, in galaxies billions of light years away, making it difficult to ascertain what the progenitors of FRBs are. The PRECISE project seeks to study FRBs and their immediate environments in detail. It was initiated by Franz Kirsten (Onsala Space Observatory, Sweden), and is jointly executed by scientists from the University of Amsterdam, JIVE, and VLBI experts from EVN observatories.

Using twelve EVN antennas, the bursts of FRB 20200120E were localised to the outskirts of the nearby spiral galaxy Messier 81 (M 81), about 12 million light years away. This is the closest ever detection of a source of fast radio bursts. The location matched exactly that of a globular cluster associated with M81, pointing to an origin in a very old stellar population. Previously, FRBs have been found in places where stars are much younger. Magnetars are neutron stars with powerful magnetic fields, and the prime suspects as progenitors of FRBs. Magnetars are also thought to be young, with a natural formation channel through the explosion of young stars. It was not expected to find them in areas surrounded by old stars. It is possible that the FRB source in M81 is a magnetar that formed when an old star, a white dwarf, became massive enough to collapse under its own weight.

In a project led by Kenzie Nimmo (UvA/API and Astron, Netherlands), the same bursts have also been studied at the highest frequency and time resolution thanks to the advanced capabilities of the JIVE SFXC software correlator. This revealed that some of the bursts were even shorter than expected. They flickered in brightness within as little as a few tens of nanoseconds. This indicates that they must be coming from a tiny volume in space, perhaps only tens of meters across. Some of these bursts have been extremely powerful, too. This is very similar to what is seen in the Crab pulsar, where 'giant pulses' are regularly witnessed. The observation further supports a magnetar scenario. However, magnetars have not been found inside a globular cluster, or other environments like this before. Future observations of this system and others will help to tell whether the source really is a magnetar, or another candidate, such as an unusual pulsar, a black hole or a dense star in a close orbit.

Kirsten et al. 2022, Nature, 602, 585
Nimmo et al. 2022, Nature Astronomy, 6, 393

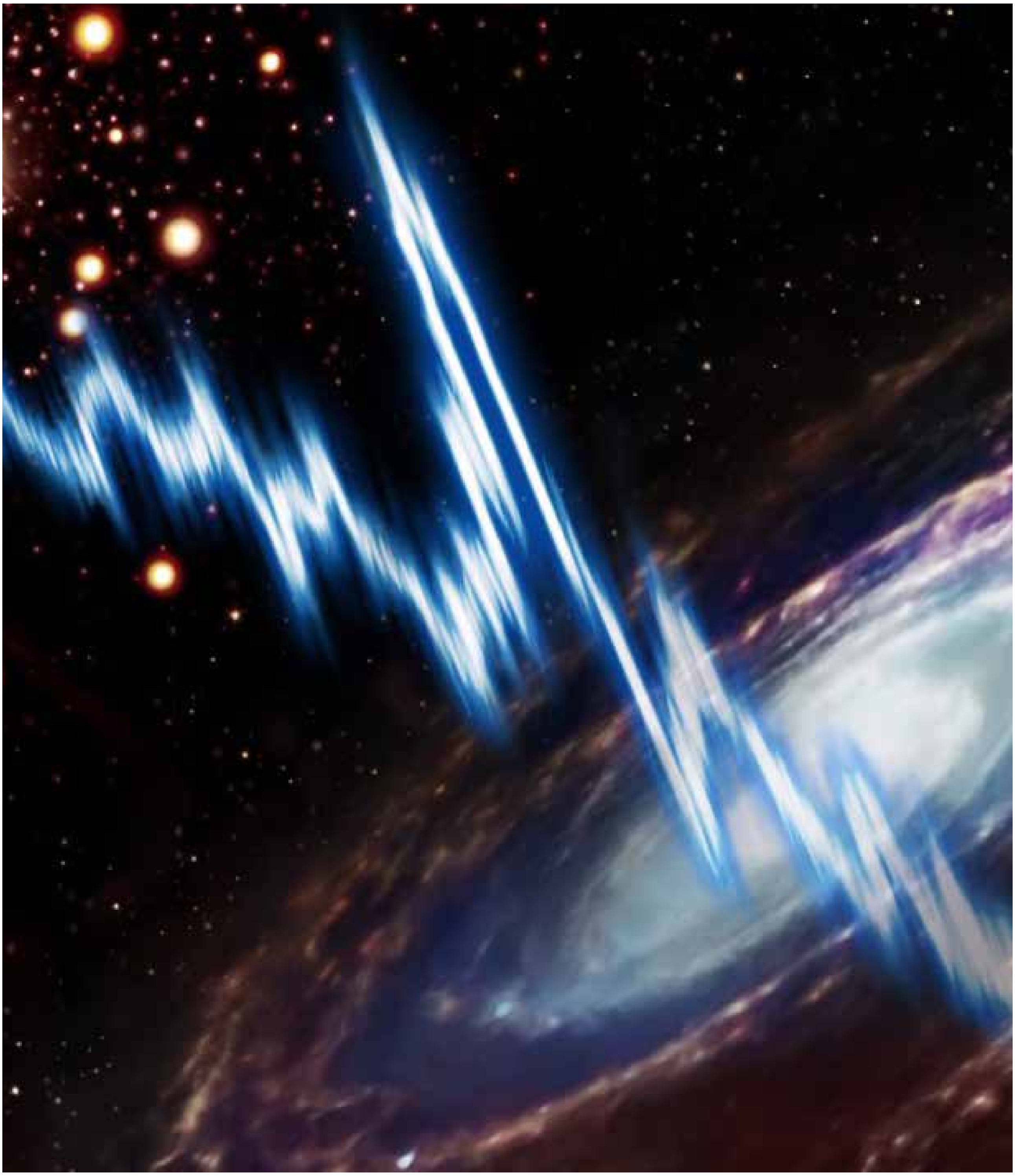


Figure 2.2: The EVN detected extremely fast radio signals from a globular cluster in M81. Both the environment (old stellar population) and the very high time resolution studies of the bursts provide clues on FRB progenitors and their formation. Image credit: Daniëlle Futselaar/ASTRON, artsource.nl.

2.3 MILKY WAY CENTRAL MASSIVE BLACK HOLE REVEALED

The Event Horizon Telescope (EHT) Collaboration unveiled the first image of the supermassive black hole at the centre of our own Milky Way galaxy, Sagittarius A* (Sgr A*). This result provides overwhelming evidence that the object observed is indeed a black hole and yields valuable clues about the workings of such monsters, which are thought to reside at the centre of most galaxies. The EHT Collaboration is comprised of researchers from all over the world, including from JIVE and other institutes in the Netherlands. The image was unveiled by JIVE Chief Scientist and EHT Project Director Prof. Huib Jan van Langevelde at the European Southern Observatory Headquarters in Garching (Germany), during one of the simultaneous international press conferences.

It is not possible to 'see' the black hole itself, but glowing gas around it reveals a tell-tale signature: a dark central region (called a 'shadow') surrounded by a bright, ring-like structure. The new view captures light bent by the powerful gravity of the black hole, which is four million times more massive than our Sun. The black hole is about 27,000 light-years away from Earth, and to image it, the team linked together eight existing radio observatories that work at very high radio frequencies – collectively known as the Event Horizon Telescope (EHT). Together the telescopes observed Sgr A* on multiple nights, collecting data for many hours in a row.

The breakthrough follows the EHT collaboration's 2019 release of the first image of the supermassive black hole Messier 87* (M87*), in the galaxy Messier 87. The two black holes look remarkably similar, even though the black hole at the centre of the Milky Way is more than a thousand times smaller and less massive than M87*. Despite being closer to Earth, imaging Sgr A* was a more difficult task. The gas in the vicinity of the black holes moves at the same speed — nearly as fast as light — around both Sgr A* and M87*. Yet, where gas takes days to weeks to orbit the larger M87*, in the much smaller Sgr A* it completes an orbit in mere minutes. This means that the brightness and pattern of the gas around Sgr A* was changing rapidly as the EHT Collaboration was observing it. M87* had provided a steadier target with nearly all images looking the same. But for Sgr A* the team had to develop sophisticated new tools that accounted for the gas movement around Sgr A*. This resulted in the image of the Sgr A* black hole being compiled as an average of the different images the team extracted, to reveal the giant lurking at the centre of our galaxy for the first time.

EHT Collaboration, 2022, Astrophys. J. (special issue), L12-L21

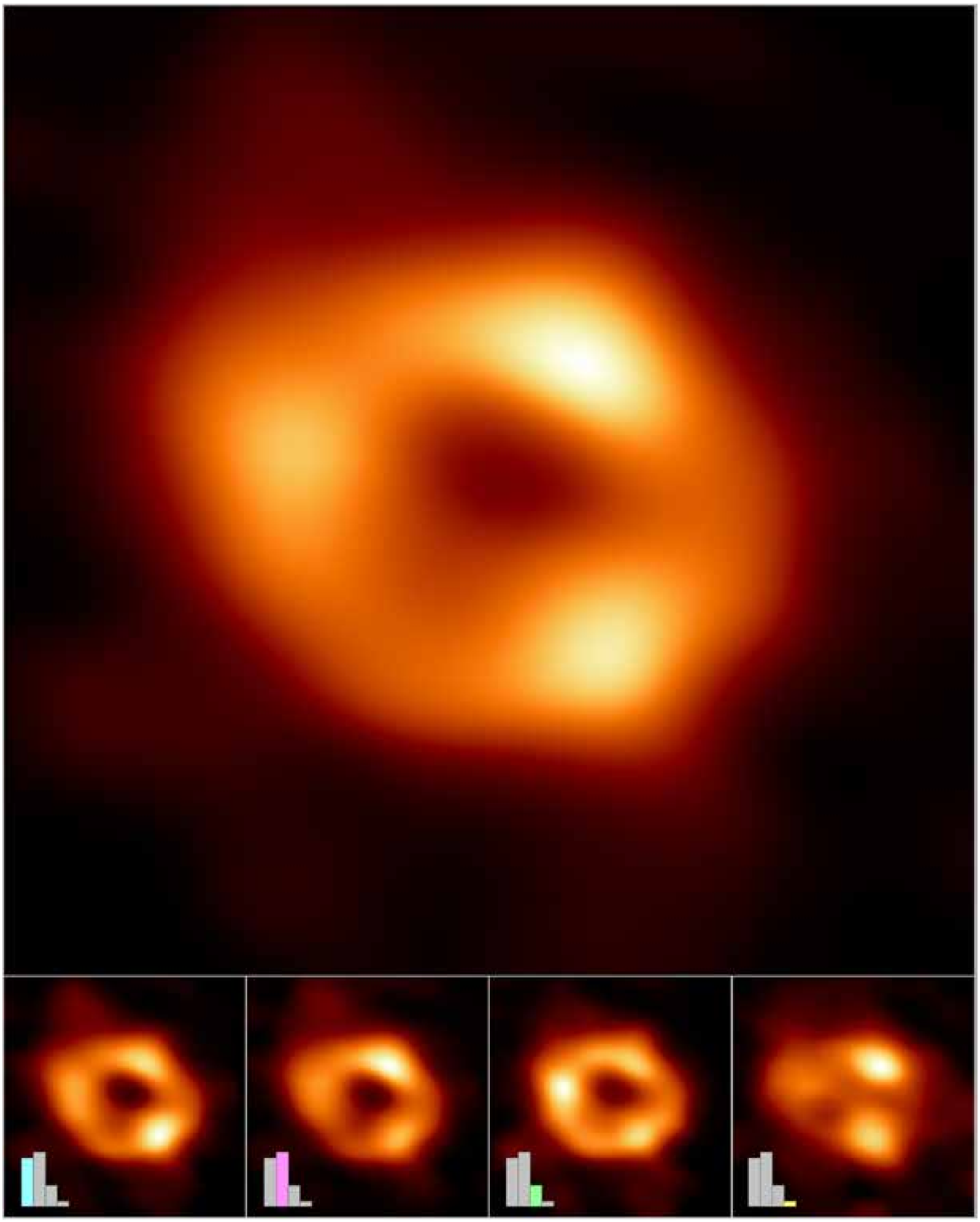
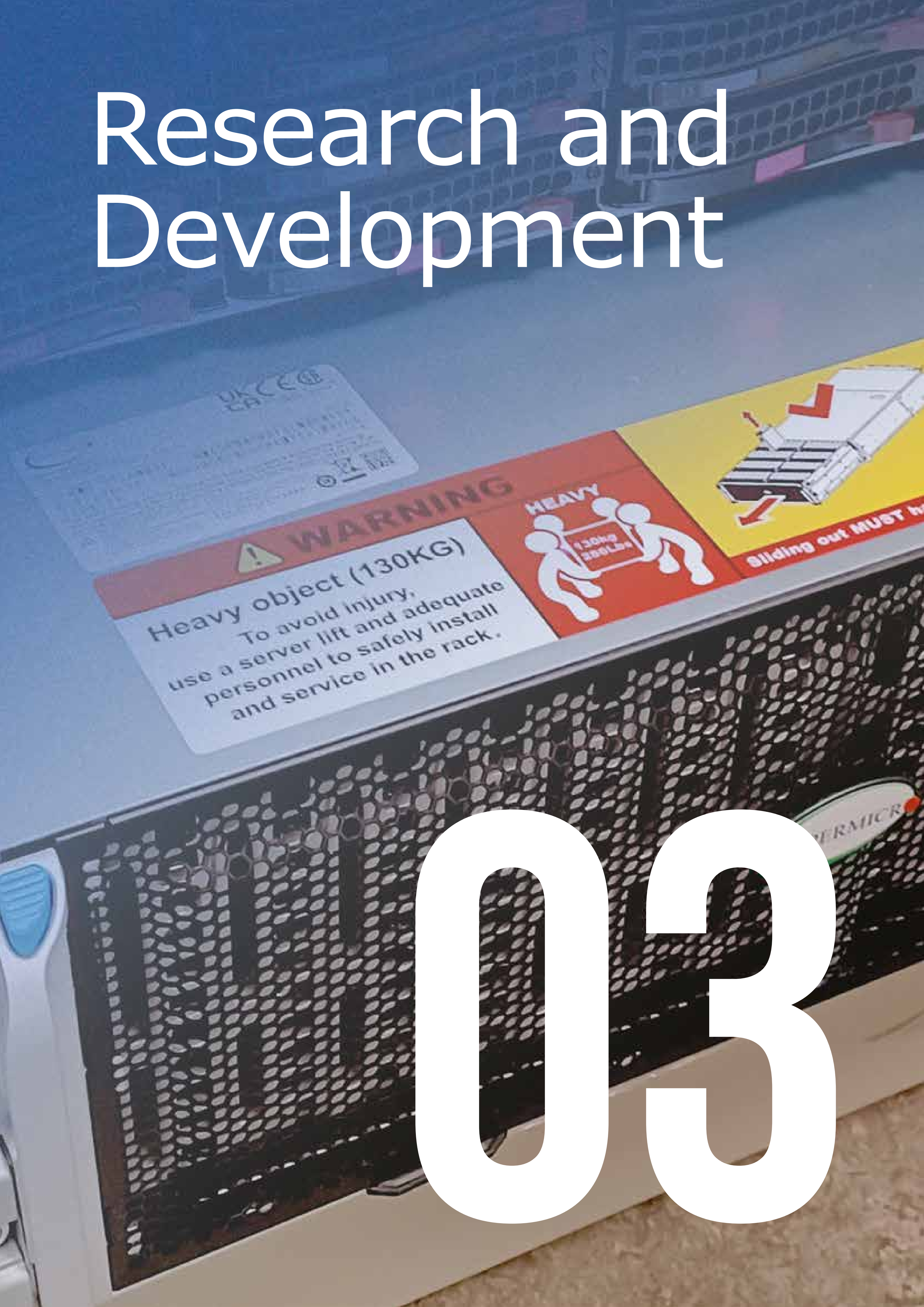


