Bologna VLBI
Life begins at 40!

Abstract booklet

MAY 22—26, 2023
BOLOGNA, ITALY

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1. Talk abstracts

Monday, May 22nd

Session: Synergies I

The Event Horizon Telescope journey from the Earth to the heart of the Milky Way (invited)

Rocco Lico
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In this talk I will provide a review of the science process, imaging analysis and theoretical interpretation that led to the publication of the first Event Horizon Telescope (EHT) images of the supermassive black hole at the center of the Milky Way, known as Sagittarius A*. These EHT 1.3mm observations, carried out in 2017, allowed us to resolve the compact emission region and to reveal a morphology dominated by a bright and thick ring with a central dark depression, the so-called black hole shadow, with a diameter of $\sim$52uas. As supported by a comprehensive suite of numerical simulations, the observed brightness distribution and morphology are consistent with the expected appearance of a $\sim$4.3 million solar masses Kerr black hole viewed at low inclination ($<$50deg).

Future prospects for constraining black hole space time

Kotaro Moriyama
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The Event Horizon Telescope (EHT) has ushered in a new era for observing the strong gravitational field and testing general relativity. Recent observations of the horizon scale images of the supermassive black hole M87* at the nearby galaxy M87 provide direct information in the vicinity of the black hole. The comparisons of the EHT observations and theoretical simulations enable us to constrain the spacetime, while it is not easy to decompose into the accretion flow properties and spacetime information because the radiation complexly depends on their effects. The next generation EHT (ngEHT) projects are expected to explore the astrophysical jet dynamics around the black hole, one of the most promising topics for extracting spacetime information. We demonstrate that the black hole spacetime can be constrained by focusing on the dynamics of the jet under the observational environments of ngEHT projects. We utilize the three-dimensional general relativistic magnetohydrodynamic (GRMHD) simulation of magnetically arrested disks (MADs) with the numerical code BHAC. The simulated jet movies are calculated with the general-relativistic radiative transfer (GRRT) scheme of the numerical code BHOSS. We introduce the hybrid thermal–non-thermal particle distribution function optimized by comparing observational and simulated continuum spectra of M87* provided in Fromm et al. (2021). Around the jet base, the launched jet has intermittent wave structures, which propagate with a relativistic time scale. The wave velocity and time development can be extracted from the simulated movies and show monotonic dependence on the black hole spacetime. We finally perform the synthetic observation of M87* and show the detectability of velocity features and the black hole spacetime information under the expected ngEHT observations.

VLBI probes of jet physics in neutrino-candidate blazars

Florian Eppel
Julius-Maximilians-Universität Würzburg, Germany

In recent years, evidence has started piling up that some high-energy cosmic neutrinos can be associated with blazars. The strongest evidence for an individual association was found in the case of the blazar TXS 0506+056 in 2017. In July 2019, a different track-like neutrino event (IC190730A) was found spatially coincident with the well-known bright flat-spectrum radio quasar PKS 1502+106. PKS 1502+106 was not found to be in a particularly elevated gamma-ray state, but had been exhibiting a remarkable bright radio outburst at the time of the neutrino detection, similar to TXS 0506+056. We have performed a multi-frequency VLBI study from 15 GHz up to 86 GHz on TXS 0506+056 and PKS 1502+106 and one additional neutrino-candidate blazar (PKS 0215+015) to study the radio structure of neutrino candidate blazars in response to their neutrino association. We have obtained target of opportunity observations with the VLBA for all three sources within $\sim$1 month from the associated neutrino event and perform multi-epoch studies on the jet kinematics at 15 GHz as part of the MOJAVE program. Here, we present first results on the contemporary parsec-scale jet morphology of all three sources in total intensity and polarization to constrain possible physical processes leading to neutrino emission in blazars.