Figure 2.3: EHT images of the Milky Way supermassive black hole Sgr A. The main image (top) is an average of 1000s of images that all fit the data perfectly well. These images can be grouped in four classes (shown below, with the number of images in each class indicated in the bar chart). Credit: EHT Collaboration.*

Research and Development

03



3.1 TECHNICAL OPERATIONS

Starting from the end of March the Dutch government decided to ease the COVID-19 restrictions to a level where return to the office became a reality. By the end of the year the Technical Operations and Research and Development group had settled into a routine where staff spend a minimum of 60% of their time at the office. Whilst no essential functionality was lost or missed during the lockdowns, a reduction in spontaneous hallway and in-person discussions had an obvious effect on sparking interest, sharing solutions, and feature request and development. The subsequent combination of in-person presence at the office, and ‘working from home’ to focus on specific tasks or improve work-life balance appears to work out well for the group.

The advertised Linux-/Network specialist position was successfully filled; a suitable candidate accepted the offer that was made. The (re)hire started work at JIVE on June 1st with the Technical Operations / R&D group.

3.1.1 HARDWARE

Twenty-three of the twenty-four Mark5 recording units at JIVE remain operational. One unit was discontinued and some of its parts used as spares for other units.

The EVN storage pool at JIVE now holds approximately 6 PB of online storage. The hardware and disks for the 'PetaBuff', a 90-bay FlexBuff system funded by Noto, Medicina (INAF), Sardinia (INAF-OA) and Onsala (Chalmers), arrived in May and added 1 PB to the pool shortly thereafter (Fig 3.1).

Kunming (Yunnan Observatories) donated a full Mark6 unit consisting of a Mark6, expander chassis, and four disk packs with six 14 TB disks each. The unit was reconfigured as a FlexBuff system, adding a further 270 TB to the storage pool. JIVE, as a recognised international organization as per Dutch tax law, is exempt of VAT duties when importing equipment from outside the EU into the Netherlands. Before 2019 negotiations with Yunnan Observatory staff on details of the donation and planning of the shipment were started. The actual shipment and execution of the administrative procedure resulted in the arrival of the unit at JIVE on 24 October 2022.

The delay was only partially the result of COVID restrictions; the execution of the administrative procedure requires arranging the shipment and its arrival, with JIVE staff being available to travel in person to Den Haag to get the proper Customs form stamped within the short time window it is valid for. It is expected that the same procedure can be used for future donations from the UK and other non-EU EVN/JIVE members.

In 2022 a total of 31 failed FlexBuff hard disks were replaced of which only two remained under warranty. This was not surprising given the age that previously donated FlexBuffs are reaching. Starting from 2022, a more systematic bookkeeping of failing and replaced FlexBuff hard disks was started. This allows for more detailed information to be extracted, as can be seen in Fig 3.2.

The – very cheap - brandless fiber optic modules purchased from FiberStore were sent in for repair and were returned only after several months. It transpired that FiberStore had sent new units instead of repairing them. Several (more expensive) modules were purchased from a

Replaced HDDs	**Warranty**		
Year	**no**	**yes**	**total**
2022	29	2	31

Table 3.1: Table of 2022 Hard Drive Disks (HDD) replacement under warranty

Figure 3.1: The shared PetaBuff is larger than the standard FlexBuff chassis;

The Kunming Mark6 arrives at JIVE.

different supplier to guarantee connectivity whilst waiting for the original FiberStore modules to be returned.

The Virtual Machine infrastructure for running most of JIVEs internal and external services was migrated to a pair of new hosts; the existing pair cl0/1 were retired, almost five years after their warranty had already expired in 2018.

JIVE staff spent time helping to finalise ASTRON's network redesign and migration onto the shared redundant 2x100 Gbps SURFnet connection.

Following the purchase and installation of an LTO-8 tape drive last year, the backup software was updated to support archiving onto the LTO-8 system data from three separate subsystems (the EVN Archive, raw correlator output, and the backup server). Subsequently the process of re-spooling LTO-[345] tapes was begun.

To work towards its Green Deal goals JIVE started to critically investigate its power consumption. Monitoring of this has already been in place for some time and looking at the daily graph of electricity use in Fig 3.2, several observations can be made. The most striking feature seems to be that the daily power consumption is very stable over the year - including weekends.

Specifically, the day with the highest power consumption is on a weekend. This is because operators sometimes let demanding jobs run over the weekend (such as multiple phase centre correlations or globals), but normally correlation does not occur over the weekend. Clearly visible are the few days when the building's cooling system was shut down in March and April, causing a complete shutdown of the compute and storage clusters at JIVE. The implication of the stable power consumption, almost irrespective of correlation workload, is that the only way to substantially bring down the power consumption is to switch equipment off when it is not used. Whether this is feasible in practice and not actually harmful for the equipment are questions whose answers will be investigated. A simple test was performed to switch off all twenty-three Mark5 and three Mark6 units, which brought down the power consumption by ~5kW. At the current electricity price that would equal a saving of 17k€ per annum. However, when shut down it is impossible to correlate. Therefore, this number should be interpreted as worst case operating cost - i.e. all units ready-for-production 24/7/365 -, or, alternatively interpreted as the maximum possible savings on an annual basis for this part of the equipment.

The upgrade of the cluster nodes and FlexBuffs to a newer operating system was started; the current setup was based on a 2014 edition. Many configuration and security options were updated or added in the newer version and required significant effort to find the settings to produce a working cluster environment for the complex software setup.

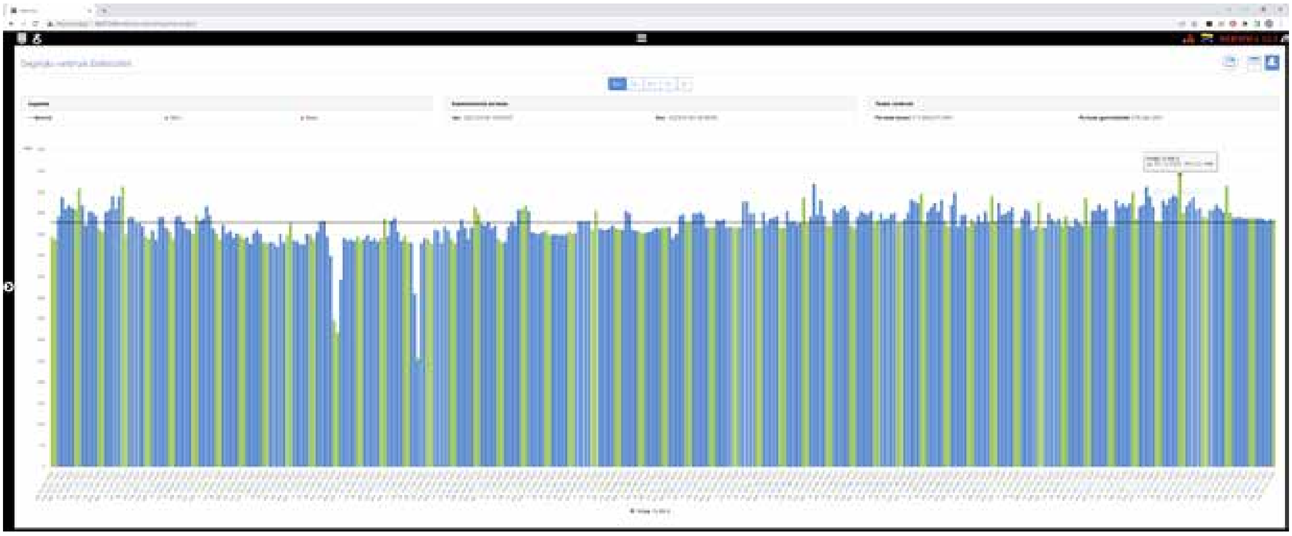


Figure 3.2: 2022 daily power consumption of the compute and storage cluster.

The ageing, by now very old, SFXC cluster physical 'head' nodes (named 'head' and 'tail') were retired and replaced by virtual machine (VM) instances on the VM cluster. The new VM cluster is powerful enough to allow the 'cluster head node' functionality to be run there, and, at the same time, removes the need for a physical duplicate backup and development environment because of having moved to a virtualised infrastructure anyway.

Cyber security is an area that requires a lot more attention than a decade ago. To address this a process of improving overall security measures was started and several simple restrictions were rolled out using the local Ansible centralised configuration solution setup for automation. More systems were onboarded onto this system, as well as adding more configuration options.

This effort not only allows immediately improved centralised system administration but is also a precursor towards supporting the planned migration of all compute- and storage nodes and general servers in our production environment to a different (newer, more secure) operating system distribution.

3.1.2 SOFTWARE

The correlator control software (> 30k lines of code (LOC) in twelve modules) was updated from Python2 to Python3, resulting in a necessary update from Python bindings PyQt4 to PyQt5.

The previously developed publications database and interface (PapersDB) to link the EVN Archive data with publications, was restyled, and its backend upgraded to automatically handle replacements, for example, when a publication moves from an arXiv preprint to being published in a refereed journal. Following a request from an EVN station - "Do you have a list of publications in year 2020 where our station (Toruń) contributed to the observations?" - a URL based query interface to the database was developed to allow any station to query the database for any year of interest by themselves. To access publications using data from station Toruń in 2020, the URL would read:

https://services.jive.eu/Papers/station/Tr/2020

Accessing this URL results in a webpage (see Fig 3.3) showing a list of publications, with cited EVN observations that Toruń participated in. By replacing the station code (case insensitive) and/or the year the corresponding results can be extracted from PapersDB.

Figure 3.3: Screenshot of the dynamically generated web page based on the URL "query parameters" Tr and 2020.

Considerations made to address cyber security, highlighted the risk that the old.evlbi.org server needs to be decommissioned. This server currently runs the EVN Feedback utility where stations provide station specific feedback on EVN experiments that is relevant for the support scientists at JIVE, and/or the experiment's Principal Investigator (PI) when calibrating or analysing the correlated data. It was discovered that the code of that webservice dates from approximately fifteen years ago and due to lack of resources for maintenance contains unacceptable security risks. Therefore, the code cannot be just migrated to a new web server. A pilot project was concluded that demonstrates that a Mattermost plugin ('bot') for the https://coms.evlbi.org instance can be developed, which stations can then use to provide feedback on experiments. The tool's backend is organised around EVN sessions, based on files prepared by the operations group. Fig 3.4a shows the dialogue displayed; the interface can only be used to insert feedback. To support viewing and editing of feedback after submission a new web-based password protected tool is under development in parallel (Fig. 3.4b). The new system will be proposed to the stations for comments and approval at the EVN Technical Operations Group (TOG) in January 2023.

Some databases and frontends have been set up as experiments, such as the analytics frontend (based on the Grafana application) to the EVN Feedback and statistics, which require continued maintenance and (technical) support. It was agreed that these will be brought under the Technical Operations group's responsibility to ensure ongoing availability. For example, the current Grafana front end needs to be manually run from an interactive terminal, which means the service cannot be rebooted or updated without human interaction. Furthermore, the service will be enrolled under the automatically applied security updates mechanism.

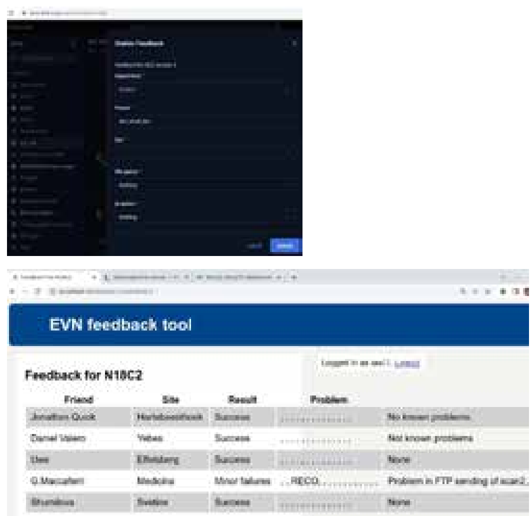


Figure 3.4: Station feedback dialogue in the EVN Mattermost environment (top), web based tool to view and edit feedback (bottom).

Many EVN stations are using DBBC2/FiLa10G for their VLBI data acquisition, including during real-time VLBI observations. The data is then sent from the FiLa10G network interface directly into the software correlator at JIVE. The monitoring of equipment is extremely important during real-time VLBI in order to (quickly) locate or identify root cause(s) of problems, which often result in loss of (science) data.

The e-VLBI monitoring tool for the JIVE operators was updated to extract FiLa10G configuration parameters to help confirm correct configuration and operation of the hardware. Fig 3.5 is a screenshot of the utility displaying what useful diagnostic information can be read out from the FiLa10G subsystem.

The central EVN Monitoring system, resulting from previous work in the JUMPING JIVE project, was improved by editing and adding scripts to make it easier for EVN stations to upload data in general and multiple sample point values at the same time. A user guide was compiled for the EVN stations to document usage and integration of the EVN monitoring system within their own systems.

controlDBBCs.py (on ccs)

	station	status	address	dbbc_proxy	dbbc_reachable	selected_input	input_sample_rate	num_bits_set	frames_per_second
1	Tv	started	150.254.213.90:2630	dbbc_proxy.astro.umk.pl:4000	reachable	vsi1-2	128000000 Hz / 4	32	16000 (32bit@32MHz)
2	Ys	started	none	193.146.252.29:2620	reachable	vsi1-2	128000000 Hz	32	64000 (32bit@128MHz)
3	Hh	stopped	192.168.1.11:46227	192.96.5.247:4218	reachable	tvg	64000000 Hz	32	31250 (32bit@64MHz)
4	Ef	stopped	none	195.37.231.45:4000	reachable	vsi1-2	128000000 Hz / 2	16	16000 (16bit@64MHz)
5	Mh	started	none	dbbcproxy.metsahovi.fi:4000	reachable	vsi1-2	128000000 Hz	32	64000 (32bit@128MHz)
6	Wb	stopped	none	192.168.3.24:5000	reachable	vsi1	128000000 Hz / 2	16	16000 (16bit@64MHz)
7	Nt	stopped	none	192.167.187.103:4000	reachable	vsi1-2	128000000 Hz / 2	16	16000 (16bit@64MHz)
8	Tr	started	none	158.75.6.8:4000	reachable	vsi1-2	128000000 Hz / 4	32	16000 (32bit@32MHz)
9	T6	unknown	unknown	202.127.3.147:4002	unreachable			0	0
10	Sr	unknown	unknown	90.147.132.214:2621	unreachable			0	0

Figure 3.5: screenshot of the utility displaying what useful diagnostic information can be read out from the FiLa10G subsystem.

3.2 RESEARCH & DEVELOPMENT

Efforts were also made to provide feedback on the Giant Metrewave Radio Telescope (GMRT, India) phased-array VDIF formatted output for VLBI compliancy.

In addition, Technical Operations and Research and Development staff participated in EC-funded projects ESCAPE and ORP-PILOT, their contributions are outlined below.

ESCAPE

Without a doubt the most (in)visible result of the European Science Cluster of Astronomy and Particle physics ESFRI research infrastructures (ESCAPE) funded effort at JIVE was the formal addition of the EVN Archive to the Virtual Observatory (VO) ObsTAP-based catalogues in March. From that date, all public data in the EVN Archive can now be found through querying the evn-vo ObsTAP service. This makes the EVN Archive available to VO-compatible GUI-based tools such as Strasbourg Astronomical Data Centre's (CDS) Aladin as shown in Figure 3.6. As well as programmatically, e.g., using the pyvo Python library, as shown in Fig 3.7, allowing for more complex and faster queries against the EVN Archive compared to the current fitsfinder.php search interface on there.

In addition, as part of the ESCAPE project, CASA improvements that were worked on over the course of 2022 resulted in pull-requests ready to be included in a future CASA release, mostly held up by the required external verification/validation process.

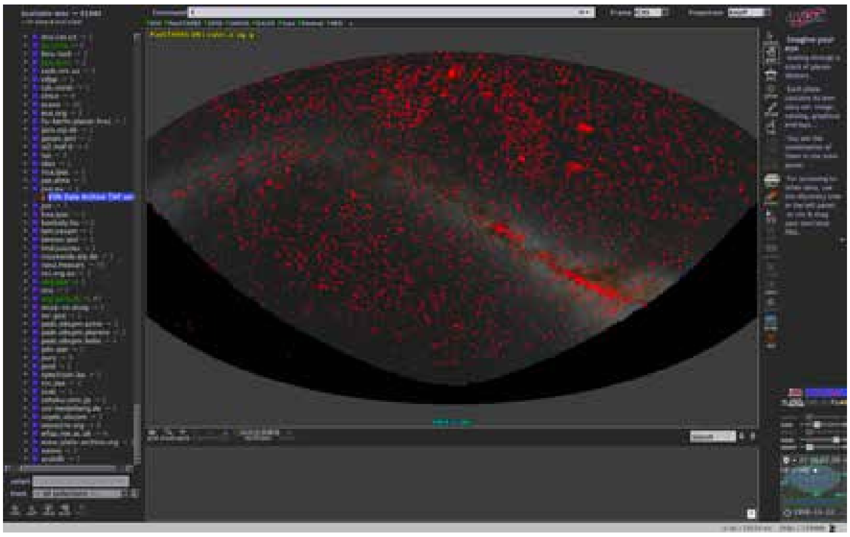


Figure 3.6: The Aladin VO-enabled tool overlaying all public EVN observations on top of the Panoramic Survey Telescope & Rapid Response System data archive (PanStarrs DR1).

A simple user request, to add the (already officially supported) uvrange-parameter to the fringefit task selection parameters, was implemented, documented, and incorporated in v6.5.2. The JupyterCASA image was updated to be based on the latest CASA release whenever a newer version is released, and several support packages were included such as the CASA VLBI tools, AOFlagger and WSClean. Maintenance on the JupyterHub installation was done to keep the system compatible with recent versions of JupyterLab.

The JupyterHub was successfully added to the SURFconext production environment as a public service (https://jupyterhub.jive.eu) offered through federated access using a user's home institute as Identity Provider (if federated with SURFconext). The git-based version control for notebooks JupyterLab plugin was finalised, allowing users to publish specific version(s) of their private notebooks in the public archive.

JIVE staff continued to be involved in the design of the Open-Source software and Service Repository policy and curation process of submissions.

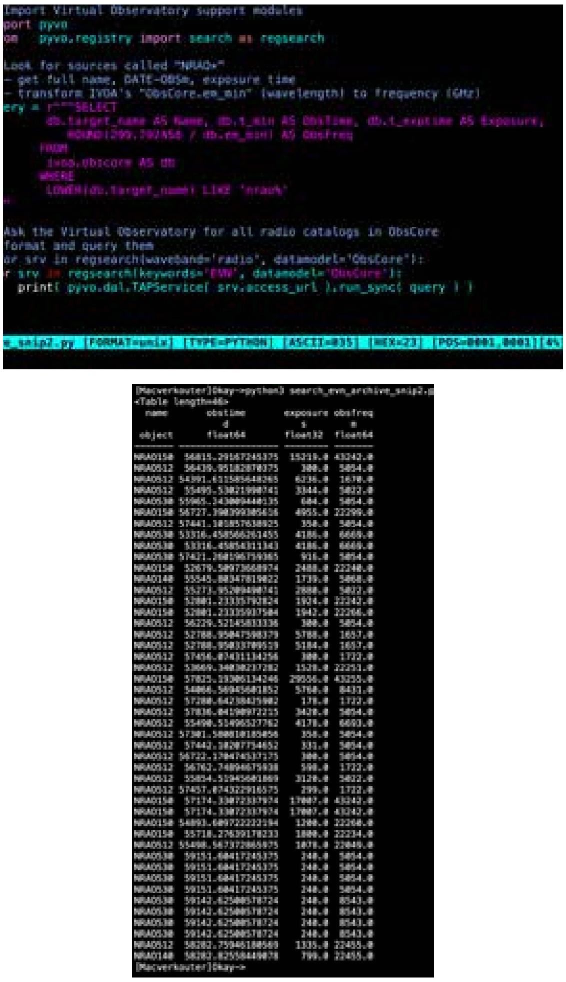


Figure 3.7: A complex query against the EVN Archive from Python (above) and the returned results (right)

ORP-PILOT

The backend for the EVN-TOM Toolkit module was enhanced to include the infrastructure for storing an observation's details, data products, planobs observation planner, and pySCHED.

The combined installation can, given a limited set of observing parameters, such as target position, preferred observing band, and selected stations, automatically generate planobs-based predicted array figures of merit/imaging performance for download and, using pySCHED's templating mechanism, an automatically generated VLBI Experiment description (VEX) file for the observation.

A separate webtool was developed where stations can log in and self-administer availability periods for observing band(s). This allows the frontend EVN-TOM Toolkit module to automatically find time slots with matching observing request station requirements. The generated VEX file(s) are made available in the webtool for download by the stations. The screenshots in Figure 3.8 illustrate a station's self-administration overview and a period where two requested stations have simultaneous availability where the system has scheduled a matching observation request in that period.

Figure 3.8: A station's self-administration of availability (top) and a scheduled observing request (in pink) in the period of common availability (bottom).

3.3 SOFTWARE CORRELATION

The software correlator SFXC saw some minor bug fixes when new corners of (observing, correlation) parameter space were explored. Several minor new features were added.

It is now possible to let SFXC provide unnormalised visibilities. The use case for this was an EVN user requiring primary beam maps of all stations for wide-field observations dedicating part of the allocated observing time to measuring those beam patterns because several stations have still not provided these to JIVE.

The output buffer size is now configurable, which fixes a bottleneck preventing multiple phase centre correlation during real-time observing runs. It is now also possible to sustain several phase centres during e-VLBI. The specific performance may depend on the number of stations and observing bandwidth or (lack of) mixed bandwidth correlation.

The Polyphase Filter Bank (PFB) mode algorithm was significantly sped up by using the Intel Integrated Performance Primitives (IPP) libraries.

In order to better support FRB localisations a tool was developed that automates burst correlation. The application first (automatically) finds the burst in the data and computes the gating that maximizes the burst SNR, see Figure 3.9 for an example burst and automatically generated window; SFXC will only correlate the data within the gate. Subsequently the tool then generates the control files to run the correlator, and then actually runs the correlation.

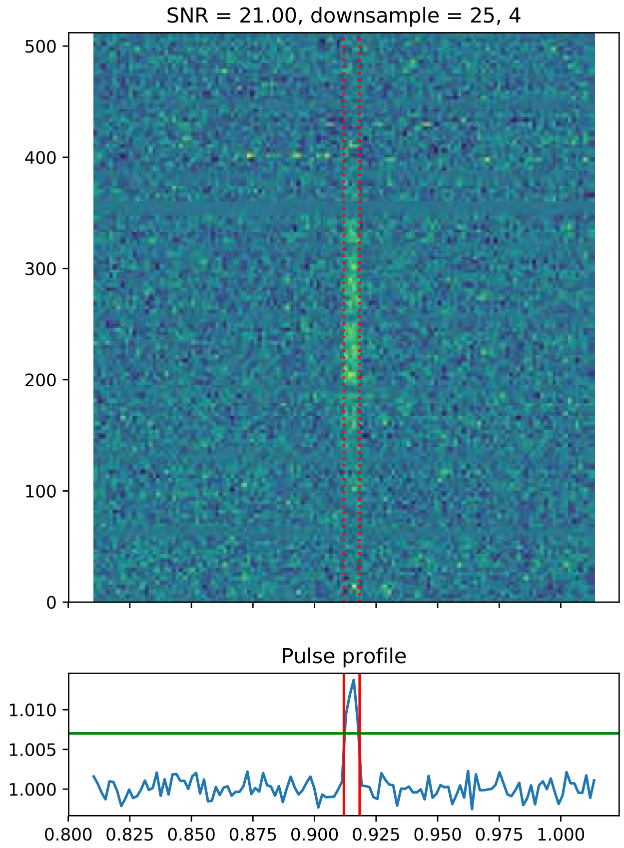


Figure 3.9: Example fast radio burst with automatically selected window-to-correlate that maximizes the burst's signal-to-noise ratio

3.4 USER SOFTWARE

CASA

In collaboration with NRAO a CASA VLBI companion paper (https://doi.org/10.1088/1538-3873/ac81ed) to NRAO's CASA reference paper (https://doi.org/10.1088/1538-3873/ac9642) was published. The CASA VLBI paper describes all VLBI-specific tasks, options, and improvements that JIVE has worked on in the past years. Of special interest is the most thorough comparison between Classic AIPS VLBI processing and its CASA based equivalent. Figure 3.10 is a replication from Figure 1 of the VLBI paper, comparing images produced using both data calibration and reduction packages. Another CASA highlight was the publication of the EHT SgrA* image where JIVE staff contributed at several levels (algorithm, tooling, writing, review, dissemination).

Besides the improvements mentioned under the ESCAPE project (see section 3.2: Research and Development, ESCAPE) several other CASA and casacore related work was completed, alongside some generic bug fixing based on user reports in both systems. On the topic of VLBI metadata improvements in casacore the GAIN_CURVE and PHASE_CAL table definitions were bug fixed or improved.

A prototype Earth Orientation Parameter (EOP) correction task was developed and evaluated. The adopted approach, which computes corrections based on the difference between EOPs used and EOPs desired and generates a generic calibration table for CASA's applycal task, provides accurate enough fixes to accommodate EOP corrections for a practical range of date differences.