At the extremes of the electromagnetic spectrum: synergy of MAGIC and VLBI arrays

Cristina Nanci on behalf of the MAGIC collaboration
University of Bologna / INAF-IRA, Italy

The emission from blazar jets extends over the entire electromagnetic spectrum, from the radio to the very-high-energy (VHE) gamma rays range. The VLBI technique characterizes the parsec-scale regions of blazar jets. VLBI observations, e.g. through core-shift studies, can break degeneracies in the parameters describing the VHE emission. In the VHE gamma rays range, Imaging Cherenkov telescopes as the MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) telescopes allow the investigation of the high energy part of the blazar spectrum, strongly connected with the jet evolution. The VLBI+MAGIC combination can lead to constraining the emission scenario of a variety of blazar objects (and also of other sources as radio galaxies like M87 and 3C84). Both BL Lacs and flat spectrum radio quasars (FSRQ) have been analyzed in a multi-wavelength context, with a focus on the VLBI - gamma ray link.

In several cases, as the one of the FSRQ QSO B1420+326 and the one of the BL Lac S5 0716+714, the analysis of multi-epoch VLBI images has revealed a connection between VHE variability and the ejection of new knots of relativistic plasma which allowed us to confine the VHE emitting region in the jet. A brightening of the VLBI core in BL Lacertae was detected during its flaring activity in 2015, indicating a link between the emission processes in the radio and the high energy regime. In this case, VLBI measurements were also used in setting the parameters for the modelling of the broadband spectral energy distribution. In this contribution, we report successful examples of the VLBI+MAGIC synergy, as the ones cited above and others currently in preparation within the MAGIC collaboration.

The impact of Southern hemisphere VLBI blazar observations on Neutrino Astronomy

Florian Roesch
Julius-Maximilians-Universität Würzburg, Germany

The origin of high-energy cosmic neutrinos detected by the IceCube observatory is a hotly debated topic in astroparticle physics. Evidence is accumulating that some of these neutrinos can be associated with AGN and especially with blazars. Several recent studies have revealed a statistical correlation between radio-bright AGN samples and IceCube neutrino event catalogs. In addition, a growing number of individual high-energy neutrinos have been found to coincide with individual radio-flaring blazars. These observational results strongly call for high-quality, high angular-resolution radio observations of such neutrino-associated blazars to study their parsec-scale jet structures. TANAMI is the only large and long-term VLBI monitoring program that focuses on the Southern sky. Within TANAMI, we put a focus on Southern IceCube neutrino-candidate blazars at the S and X band. Here, we present first results of these S-band observations. The rapidly growing KM3NeT, located in the Mediterranean sea, is joining IceCube, located at the south pole, in yielding complementary neutrino data in both hemispheres. This further increases the importance of southern-hemisphere radio monitoring programs of neutrino-associated blazars, like TANAMI.

Low-frequency VLBI with the International LOFAR Telescope (invited)

Roland Timmerman
Leiden Observatory, The Netherlands

Recent breakthroughs in the calibration of observations taken with the International LOFAR Telescope (ILT) have enabled imaging with an angular resolution of only 0.3 arcseconds in the low-frequency regime ($\sim$100 MHz). Compared to the previous best resolution achievable at these frequencies (6″), the ILT's resolution is a transformational twenty-fold improvement. As we are now able to study the structure of many AGN radio lobes, star-formation regions and high-redshift radio galaxies in detail at such low frequencies for the first time, the ILT has unlocked a wide variety of scientific opportunities. Thanks to its low observing frequency, ILT observations are not only particularly well suited to map steep-spectrum emission, but they also provide an excellent match to higher frequency observations for spectral index mapping purposes. For instance, the ILT at 144 MHz is able to match the resolution of the Very Large Array up to C band (5 GHz). In this talk, I present the progress we have made with the calibration of ILT observations, the science that has been enabled by this order-of-magnitude improvement in angular resolution, and the future of the ILT.