For the fringefit task, the per-scan interpolation mechanism was implemented and validated, which is important for VLBI. A memo on the fringefit task was requested by NRAO and, following review, accepted in the official CASA memo series as CASA Memo #12 (https://casadocs.readthedocs.io/en/latest/notebooks/memo-series.html).

Together with the Space Science and Innovative Applications Group at JIVE, several issues regarding near-field VLBI data processing with CASA are under active investigation to be understood and, in the future, fixed.

In general, JIVE staff spent significant amounts of time supporting external scientists with their CASA-based VLBI calibration or data analysis.

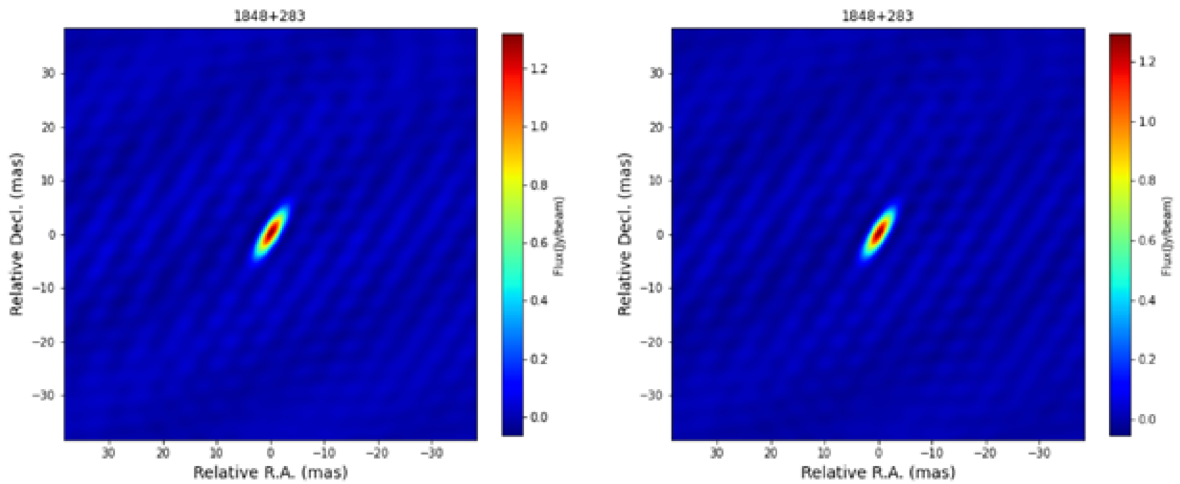


Figure 3.10: Total intensity images of calibrator 1848+283. Data calibrated in AIPS (left) and CASA (right). Both calibrated data sets were imaged with tclean using the same parameters.

pySCHED

The distribution of EVN setup files before a session was simplified: pySCHED was updated to support using setup files from the distribution itself. Because of pySCHED's 'auto update' capability, users can produce schedules and keep them synchronised with any changes in a session's setup(s).

Improved warning messages are now issued for sources observed too close to the sun. The thresholds can be configured on a per-station basis. This required converting another group of functions and functionality from the programming language FORTRAN to Python.

Continued incidental maintenance is required to handle changes in the numpy and matplotlib plotting library dependencies of pySCHED.

Space and Planetary Science

04

The space and planetary science activities at JIVE have been instrumental in pushing innovation and establishing new collaborations. In 2022, this effort continued to demonstrate JIVE's capacity of bridging the European and global VLBI community with new potential users from planetary science to fundamental physics. With the European Space Agency (ESA) Jupiter Icy Moons Explorer (JUICE) mission set to launch in April 2023 to explore Jupiter and its moons, the development of near-field VLBI applications has accelerated. Furthermore, the exciting results of the Event Horizon Telescope (EHT) collaboration showed that the sky has no limits, and the space VLBI TeraHertz Exploration and Zooming-in for Astrophysics (THEZA) concept has been presented to NASA as a potential European component of their mission's concept Event Horizon Explorer, which would extend the EHT with an additional space-based node.

4.1 SPACECRAFT OBSERVATIONS IN THE SOLAR SYSTEM

The year 2022 has been marked by significant progress and achievements in the preparation of JIVE's contribution to ESA's JUICE mission. The suite of scientific experiments of the mission will explore the habitability of the Jovian system and its icy moons. The VLBI component of JUICE, known as PRIDE (Planetary Radio Interferometry and Doppler Experiment), is an international endeavour led by JIVE that provides high-precision measurements of the spacecraft's position and velocity using radio telescopes around the world.

The Space Science and Innovative Applications group at JIVE continued to refine and validate the software tools for data processing and analysis. An open-source code that uses ESA operational and predicted orbit parameters to calculate spacecraft coordinates and state vectors, is available to the community and is used to calculate the near-field delays for the correlation of VLBI observations of spacecraft. In collaboration with the Delft University of Technology, a study was conducted on how simultaneous VLBI observations of the upcoming ESA's JUICE and NASA's Europa Clipper missions will improve the estimation solution for the Galilean satellites' ephemerides and related dynamical properties.

Observations of several operational planetary missions, such as ESA's Mars Express and China's Tianwen have been conducted in collaboration with the University of Tasmania and the Chinese Academy of Science. The correlation of the spacecraft signal provided a novel approach to studying the solar wind structure and the inhomogeneities in the interplanetary plasma.

Another fundamental novel application of VLBI has been the observations of the space VLBI radio telescope, the Russian-led mission RadioAstron, to test Einstein's equivalence principle by measurements of the gravitational redshift of RadioAstron.

4.2 VLBI IN SPACE

On the subject of space, the JIVE-led proposed concept for a multi-element spaceborne millimetre and submillimetre interferometric system, THEZA, has gained traction. This idea of space VLBI at higher frequencies, proposed in the ESA Call for Ideas Voyage 2050, was presented as a possible European contributor to the Event Horizon Explorer, a NASA mission concept to extend the Event Horizon Telescope via an additional space-based node. The THEZA collaboration published a paper (Gurvits *et al*. 2022, https://www.sciencedirect.com/science/article/pii/S0094576522001692) on the science case and challenges of space-borne sub-millimetre interferometry: 28 out of 54 co-authors are affiliated with EVN organisations.

Figure 4.1: Artistic representation of the THEZA space VLBI mission

An important step forward in building a multi-disciplinary collaboration in the field of space VLBI was the organisation of the next-generation space VLBI workshop in Dwingeloo. The event, a hybrid workshop attended by almost one hundred people, focused on the future of high-resolution radio interferometry in space as a natural space-borne extension of advanced existing and prospective Earth-based facilities and space VLBI. The workshop programme spread across all spectral domains and covered a wide range of science cases from the detection of cosmological inhomogeneities of the atomic hydrogen distribution in the early Universe to enigmatic processes near supermassive black holes.

4.3 SPACE APPLICATIONS TO FOSTER COLLABORATION

The next-generation space VLBI meeting in Dwingeloo made a critical contribution toward future radio interferometers in space. It is also a clear example of the important role of space applications in advocating VLBI (and VLBI facilities such as the EVN) to a wider community, and fostering multidisciplinary collaborations on science and technology to drive innovation.

Likewise, the JIVE-led experiment PRIDE for the ESA's JUICE mission uses a well-established radio astronomical technique to study non-traditional fields, attract new users and facilitate the creation of novel uses of VLBI networks. From space weather to planetary ephemerides, from space VLBI to fundamental physics, the space applications developed at JIVE continue to generate growing interest for VLBI outside of the 'traditional' community.

Figure 4.2: The JUICE spacecraft and its targets (credits: Airbus)

Communication and Training

05

5.1 COMMUNICATION AND OUTREACH

JIVE coordinates and organises different communication and outreach initiatives to expand the visibility of JIVE and the EVN activities among the international community of astronomers, policymakers and the general public.

One of the highlights of JIVE communications activities comprised the publication of thirty-seven news items over the year.

Besides maintaining the JIVE and EVN websites, JIVE introduced the online version of the JIVE/EVN Newsletters. In 2022 three newsletters were published, which were distributed in January, May and September.

Regarding the JIVE outreach activities:

- From 27 June to 1 July 2022, JIVE and the European VLBI Network (EVN) participated as exhibitors at the European Astronomical Society 2022 (EAS 2022) Annual Meeting, the largest conference of European astronomy, which was held in Valencia (Spain).

- During the ASTRON/JIVE open day, an interactive interferometry demonstration system was shown. It had been developed previously (adapted from an existing demo) to use a (magnetic) whiteboard, circular magnets, a webcam, and a computer running proof-of-concept code, which was rewritten to work consistently and correctly. People could interact with the demo, placing and moving the magnets on the whiteboard. The software continually reads the video stream of the webcam pointed at the whiteboard, finds the positions of the circles, and convolves a sample image from the magnet ('VLBI array') configuration. It was enjoyed by both the participants and the volunteers.

Following the succes of the EVN e-seminars in 2021, three more seminars were organised in 2022:

- High resolution observations of magnetic fields in the Central Molecular Zone of the Galactic Center (Cornelia C. Lang, University of Iowa);
- Exploring the lowest mass objects at the highest angular resolution: low-mass stars, ultracool dwarfs and exoplanets (Juan B. Climent, University of Valencia);
- Intermediate-mass black holes in the era of radio astronomy (Mar Mezcua, Institute of Space Sciences (ICE-CSIC)).

Figure 5.1: Participants of the 3rd Next Generation VLBI Workshop

On 17-19 October 2022, JIVE and ASTRON co-hosted the 3rd Next Generation VLBI workshop (ngSVLBI-3) in Dwingeloo, the Netherlands. The hybrid workshop was attended both in-person and remotely by about ninety participants from all over the world. The presentations at the workshop covered a range of science topics from detection of cosmological inhomogeneities of the atomic hydrogen distribution in the early Universe to enigmatic processes in the immediate vicinity of supermassive blackholes.

The workshop devoted a sizable part of its program to the discussions of technological challenges and potential synergies of SVLBI systems at various frequency domains. At the ultra-long wavelength domain, several ongoing project studies aim to create free-flying and Moon-based interferometric systems in the next one-two decades. Such projects are being worked on in the United States, Europe and China.

Several mission studies in the 'traditional' VLBI domain of decimeter-centimetre wavelengths are being conducted in China.

Finally, at millimetre and sub-millimeter wavelengths, several teams work toward formation of a system, ad hoc or dedicated, able to achieve a single-digit microarcsecond resolution.

In addition to the activities mentioned above, JIVE continued to update the JIVE website and coordinate communications for the ORP Project.

5.2 TRAINING

The first online EVN Users' training was organised on 11 May 2022 with the aim to support first-time users of the European VLBI Network (EVN). The EVN Support Scientists guided participants through the different steps to allow them to prepare and submit an observing proposal as well as the scheduling of observations.

A total of sixty-one participants from twenty different countries registered to attend this training event from completely different backgrounds, mostly outside the VLBI radio community. We hope this kind of training will boost connections and collaborations between groups from different fields across the world.

Participants could join through Zoom, YouTube, and Mattermost (chat only). This was an opportunity for users to get to know the JIVE support staff, ask questions and get answers in real time. The morning session briefly introduced the EVN, provided background information on the Call for Proposals, and demonstrated the use of the EVN Observation Planner and the NorthStar proposal tool. The afternoon session focused on observing schedule preparation. The online training attracted fourty-eight people from all over the world, including some first-time PIs.

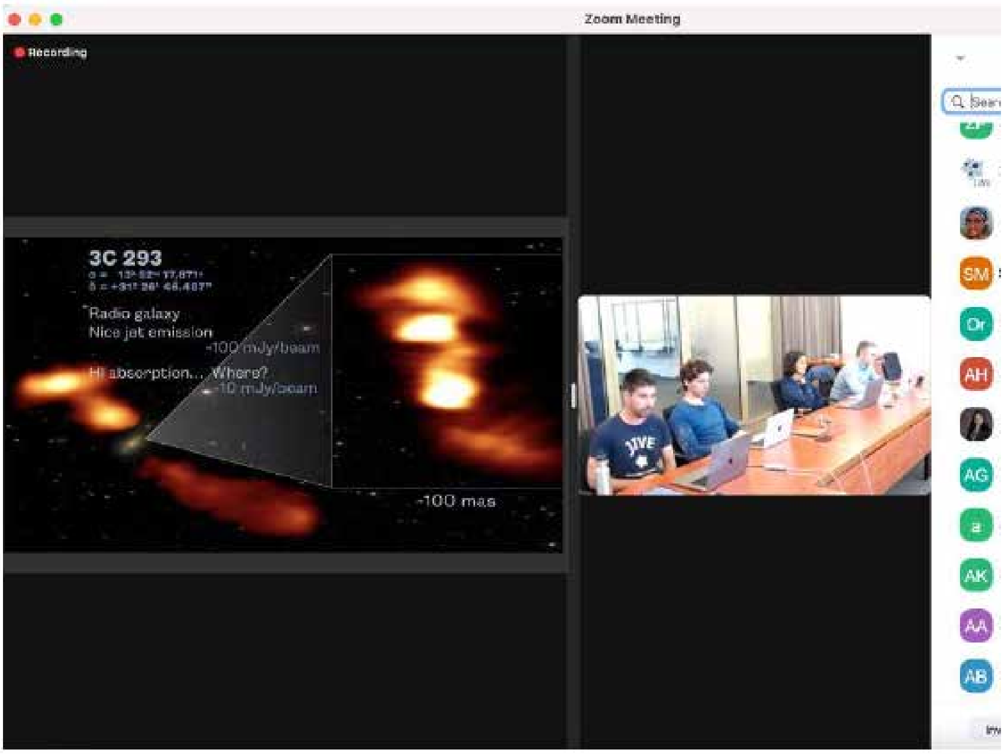


Figure 5.2: Zoom screenshot of online EVN users' training

The EVN Users' meeting took place during the 15th EVN Symposium in Cork, Ireland. It included an information session from the EVN Scheduler (Alastair Gunn), and the EVN Programme Committee Chair (Zsolt Paragi), a brief presentation by two EVN users (Yoshiaki Hagiwara and Krisztina Perger), and an on-site questionnaire on EVN and JIVE support, organised by the JIVE support scientists (with Gábor Orosz in the lead). The feedback was then discussed openly. An important lesson learnt was that the EVN Newsletter needs to be distributed more broadly, as some of the users were unaware of it.

Following a few years postponement due to COVID-19, the ASTRON/JIVE summer student programme began again in 2022. JIVE offered two short research programme positions, in the fields of HI absorption (spectral line VLBI) and fast radio bursts. Claire Cook (USA) successfully completed the programme along with other students at ASTRON, but unfortunately the second JIVE student was unable to secure a visa to travel to the Netherlands. It is hoped that in 2023 the ASTRON guesthouse and JIVE visitor room will once again be filled during the summer.

The ERIS 2022, the ninth in the series, was jointly organised by Zsolt Paragi (JIVE) and John McKean (ASTRON). It was a week of training in techniques of radio interferometry via lectures and tutorials, sponsored by the OPTICON-RadioNet pilot. The topics included calibration and imaging of continuum, spectral line and polarization data in all the radio domains (LOFAR, e-MERLIN, VLA, ALMA/IRAM) and including VLBI interferometry (EVN). This time VLBI was actually one of the most popular topics, thanks to the increasing interest of using very long baselines at low (ILT) and high (EHT) frequencies. The school was attended by seventy-two students from all over the world. The public lecture was given by the VLBI legend Jim Moran. At the end of the school, we thanked Anita Richards (a long-time permanent SOC member, now retired) for her exceptional work on keeping ERIS running through the years.

Figure 5.3: ERIS participants at the e-VLBI demo (above), group picture (below)

Operations

06

6.1 CORRELATION

The core of JIVE's service is the correlation of astronomers' observations conducted with the EVN and global VLBI arrays; the table below summarises experiments that were correlated or distributed in 2022. For a detailed list of the user experiments, see Section 9.5, 'Correlator Activity'.

	USER EXPERIMENTS			TEST & NETWORK MONITORING		
	Number Experiments	Network Hours	Correlator Hours	Number Experiments	Network Hours	Correlator Hours
Correlated	114	988.5	1111	15	66.5	68.5
Distributed	90	772.5	869	9	48	51
e-EVN experiments	29	209.5	209.5			
e-EVN ToO/ triggers	6	44	44			

Table 6.1: Summary of projects correlated or distributed in 2022. Here, 'network hours' sum the total duration of experiments, and 'correlator hours' are the network hours multiplied by any multiple correlation passes required -- the actual time to correlate can be several times larger for more complex correlations.

The COVID-19 restrictions in the Netherlands were removed in the spring. There was usually at least one operator in Dwingeloo every workday, but the successful development of remote-correlation capabilities during the two years of the COVID-19 era have continued to provide an additional measure of flexibility.

The number of correlator hours completed in 2022 was 1179.5, the third highest since shifting to the SFXC correlator in 2011. But the unusual situation arose in which the amount of correlated observations still to distribute to the observing teams has widened. This was due to a number of factors, including an increasing total correlation load as illustrated below. Additional contributing factors included being short one support scientist from March to September and demands on the time of support scientists for EVN Symposium LOC responsibilities, tutorial preparation and serving on the LOC for the ERIS.

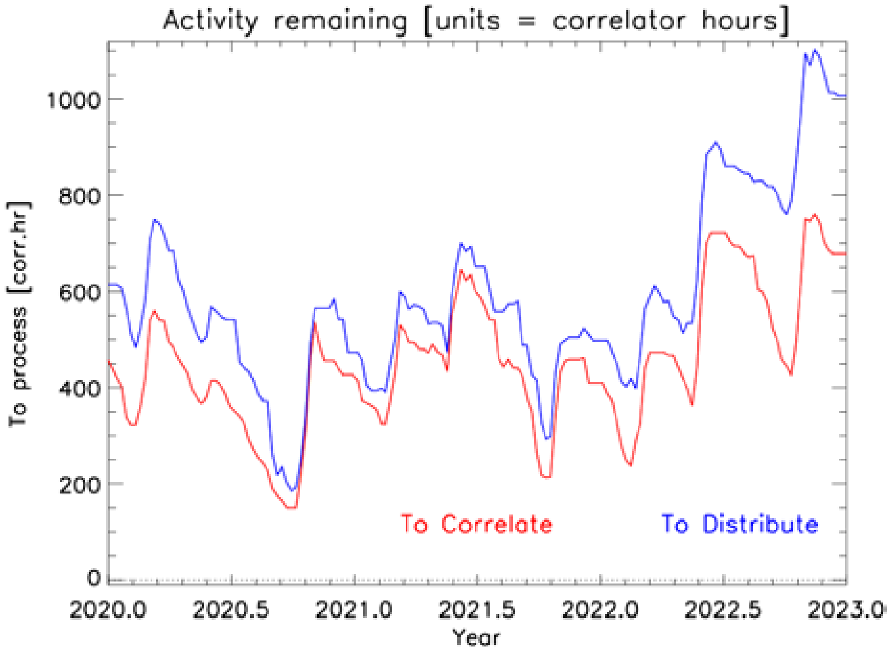


Figure 6.1: The size of the correlator queue at different stages in the processing cycle. The red line shows the number of correlator hours that remain to be correlated. The blue line shows the number of correlator hours in experiments whose data remain to be distributed to the observing teams.

In the following images the left panel of figure 6.2 traces the evolution of the annual EVN network hours. 2022 established another new record (1121, topping 1044.5 from 2021); this is the third time the record has been broken in the past four years. The number of disk-based EVN network hours increased by 12% compared to the previous record: 911.5, up from 817 in 2021.

The right panel of figure 6.2 focuses on e-EVN experiments, showing their division among the proposal categories. Total e-EVN network hours again exceeded 200, with 2021-22 being the first two-year period with each year having more than 200 e-EVN hours since 2016-17.

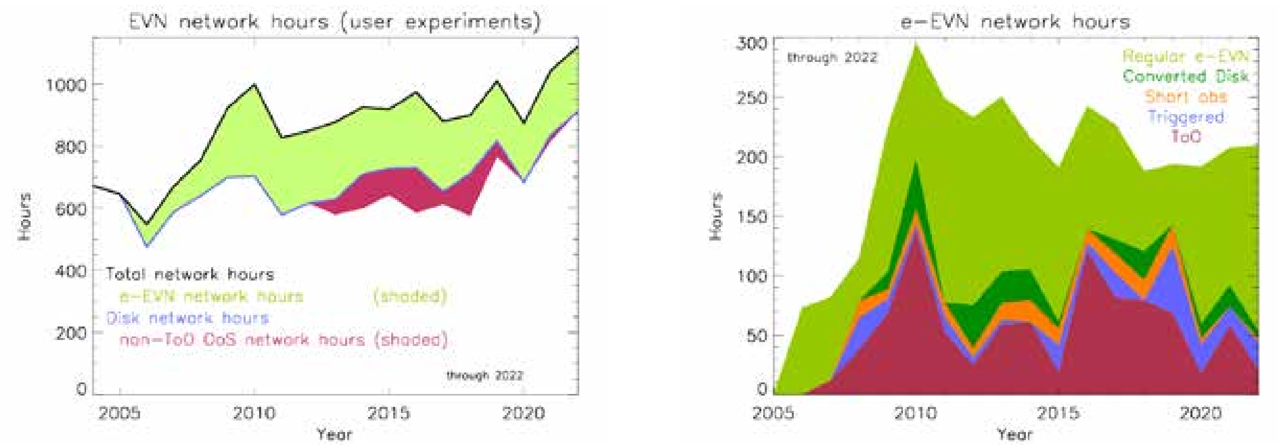


Figure 6.2: Left: Annual EVN network hours, with separate color-coded areas for different categories of user observations, from top to bottom: real-time e-EVN (light green), non-ToO out-of-session disk-based (dark red), and 'traditional' disk-based (white) Right: e-EVN network hours, with separate color-coded areas for different proposal categories, from bottom to top: target-of-opportunity, triggered, short observations, converted from disk, and regular.

Other highlights from 2022 included:

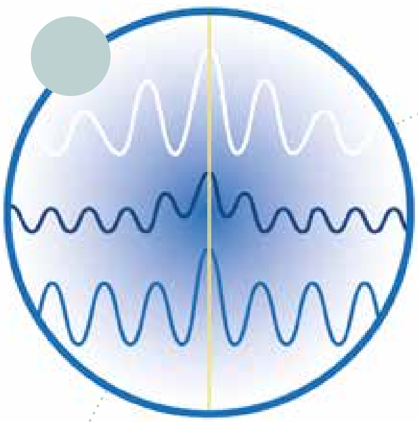
— Alongside the new record for the number of network hours in 2022, the year also set new records for the number of user observations (152; was 127 from 2019) and disk-based user observations (123; was 94 also from 2019).

— EM160 was a correlator-only experiment to recorrelate one of the proposer's earlier observations with a large number of multiple phase centres (127 around the target, 130 around the phase-reference source). The 21.9 hours contained in the scans took 218.5 actual correlator hours to complete. The post-correlation processing required multiple iterations, as bugs in recently introduced steps were ironed out. In the end, this correlation resulted in 17.9 TB of FITS files, a record for a single observation.

— There were fourteen 4 Gbps user observations in 2022, spread evenly across the sessions (5,5,4), including a project from a first-time PI (who was also from a non-EVN institute). The 4 Gbps observations in the first session had a couple of stations experiencing problems, but those in the last two sessions proceeded robustly. The first 4 Gbps user observations at 1.3 and 3.6 cm took place in the third session.

— There were seven EVN target of opportunity observations (three via e-EVN) and three e-EVN trigger observations, arising from five proposals. These projects covered scientific topics ranging from jet ejections from an AGN undergoing a state transition, evolution of the jet in a TDE, a possibly merging binary AGN, a newly discovered long GRB, and whether jets in blazars could be associated with neutrinos detected by IceCube Neutrino Observatory.

— There were thirteen FRB triggers from the on-going correlation-only projects based on VLBI observations shadowing the CHIME radio telescope (and other facilities). The triggers cover five different FRB targets. Correlation of the shadowing VLBI observations is triggered if a burst is detected by the tracking facilities. Depending on the accuracy of the a priori position of the FRB, one or two correlation passes over the whole range of the phase-referencing data (ranging from 2-10 hours) would ensue, with the ultimate goal of deep-imaging to detect any associated persistent radio source (three of the thirteen needed just one pass). There is also a special off-line high time-resolution correlation of the burst itself (i.e., no more than a few milliseconds of data), which would be required before beginning the second, full pass, if the target's a priori position was not good enough.



6.2 EVN SUPPORT

JIVE coordinated tests of new receivers/back-ends at EVN stations, including a wide-band/linear-pol 4.0-9.3 GHz receiver at Effelsberg, initial tests within EVN observations of DBBC3 back-end at Onsala during the Oct/Nov 6 cm Network Monitoring Experiment (NME), and the inclusion of the new VRA back-end at Robledo in some user observations. Both these last two back-ends required use of VEX2 for correlation to handle the multiple VLBI Data Interchange Format (VDIF) streams, each of which could contain multiple channels.

At present, VEX2 files cannot yet be used to drive observations, so both versions of the same schedule need to be made — which pySCHED can do (any manual fixes of cable-(un)wraps must be done to both output schedules). JIVE also developed in consultation with the stations a local oscillator (LO) tuning scheme for the 3.6 cm, 4 Gbps user observation in the Oct/Nov session.

JIVE coordinated test observations for telescopes that could potentially join in future EVN observations. The 500 m FAST telescope in China participated in two more EVN observations, the 18 and 21 cm NME in the Feb/Mar session and in a stand-alone observation in the May/June session, both including phase-referencing. Internal policies at FAST prevented data being sent to JIVE for correlation. Therefore data from other stations were e-shipped to Shanghai Astronomical Observatory (ShAO).

uGMRT participated in two test EVN observations in February including simultaneous data from both a single-dish and a tied-array configuration. Data must be re-sampled (in some cases) and translated into VDIF. Fringes were seen to both single-dish and tied-array 'stations'. Another test observation during the Oct/Nov session was conducted, whose data are still being investigated.

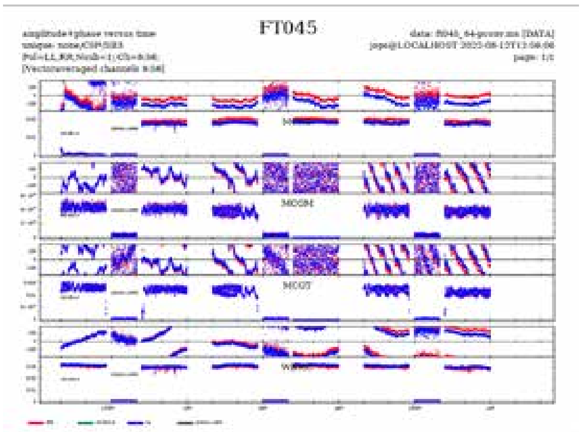


Figure 6.3: Amplitude and phase versus time for baselines to Medicina from Noto, uGMRT/single-dish, uGMRT/tied-array, and Westerbork (from top to bottom) from the second test observation in February.