Deep International LOFAR observations of the NEP region

Marco Bondi
INAF - Istituto di Radioastronomia, Italy

During the past year the International LOFAR Telescope (ILT, aka LOFAR-VLBI) data analysis has been greatly improved and refined reaching sub-arcsec resolution imaging at 144 MHz with noise of a few tens of microJy/beam (for an 8-hr observation) on a routine basis. The improvement of about a factor of 20 in angular resolution (from 6″ of LOFAR to 0″.3 of ILT) is fundamental to study the bulk of radio sources detected in the deep fields which are located at redshift about or greater than 1 and, at the same time, to obtain images of the lobes and hotspots of the brightest giant radio galaxies in the field with unprecedented details at this frequency. The LOFAR Deep Fields are a great opportunity to exploit the sub-arcsecond resolution of the ILT since the main targets of these deep observations are galaxies at z geq 1 and the longer observations allow to reach noise level around 10 microJy/beam. In this talk I will present the results obtained from 72 hours of observation centered on the Euclid Deep Field North (EDFN) in the North Ecliptic Pole (NEP) region. In particular, I will show and discuss some of the deepest ILT images (rms $\sim$15 microJy/beam) obtained so far of high-redshift radio galaxies and bright sub-mm sources in the NEP region.

Session: Cosmology

Surveys using VLBI – the past, present, and its bright future (invited)

Jack Radcliffe
University of Pretoria, South Africa

For over 20 years, a significant effort has been made to map the milliarcsecond sky with VLBI. The largest surveys are targeted and require many years of observations to build up an extensive sample. However, computational improvements have enabled us to map the entire primary beam of VLBI arrays and push into the lower frequency regime through the International LOFAR telescope. In this talk, I will talk about the scientific and technical discoveries arising from such surveys and focus on the bright future of VLBI surveys. This includes the transition from the current modus operandi of a small number of surveys of a few "famous" deep fields to a ubiquitous VLBI survey instrument. I will touch on other developments, such as the incorporation of SKA and MeerKAT, ultra-wideband receivers, and GPU-accelerated correlation and calibration.

Cosmological studies with VLBI and strong gravitational lensing (invited)

Cristiana Spingola
INAF - Istituto di Radioastronomia, Italy

Current small-scale cosmological controversies are coming down to the precision level of observations. The key point is whether a better understanding of baryonic physics, dark matter physics, or both is required to address these challenges. In this talk, I will describe how VLBI and strong gravitational lensing are contributing to understand some of these small-scale cosmological issues from both a dark matter and a baryonic perspectives up to high redshift.

The SMILE project

Carolina Casadio
Institute of Astrophysics - FORTH, Greece

Several methods are employed in projects seeking to understand the elusive nature of dark matter. The approach used by the Search for MIlli-LEnses (SMILE) project makes use of strong gravitational lens systems in the milliarcsecond regime, where the lens is a compact object with mass between $\sim 10^6$ and 10^9 solar masses. This mass range is crucial for the widely accepted ΛCDM cosmological model, which predicts the existence of many more DM sub-galactic halos ($< 10^{11}$ solar masses), than the currently observed number. To explore such small angular scales, high-resolution radio VLBI data are used. Searching for milli-lenses in a catalog of $\sim$ 5000 radio loud sources, will allow us to detect lenses in this mass range, or, failing that, to tighten significantly our constraints on the number of sub-galactic halos and consequently discard some viable DM models, as we demonstrated in Loudas et al., 2022 (2022A&A...668A.166L).

Results from the EVN follow-up study of a sample of milli-lens candidates

Felix Pötzl
Institute of Astrophysics - FORTH, Greece

The SMILE (Search for MIlli LEnses) project (see talk by Carolina Casadio, also Casadio et al. 2021) aims at discerning the number of milli-lens systems in a sample of 5000 sources based on the CLASS VLA survey at 8 GHz, observed with Very-Long-Baseline Interferometry (VLBI) at milliarcsecond resolution. In a pilot project, we have searched for milli-lens candidates in a sample consisting of 13,828 compact radio sources from the Astrogeo VLBI FITS image database at 5 and 8 GHz to identify lens candidates. Forty candidates with compact double structures have been found using a citizen-science approach, for which I will present the ongoing analysis of EVN follow-up observations at 5 and 22 GHz in phase-referencing mode. These observations with increased sensitivity and frequency coverage allow us to better constrain the nature of the lens candidates. We find some interesting sources that are still viable lens candidates, given constrains such as surface brightness ratio, stability of flux density ratio of components over time, and their spectrum. Other sources are potential compact symmetric objects or even binary black hole candidates, and thus also deserve closer attention.