6.3 USER SUPPORT

With COVID-19 restrictions gradually lifting, JIVE and the User Support group started returning to normal operations. Some of the support and training activities were still done remotely, like the first online EVN users' training. The support scientists set up a Mattermost platform for easy interaction with users, where people can ask questions to JIVE personnel, but also share experiences with each other. Some events and activities, like the ASRON/JIVE summer student programme and the ERIS 2022 school were organised in-person; the EVN Symposium in Cork provided a welcome opportunity to meet with the broader community, which included an EVN Users' Meeting. Users appeared on JIVE corridors again: Yoshiaki Hagiwara (Tokyo University, Tokyo, Japan) spent his sabbatical at ASTRON/JIVE, starting in April 2022. We had a number of additional EVN users coming for data reduction visits, from master's student to postdoc and more senior levels. The training events are described in section 5.2, and a list of visitors to JIVE can be found in section 9.4.

JIVE provided support in all stages of a user's EVN observation, from proposal definition to data analysis. There were fourteen first-time PIs in 2022 observations; four of these were students and four were female (no overlap in these two sub-categories). Eight of the fourteen first time PIs came from non-EVN institutes, including six different universities in Ireland, the UK, Belgium, Australia, Israel, and China. This support included experiment-specific set-up templates when needed, to track the evolving configurations of equipment at EVN stations, and correspondingly updating the pySCHED catalogues.

Besides making the various EVN data products available through the archive, user support included helping in all steps from proposing through observations to scheduling and data processing. A crucial step in this was assuring EVN data integrity and good calibration — although the latter was primarily in the hands of the individual observatories. To this end, the support scientists and the R&D department worked together to continuously update and improve the tools in the EVN/JIVE data chain. In particular the antab_editor was updated to allow for a subband-dependent gain correction, should the a priori gains from the stations clearly be in error. The feedback to stations about this was given through Grafana plots and the TOG reports. The TY (system temperature) and GC (gain curve) tables have been attached to FITS files starting from session 1/2022.

Existing users who asked for help still largely used AIPS for processing, but new users often only work in CASA. JIVE supported both worlds and promotes CASA use, but it is clear that the bulk of the core users will require keeping AIPS support for quite a few years to come. While the missing functionalities in CASA VLBI processing are continuously addressed (aspects of ionospheric correction, fringe fitting, and polarization calibration, among others), some limitations of the package have surfaced as well. CASA has known performance issues, especially when visualising data, which makes classical, iterative processing more difficult; although it has clear advantages for automated processing. Updates to CASA, will need to address these issues though. Perhaps a future solution requires a platform where processing is largely independent of heavy user packages.

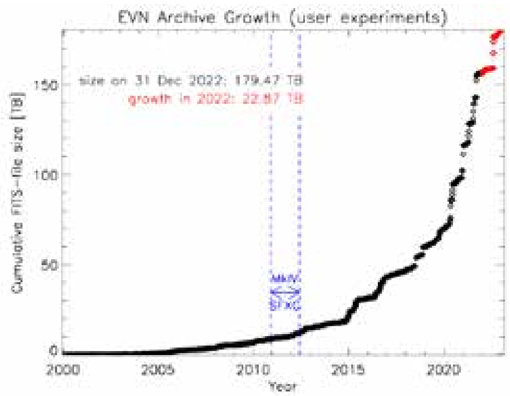


Figure 6.4: Growth of user experiments in the EVN Archive. Experiments archived in 2022 are plotted in red. Vertical dashed lines show the transition period between the MkIV and SFXC correlators.

JIVE offers a 'Support+' pilot programme to teams that are particularly unsure about the VLBI-specific part of observe file preparation and processing. Two teams applied for this in 2022. Support scientists offered additional help for scheduling and data post-processing, as required. Whether this is a sustainable mode of operation will depend on the user demand and the available resources at JIVE. If JIVE wants to reach a broader community, this is one of the possible steps forward, along with improving the science readiness of the available data products.

The EVN Archive remains the entry point for users to retrieve their correlated EVN data, and provides open access to others following the one-year proprietary period (six months for Target of Opportunity (ToO) projects). The total size of user-experiment FITS files in the Archive reached almost 180 TB by the end of 2022, increasing by 15% during the year.

Finances

07

7.1 JIVE FINANCIAL REPORT

BALANCE (AFTER ALLOCATION OF RESULTS)

ASSETS	31 DECEMBER 2022 in €	31 DECEMBER 2021 in €
TANGIBLE FIXED ASSETS		
Tangible fixed Assets	53,712	52,468
Total of Tangible fixed Assets	*53,712*	52,468
CURRENT ASSETS		
Work in Process	0	0
Receivables	465,036	277,476
Cash at bank	3,124,496	3,269,199
Total of Current Assets	*3,589,532*	*3,546,675*
TOTAL ASSETS	**3,643,244**	**3,599,143**

LIABILITIES	31 DECEMBER 2022 in €	31 DECEMBER 2021 in €
CAPITAL		
General reserve	1,537,405	1,895,094
Designated funds	300,000	300,000
Total capital	*1,837,405*	*2,195,094*
OTHER LIABILITIES		
Short term debts	1,805,839	1,404,049
Total of Current Liabilities	*1,805,839*	*1,404,049*
TOTAL LIABILITIES	**3,643,244**	**3,599,143**

STATEMENT OF PROFIT AND LOSS

	2022			2021
	BUDGET	**ACTUAL**	**DIFFERENCE**	**ACTUAL**
REVENUES	in €	in €	in €	in €
INCOME				
Contributions/subsidies third parties	2,176,345	2,104,160	-72,185	2,530,785
Interest	0	9,885	9,885	0
Other	304,061	266,190	-37,871	255,586
Total Income	*2,480,406*	*2,380,235*	*-100,171*	*2,786,371*
TOTAL REVENUES	**2,480,406**	**2,380,235**	**-100,171**	**2,786,371**

	2022			2021
	BUDGET	**ACTUAL**	**DIFFERENCE**	**ACTUAL**
EXPENDITURES	in €	in €	in €	in €
OPERATIONS				
Grants/expenditures	2,809,193	2,737,924	-71,269	2,626,742
Total Operations	*2,809,193*	*2,737,924*	*-71,269*	*2,626,742*
TOTAL EXPENDITURES	**2,809,193**	**2,737,924**	**-71,269**	**2,626,742**

RESULT	**-328,787**	**-357,689**	**-28,902**	**159,629**

Figure 7.1: Dwingeloo Telescope. Credit: Uberprutser / Wikimedia Commons.

EC Projects

08

H2020 ESCAPE

JIVE is a partner in the ESCAPE project, which aims to find solutions for common problems identified between astronomical, astrophysical and particle physics research domains, with the intent to define requirements of the European Open Science Cloud.

Examples of these common problems have been identified in the areas of handling (extremely) large datasets, finding the scientifically verified /curated software for extracting science from those datasets and knowledge of requirements to run it. This enables discovery of datasets and a science analysis platform that allows joint analysis of datasets from different (ESCAPE) partner instruments or observations.
Those four areas are addressed in four WPs (DIOS, OSSR, CEVO and ESAP) of which JIVE participates in three: OSSR (Open Source software and Services Registry), CEVO (Connecting ESFRI projects to EOSC through VO framework) and ESAP (European Science Analysis Platform).

JIVE is actively involved both in defining standards, such as metadata for the software (OSSR), radio visibility data in the VO (CEVO) as well as improving the JupyterCASA entry in the OSSR, making the EVN Archive findable and searchable in the VO and providing an analysis platform for (EVN) visibility data using CASA in version-controlled Jypyter notebooks.

H2020 ERIC FORUM

The ERIC Forum project aims to strengthen the coordination within the European Research Infrastructure Consortium (ERIC) community and enhance collaboration between partners. The strategic approach of the ERIC Forum contributes to address critical challenges, develop best practices and frame the necessary knowledge to support ERICs with various aspects. Moreover, this will contribute to building the brand identity of ERICs as an important body and stakeholder in consultation of related policy action.

Participating in the ERIC Forum allowed JIVE to explore a network of infrastructures that share common challenges, such as long-term sustainability, reporting, VAT exemption practices, and training of governance representatives. Furthermore, JIVE had a prominent role in the project, with Paco Colomer (JIVE director at the time) serving as Chair of the Forum.

H2020 OPTICON-RADIONET PILOT

The OPTICON-RadioNet Pilot (ORP) project brings together the well-established ground-based astronomy community to offer, support and develop access to radio and optical facilities in an efficient, coordinated, and forward-looking programme.

JIVE is involved in the project through the EVN transnational access (for which JIVE also provides the work package lead), as well as coordinating the communications of the project, and co-leads the Joint Activity 2 subtask 2 'Time-Domain, Multi-Facility & Multi-Frequency access to Research Infrastructures'. The latter aims to develop tools to help researchers to seamlessly access multiple partner RIs observations and data from a centralised access mechanism.

HORIZON EUROPE RADIOBLOCKS

In July 2022, an ambitious project led by JIVE was approved for the European Union's Horizon Europe research and innovation programme. In December, the Grant Agreement of RADIOBLOCKS between JIVE as the coordinator, and the European Commission was signed.

The goal of the RADIOBLOCKS project is to boost world-leading European research infrastructures in radio astronomy, which over the years have invested heavily in maintaining existing facilities as well as in substantial upgrade programmes, after identifying common challenges towards their mid- and long-term scientific visions.

In this project, the institutes responsible for these facilities join forces, together with partners from industry and academia, to develop 'common building blocks' for technological solutions beyond the state-of-the-art, which will enable a broad range of new science to be realised and enhance European scientific competitiveness.

This project carries out carefully targeted development work and addresses common aspects in the complete data chain, categorising this in four phases: Novel detectors and components, digital receivers, transport and correlation, and data (post)processing. The building blocks will be new instrument components and advanced digital solutions based on newly available (HPC/AI optimised) hardware. This approach will enable a tremendous increase in the potential for the delivery of science from Europe's major radio astronomy observatories. Particularly, in ensuring the realisation of long desired projects, which will achieve far reaching impact for the wider international science community.

The project starts its activities on March 1st, 2023. It will run for four years until February 27th, 2027.

Tables and Metrics

09

9.1 JIVE COUNCIL

MEMBER REPRESENTATIVES

Dr. Patrick Charlot	*Laboratoire d'Astrophysique de Bordeaux,* Pessac, France
Dr. Martin Giard	*Centre National de la Recherche Scientifique*, France
Dr. Jessica Dempsey	*ASTRON,* Dwingeloo, the Netherlands
Mrs. Saskia Matheussen	*NWO,* Den Haag, the Netherlands
Alexander Burgman	*Vetenskapsrådet,* Stockholm, Sweden
Prof. John Conway	*Onsala Space Observatory,* Onsala, Sweden
Dr. Aleksejs Klokovs	*Ventspils University of Applied Sciences,* Ventspils, Latvia
Mr. Dimitrijs Stepanovs	*Ministry of Education and Science,* Latvia
Dr. José Antonio López Fernández	*Instituto Geográfico Nacional,* Madrid, Spain (Vice chair)
Mrs. Monica Groba López	*Instituto Geográfico Nacional,* Madrid, Spain
Prof. Simon Garrington	*Jodrell Bank Centre for Astrophysics,* Manchester, UK
Dr. Colin Vincent	*Science and Technology Facilities Council,* Swindon, UK
Dr. Tiziana Venturi	representing the EVN Board of Directors*, IRA-INAF,* Bologna, Italy (Chair)
Dr. Grazia Pavoncello	*Ministero dell'Istruzione, dell'Università e della Ricerca,* Roma, Italy

ASSOCIATED RESEARCH INSTITUTES REPRESENTATIVES

Prof. Zhinqiang Shen	*NAOC, Shanghai Astronomical Observatory,* Shanghai, China
Dr. Fernando Camilo	*National Research Foundation, South African Radio Astronomy Observatory,* Cape Town, South Africa
Prof. Anton Zensus	*Max-Planck-Institut für Radioastronomie,* Bonn, Germany

9.2 JIVE PERSONNEL

Dr. Olga Bayandina	*Support Scientist* (until 8 March 2022)
Dr. Shivani Bhandari	*Postdoctoral Researcher* (until 1 May 2022)
Mr. Paul Boven	*Network Systems Engineer*
Dr. Bob Campbell*	*Head of Science Operations*
Dr. Giuseppe Cimò*	*Space VLBI Scientist, Head of Space Science and Innovative Applications Group* (since 17 August 2022)
Dr. Francisco Colomer Sanmartin*	*Director*
Drs. Bob Eldering	*Software Engineer*
Dr. Dhanya G. Nair	*Support Scientist* (until 1 February 2022)
Prof. Leonid Gurvits*	*Head of Space Science and Innovative Applications Group* (retired 17 August 2022)
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. Waleed Madkour	*CRAF Frequency Manager*
Dr. Benito Marcote Martin	*Support Scientist*
Dr. Mas Md Said	*Postdoctoral Near-field VLBI Support Scientist*
Dr. Suma Murthy	*Support Scientist*
Dr. Gabor Orosz	*Support Scientist*
Dr. Zsolt Paragi*	*Head of User Support*
Dr. Jorge Rivero González	*Science Communications Officer*
Dr. Des Small	*Scientific Software Engineer*
Dr. Ilse van Bemmel	*Project Scientist*
Drs. Aukelien van den Poll	*Finance and Project Officer*

** – JIVE MT member*

Dr. Huib Jan van Langevelde	*Chief Scientist*
Drs. Marjolein Verkouter*	*Head Technical Operations and R&D*
Dr. Junghwan Oh	*Support Scientist (since 1 September 2022)*
Mr. Wybren Buijs	*Linux/Network Specialist (since 1 June 2022)*

** – JIVE MT member*

9.3 EDUCATIONAL RESPONSIBILITIES

MSC PROJECT SUPERVISION

Théo Furst	by B. Marcote (co-supervisor), *University Of Liége,* Belgium. From autumn 2021 to spring 2022

PHD PROJECT SUPERVISION

Paul Boven	by H.J. van Langevelde, *Leiden University* (expected completion in 2023)
Kenzie Nimmo	by Z. Paragi and B. Marcote, *UvA* (main supervisor J.Hessels) (completed in September 2022)
Vidhya Pallichadath	by L.I. Gurvits and L.L.A. Vermeersen, *Delft University of Technology* (expected completion in 2025)

SECONDARY AFFILIATIONS

Francisco Colomer Sanmartin	affiliated with *Instituto Geográfico Nacional,* Madrid, Spain
Leonid Gurvits	affiliated with *the Department of Astrodynamics and Space Missions,* *Faculty of Aerospace Engineering, Delft University of Technology,* the Netherlands
Huib Jan van Langevelde	affiliated with *Sterrewacht Leiden, Leiden University*, the Netherlands and adjunct staff at *University of New Mexico*

9.4 VISITORS TO JIVE

NAME	INSTITUTE	PERIOD	HOST
T. Furst	*University of Liège,* Belgium	6-12 March	Marcote
Y. Hagiwara	*Tokyo University,* Japan	26 April - 30 March	Paragi
G. Molera	*University of Tasmania,* Australia	4-8 July	Orosz
V. Pallichadath	*TU Delft,* the Netherlands	6-8 July	Gurvits
S. Poshyachinda	*National Astronomical Research Institute of Thailand (NARIT)*	28 July	Colomer
W. Rujopakarn	*National Astronomical Research Institute of Thailand (NARIT)*	28 July	Colomer
W. Arjharn	*Program Management Unit for Human Resources & Institutional Development, Research and Innovation (PMU-B), Thailand*	28 July	Colomer
N. Thammajak	*Thailand Science Research and Innovation (TSRI)*	28 July	Colomer
J. Bright	*University of Oxford,* UK	22 August - 2 September	Marcote
J. Moran	*Harvard-Smithsonian Center for Astrophysics,* USA	20-21 September	van Langevelde
M. Krezinger	*Konkoly Observatory and Eotvos University Budapest,* Hungary	23-30 September	Gurvits
A. Young	*Radboud University*, the Netherlands	21 November	Kettenis
O. Ould-Boukattine	*University of Amsterdam/API,* the Netherlands	22-26 November	Marcote
P. Chawla	*University of Amsterdam/API,* the Netherlands	22-26 November	Marcote
M. Snelders	*University of Amsterdam/API,* the Netherlands	22-26 November	Marcote

9.5 CORRELATOR ACTIVITY

User experiments with correlation or distribution completed in 2022. In Column 'Observation Month/ Session', In-session observations are specified by the EVN session in which they are observed (s.N/YY, for the Nth session of year YY); e-VLBI and out-of-session observations are specified by the month and year in which they are observed.

PROJECT CODE	OBSERVATION MONTH/ SESSION	PI	TITLE
EA065B	Nov.21	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065C	Dec.21	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065D	Feb.22	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065E	s.1/22	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065F	Mar.22	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065G	Apr.22	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065H	Jun.22	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065I	Sep.22	Atri	*Identifying the true nature of compact steep spectrum sources*
EA065J	Dec.22	Atri	*Identifying the true nature of compact steep spectrum sources*
EB085B	s.3/21	Bietenholz	*Renewed Deceleration and the Nature of the Opposing Hot Spots*
EB086A-B	12/03/2022	Brooks	*Revealing a sub-kpc-scale binary AGN*
EB087	s.3/21	Burns	*The aftermath of high-mass protostellar accretion bursts*
EB088	s.3/21	Bright	*Resolving the First Off-Axis Jet-Cocoon System from a Stellar Explosion*
EB089A	s.3/21	Boven	*Astrometric observations of WX UMa*
EB089B	s.1/22	Boven	*Astrometric observations of WX UMa*
EB089C	s.2/22	Boven	*Astrometric observations of WX UMa*

EB090A-B	s.3/21	Boccardi	*Probing the expansion of relativistic jets on sub-kiloparsec scales*
EB091A	s.1/22	Boven	*Extending the astrometry on Ross 867*
EB091B	s.2/22	Boven	*Extending the astrometry on Ross 867*
EB096A	May.22	Bhandari	*A sharper view of the local environment of localized fast radio bursts*
EB096B-H	s.2/22	Bhandari	*A sharper view of the local environment of localized fast radio bursts*
EB096I	Oct.22	Bhandari	*A sharper view of the local environment of localized fast radio bursts*
EC073A-B	s.2/22	Cao	*Towards solving the X-ray puzzle of misaligned high-redshift radio quasars*
EC082A	Jan.22	Cheng	*The Origin of Radio Emission in a Complete Sample of Nearby LLAGNs*
EC082B	Feb.22	Cheng	*The Origin of Radio Emission in a Complete Sample of Nearby LLAGNs*
EC082C	Mar.22	Cheng	*The Origin of Radio Emission in a Complete Sample of Nearby LLAGNs*
EC082D	Apr.22	Cheng	*The Origin of Radio Emission in a Complete Sample of Nearby LLAGNs*
EC082E	Sep.22	Cheng	*The Origin of Radio Emission in a Complete Sample of Nearby LLAGNs*
EC082F	Dec.22	Cheng	*The Origin of Radio Emission in a Complete Sample of Nearby LLAGNs*
EC083A-D	s.1/22	Climent	*The extreme case of very ultracool fast rotators and binary systems*
EC084A-B	s.2/22	Caleb	*Probing the environment of FRB 190714A*
EC086A-D	s.2/22	Climent	*Anatomy of an aurora: star-planet interaction in LSR J1835+3259*
ED049	s.3/21	Durjasz	*Observation of strongly variable methanol maser cloudlets in G121.298+0.659*
ED050A	s.2/22	De Becker	*The gradual revival of synchrotron radiation from the massive binary WR125*
EG110A-B	s.1/22	Gabanyi	*Do Te-REXes have jets?*
EG111A-D	s.2/22	Giovannini	*Exploring the nature and properties of parsec scale jets in FRO radio galaxies*

EG113A-B	s.1/22	Principe	*Unveiling the pc-scale structure of the gamma-ray young radio galaxy PKS1007+142*
EG119A	s.2/22	Giroletti	*Finding hidden relativistic jets at z>5*
EG123A	Dec.22	Gawronski	*Zooming on Ross 15 - a possible planetary system around a nearby red dwarf*
EH039A-C	s.3/21	Hagiwara	*Revisit to the nuclear region of the merging galaxy NGC 6240*
EH040A-B	s.1/22	Hartley	*Jet speeds in a radio quiet quasar*
EJ024	Dec.21	Jiang	*Probing the compact radio emission of two special magnetic White dwarf binaries*
EK050A	Oct.21	Kirsten	*Correlation of an ad-hoc VLBI array monitoring CHIME repeating FRBs II*
EK050B	Nov.21	Kirsten	*Correlation of an ad-hoc VLBI array monitoring CHIME repeating FRBs II*
EK050E	Apr.22	Kirsten	*Correlation of an ad-hoc VLBI array monitoring CHIME repeating FRBs II*
EK051E	Sep.22	Kirsten	*Correlation of an ad-hoc VLBI array monitoring CHIME repeating FRBs II*
EM145B	s.3/21	Muxlow	*Characterising the intermediate radio structure of luminous blazar J1955+5131*
EM155A-B	s.1/22	Mueller	*Multiresolution imaging of the innermost wisp region of the Crab Nebula*
EM156B	s.3/21	Miller-Jones	*The outflow speed of a long-lived thermal tidal disruption event*
EM157	s.3/21	Migliori	*What drives an outflow? The radio emission of MaNGA 1-166919 at mas scales*
EM160	s.2/21	McKean	*A pilot VLBI All-sky Legacy Survey with the EVN*
EM161A-B	s.1/22	Marcote	*Tying the position of a second Fast Radio Burst to a persistent radio source*
EM162A	Apr.22	Mikhailov	*The research of FR0 radio galaxies at scales from parsec to sub kpc*
EM163	s.2/22	Marcote	*Tick-tock: exploring the imminent merger of a supermassive black hole binary*
EN009A-B	s.3/21	Nair	*Resolving the radio cores of the Quasar Feedback Survey sample with EVN+e-MERLIN*

EN010C	Nov.21	Nimmo	*Characterising the local environments of repeating fast radio bursts*
EN010D	Dec.21	Nimmo	*Characterising the local environments of repeating fast radio bursts*
EN011A	Feb.22	Nanci	*Are blazar jets associated with IceCube neutrinos?*
EN011B	Jun.22	Nanci	*Are blazar jets associated with IceCube neutrinos?*
EN011C	Dec.22	Nanci	*Are blazar jets associated with IceCube neutrinos?*
EO019	s.1/22	O'Fionnagain	*Resolving the stellar wind of lambda And; a RS CVn binary system*
ER052A-B	s.1/22	Radcliffe	*The final frontier in the wide-field surveys - Mapping the primary beam of the EVN*
ES101A-B	s.1/22	Stanghellini	*Old radio activity in two young galaxies*
ET048A-C	s.1/22	Titov	*Imaging extragalactic radio sources with extremely large radio-optical offsets*
EV024A	s.1/22	Vaddi	*Investigating orbital period evolution of candidate supermassive BH binary 3C66B*
EV024B	May.22	Vaddi	*Investigating orbital period evolution of candidate supermassive BH binary 3C66B*
EV024C	s.2/22	Vaddi	*Investigating orbital period evolution of candidate supermassive BH binary 3C66B*
EV024D	Oct.22	Vaddi	*Investigating orbital period evolution of candidate supermassive BH binary 3C66B*
EV024E	Nov.22	Vaddi	*Investigating orbital period evolution of candidate supermassive BH binary 3C66B*
EW022A-B	s.1/22	Wu	*EVN observations of OH megamaser galaxy IRAS 17526+3253*
EW025A-B	s.3/21	Wen	*Density profiles of galaxy dark matter halos in a compact group environment*
EW029A-D	s.2/22	Williams	*Monitoring the old discovering the new; mas-scale radio emission in M82*
EY039	Dec.22	Yang	*A disc-jet coupling in the smallest AGN?*
GM079	s.1/22	MacDonald	*Unravelling the nature of the jet's magnetic field within PKS1510-089*

GM081A-C	s.2/22	Murthy	*Radio-AGN feedback: an extension to low-power sources*
GP058A-B	s.3/21	Paraschos	*The true nature of the jet base in the prominent radio galaxy 3C84*
RA005	s.1/22	An	*e-EVN observation of a possibly imminent merger of SMBH binary*
RM017A	Mar.22	Miller-Jones	*The evolution of the jet Lorentz factor in a tidal disruption event*
RM017B	Jun.22	Miller-Jones	*The evolution of the jet Lorentz factor in a tidal disruption event*
RS003	Jan.22	Shu	*Mas-scale imaging of nascent jet ejections associated with AGN state transitions*
RSG17	Sep.22	Giroletti	*Calibrators for EG120 High angular resolution of a long-lived GRB outflow*
RSW02	s.1/22	Wandia	*VLBA Calibrator J1926+4441*
RSY08	Apr.22	Yang	*Searching for a calibrator for the high-precision astrometry on BL Lac*
RY009	s.3/21	Yang	*Observing newborn ejecta associated with the changing-look AGN 1ES 1927+654*

9.6 JIVE STAFF PUBLICATIONS

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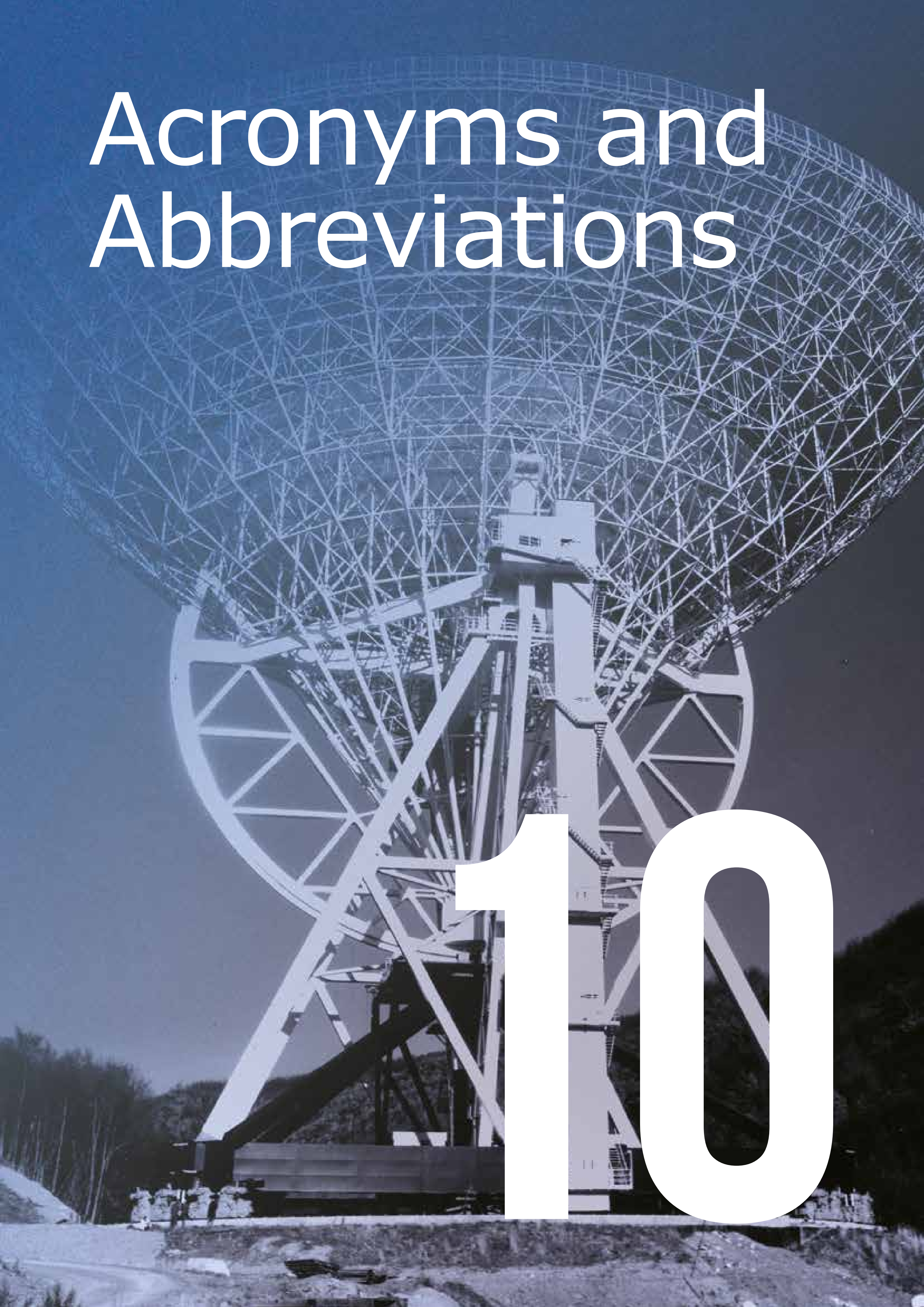
10 Acronyms and Abbreviations