Gravitational lensing in the age of ILT and SKA-VLBI

John McKean
ASTRON / University of Groningen - Kapteyn Institute, The Netherlands

The first VLBI observations of strong gravitational lensing were reported about 44 years ago, and since then, the field has grown to become an important tool for studying galaxy formation, dark matter and the distant Universe at the highest angular resolutions possible in astronomy. Unfortunately, only a handful of radio-bright lenses are known, identified mainly from the first systematic lens surveys and some serendipitous discoveries over the last four decades. However, this is set to change with the large area all-sky surveys being carried out now with the Low Frequency Array (LOFAR) and with the Square Kilometre Array (SKA) in the future, which will discover tens of thousands of new systems. Here, we present the first results from observations of known gravitational lenses with LOFAR and the new discoveries being made with the International LOFAR Telescope (ILT). For the latter, we will present a novel machine-learning based method for identifying lenses with the ILT, from which, we have determined the types of lenses that the ILT is likely to find. We will show the first results from applying this and standard catalogue-based searches for lenses in the first batch of data from the ILT, and will present the first set of new lens candidates to be identified with LOFAR. Finally, we will discuss the prospects for lens discovery with the SKA and the importance of having a VLBI array within Africa for realising the unique science cases that are only possible with strong gravitational lensing.

Fuzzy dark matter constraints from a single VLBI observation of a gravitationally lensed radio jet

Devon Powell
Max Planck Institute for Astrophysics, Germany

Strong gravitational lensing by galaxies provides us with a powerful laboratory for testing dark matter models. Various particle models for dark matter give rise to different small-scale distributions of mass in the lens galaxy, which can be differentiated if the observation is sensitive enough. The sensitivity of a gravitational lens observation to the presence (or absence) of low-mass dark structures in the lens galaxy is determined mainly by the angular resolution of the instrument and the spatial structure of the source. In this talk, I will present results from the analysis of a global VLBI observation of a gravitationally lensed radio jet. With an angular resolution better than 5 milli-arcseconds and a highly extended, spatially resolved arc, we are able to place competitive constraints on the particle mass in fuzzy dark matter models using this single observation. I will also present preliminary results from our analysis of warm dark matter models using this lens system. Our results illustrate the key role that VLBI observations will play in revealing the nature of dark matter, especially in light of the $\sim 10^5$ gravitational lens systems with radio-bright sources which will be discovered by the Square Kilometre Array.

Session: AGN I

A sharp view of the AGN central engine in M87

Rusen Lu
Shanghai Astronomical Observatory, People's Republic of China

Due to its proximity and large black hole mass, the nearby radio galaxy M87 is a prime target for high-resolution imaging studies of an AGN central engine. In this talk, we will report on the first VLBI images of M87 obtained with the Global Millimeter VLBI Array in conjunction with the phased ALMA and the Greenland Telescope at a wavelength of 3.5 mm

Transverse oscillations of the M87 jet revealed by KaVa observations: superluminal wave propagation along the jet

Hyunwook Ro
Korea Astronomy and Space Science Institute, Republic of Korea

Recent VLBI observations have found transverse motions of the M87 jet. However, due to the limited cadence of previous observations, details of the transverse motion have not been fully revealed yet. In this work, the transverse motions of the M87 jet were investigated through high-cadence monitoring at KVN and VERA Array (KaVA) 22 GHz from December 2013 to June 2016. In our observations, the M87 jet is well represented by double ridge lines in the region 2 - 12 mas from the core. In the transverse velocity field of the M87 jet, we found that the direction of transverse motion changes several times with distance and time. In addition, from the sinusoidal fit, we found that the ridge lines oscillate in all observed regions with an average period of 0.94 $\pm$ 0.13 years. The amplitude of these oscillations is $\lesssim$ 0.2 mas, and the oscillations in the northern and southern limbs are almost in phase. Interestingly, the phase of the oscillations continuously increases with distance, indicating that these oscillations originate from the propagation of waves. The apparent propagation speed of the wave is about 2.7 - 2.9 c, faster than the apparent bulk jet speed at this distance. We propose possible scenarios of the transverse oscillations, such as propagation of Alfvén wave excited by swinging of the jet base, twisted structures created by MHD instabilities, or perturbed mass injection around magnetically dominated accretion flows.