AGN	*Active Galactic Nucleus/Nuclei*
AIPS	*Astronomical Image Processing System*
ALMA	*Atacama Large Millimetre/submillimetre Array*
ApJ	*The Astrophysical Journal*
API	*Anton Pannekoek Insitute for Astronomy*
ASTRON	*Netherlands Institute for Radio Astronomy*
CBD	*Consortium Board of Directors*
CHIME	*Canadian Hydrogen Intensity Mapping Experiment*
CASA	*Common Astronomy Software Applications*
CNRS	*Centre National de la Recherche Scientifique National Centre for Scientific Research, France*
COVID-19	*COrona VIrus Disease 2019*
CRAF	*Committee on Radio Astronomy Frequencies*
DBBC	*Digital Base Band Converter*
DOI	*Digital Object Identifier*
EAS	*European Astronomical Society*
EC	*European Commission*
e-EVN	*electronic (realtime) European VLBI Network*
EHT	*Event Horizon Telescope*
e-MERLIN	*enhanced Multi-Element Radio Linked Interferometer Network*
EOP	*Earth Orientation Parameter*
EOSC	*European Open Science Cloud*
ERIC	*European Research Infrastructure Consortium*
ERIS	*European Interferometry School*
ESA	*European Space Agency*
ESCAPE	*European Science Cluster of Astronomy and Particle physics ESFRI research infrastructures*
ESFRI	*European Strategy Forum on Research Infrastructures*
EU	*European Union*

e-VLBI	*electronic Very Long Baseline Interferometry (imples real-time correlation) e-EVN*
EVN	*European VLBI Network*
FAST	*Five-hundred-metre Aperture Spherical Telescope*
FITS	*Flexible Image Transport System*
FRB	*Fast Radio Burst*
Gb	*Gigabit*
Gbps	*Gigabit per second*
GEP	*Gender Equality Plan*
GHz	*Gigahertz*
GMRT	*Giant Metrewave Radio Telescope*
GOODS-N	*Great Observatories Origins Deep Survey North*
GRB	*Gamma Ray Burst*
H2020	*Horizon 2020 EC Funding Programme*
HDD	*Hard-Disk-Drive*
ICE-CSIC	*Institute of Space Sciences, Spain*
IGN	*Instituto Geográfico Nacional, National Geographic Institute, Spain*
INAF	*Istituto Nazionale di Astrofisica, Italian National Institute of Astrophysics*
INAF-OA	*Istituto Nazionale di Astrofisica - Osservatorio Astronomico di Roma*
IRA-INAF	*Istituto di Radio Astronomia, Institute of Radio Astronomy, Italy*
IRAS	*Infrared Astronomical Satellite*
JIVE	*Joint Institute for VLBI ERIC*
JUICE	*JUpiter ICy moons Explorer*
JUMPING JIVE	*Joining up Users for the Maximising of the Profile, the Innovation and the Necessary Globalisation of JIVE*
Km	*Kunming station, Yunnan observatories, China*
kpc	*kiloparsec*
LOFAR	*Low Frequency Array*
LTO	*Linear Tape-Open*

M87	*Messier 87*
Maser	*Microwave amplification through stimulated emission of radiation*
Mbps	*Megabit per second*
MHz	*Megahertz*
MPIfR	*Max Planck Institut für Radioastronomie*
MT	*Management Team*
MWL	*Multi-wavelength*
NAOC	*National Astronomical Observatories of China*
NASA	*National Aeronautics and Space Administration*
NRAO	*National Radio Astronomy Observatory*
NRF	*National Research Foundation (South Africa)*
NWO	*Nederlandse Organisatie voor Wetenschappelijk Onderzoek* *Netherlands Organisation for Scientific Research*
OSSR	*Open Source software and Services Repository*
OPTICON	*Optical Infrared Coordination Network for Astronomy*
ORP-Pilot	*OPTICON RadioNet Pilot*
PB	*PetaByte*
PFB	*Polyphase Filter Bank*
PI	*Principal Investigator*
PRECISE	*Pinpointing REpeating ChIme Sources with Evn dishes*
PRIDE	*Planetary Radio Interferometry and Doppler Experiment*
pySCHED	*python SCHEDuling software*
R&D	*Research and Development*
RM	*Rotation measure*
SCHED	*VLBI Scheduling software*
SFXC	*Software Correlator at JIVE*
SHAO	*Shanghai Astronomical Observatory*
SMBH	*Super Massive Black Hole*

SOC	*Scientific Organising Committee*
STFC	*Science and Technology Facilities Research Council, United Kingdom*
TB	*Terabyte*
THEZA	*TeraHertz Exploration and Zooming in for Astrophysics*
TOG	*Technical Operations Group*
ToO	*Target of Opportunity*
UvA	*University of Amsterdam*
VDIF	*VLBI Data Interchange Format*
VEX	*VLBI Experiment Description*
VLBA	*Very Long Baseline Array, United States of America*
VLBI	*Very Long Baseline Interferometry*
VM	*Virtual Machine*
VO	*Virtual Observatory*
VR	*Vetenskapsrådet Swedish Research Council*

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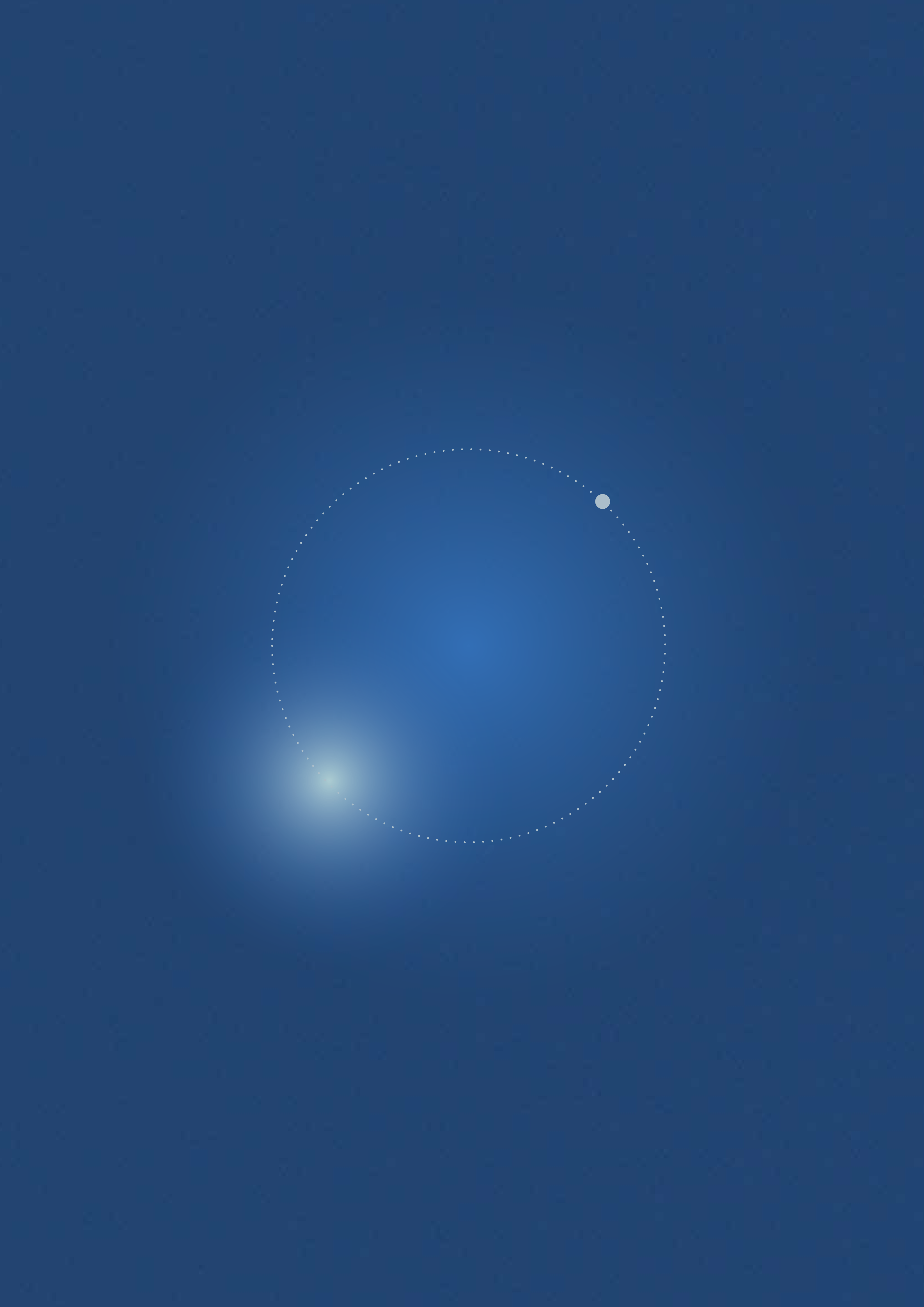

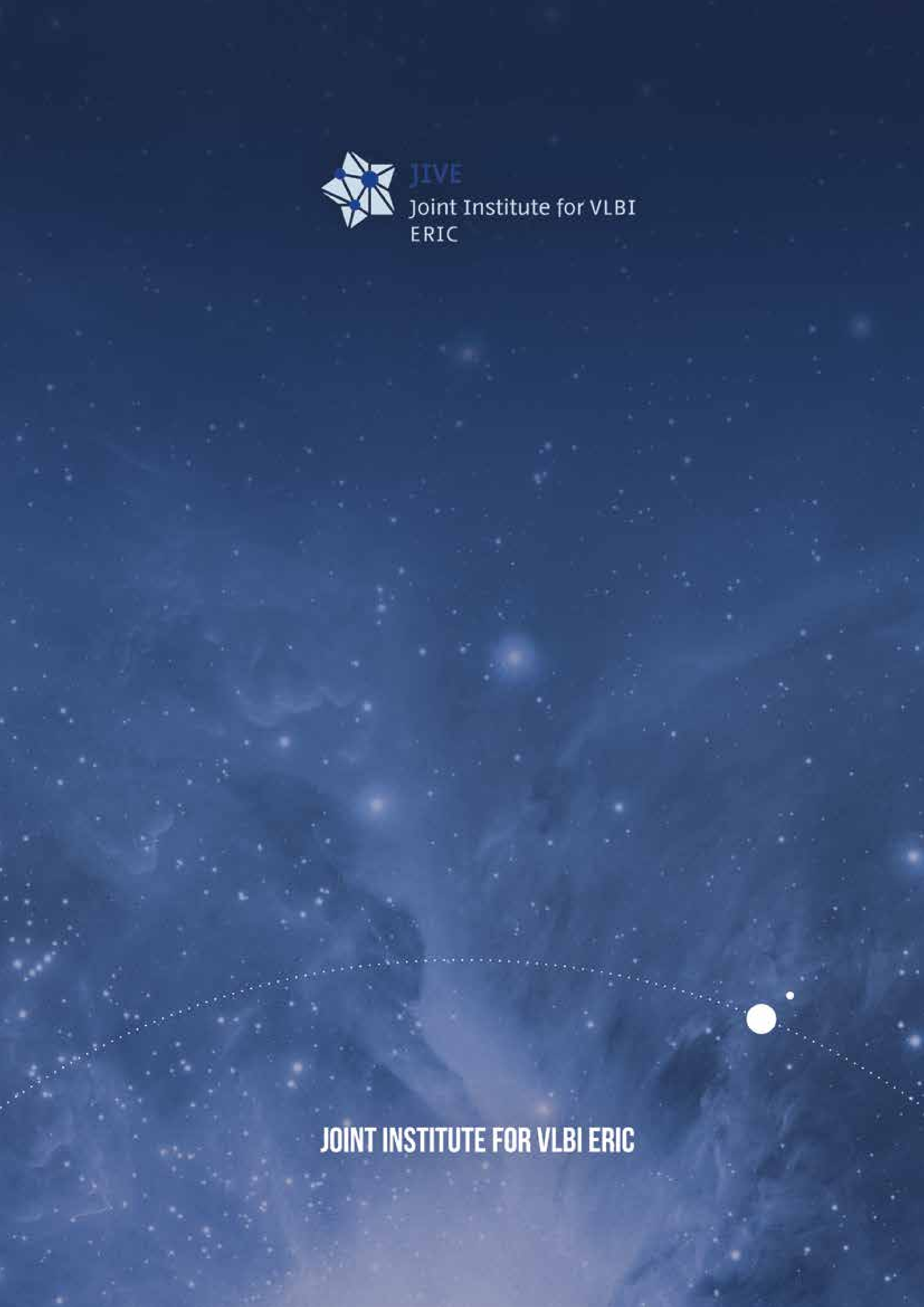
JIVE
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ERIC
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