Parsec-scale jets of FR0 radio galaxies

Rainieri Baldi
INAF - Istituto di Radioastronomia, Italy

Radio galaxies (RGs) are active galactic nuclei (AGN) able to launch relativistic jets, the most energetic phenomena in the Universe, which can have a large impact on galaxy evolution. Current high-sensitivity and high-resolution surveys have shed new light on properties of RGs, particularly in the local Universe (z<0.3) and at low luminosities ($< 10^{24}$ W/Hz a 1.4 GHz), where the bulk of the AGN population was not much explored in opposition to the well-studied powerful RGs. A large population of compact RGs, named FR0s, which differ from classical FRI/II RGs, by lacking large-scale (>10 kpc) jet emission, is emerging from recent studies and is revolutionising our idea of an ordinary RG. These compact sources show host and nuclear characteristics similar to those of FRI RGs. However, in the radio band, while FR0s and FRIs share the same core properties, the kpc-scale diffuse component dominant in FRI is missing in FR0s. VLBI observations of FR0s can probe the parsec-scale region to study their actual capability of launching jets with respect to FRIs. I will present VLBA, EVN and eMERLIN observations of a sample of FR0s, which provide evidence that parsec-scale jets in FR0s are mildly relativistic with a bulk velocity on the order of 0.5c or less. A jet structure with a thin inner relativistic spine surrounded by a low-velocity sheath could be in agreement with the observed FR0 properties.

Intermediate mass black holes: episodic jet activity in dwarf galaxies

Jun Yang
Onsala Space Observatory, Sweden

Very low-luminosity and low-mass galaxies, i.e. dwarf galaxies, may also host active galactic nuclei (AGNs) because of significant accretion and ejection activity of intermediate black holes (<1 million solar masses). In a few dwarf AGNs, very long baseline interferometry (VLBI) observations have found faint non-thermal radio emission. In this talk, we present the strong evidence for episodic, large-scale ($\sim$140 pc) and powerful jet activity observed by the European VLBI Network (EVN) in a dwarf galaxy (SDSS J090613.77+561015.2). Moreover, we collected a sample of VLBI-detected dwarf AGNs and investigated their connections with normal AGNs. We notice that these radio sources in the dwarf AGNs tend to have steep spectra and small linear sizes, and possibly represent ejecta from scaled-down episodic jet activity.

High-resolution low-frequency probes of X-ray emitting knots in blazar jets

Hrishikesh Digambar Shetgaonkar
Julius-Maximilians-Universität Würzburg, Germany

The X-ray emission of resolved jet knots in many high-luminosity quasar jets, cannot be explained as a simple extension of the radio synchrotron spectrum and so far no general consensus could be reached on the relative importance of the different broadband-emission processes at play. Hence, new observational constraints are needed to better constrain emission models. We focus our study on a sample of blazars with X-ray jets for which subarcsec-scale low-frequency radio spectral information can be obtained by applying VLBI techniques to LOFAR observations. The long international baselines of LOFAR allow us to spatially resolve the X-ray emitting jet knots in our target sources and to probe the previously inaccessible part of the low-energy electron population. In combination with shorter-wavelength radio and higher-energy broadband spectral data, these LOFAR-VLBI data can test and constrain the Inverse-Comptonization of CMB photons (IC/CMB) and alternative emission models. Here, we present first results from this project with a focus on the radio and X-ray jet of OJ287 at sub-arcsecond resolution.

Tuesday, May 23rd

Session: Technology and methods I

Exploring New Frontiers: High-Frequency VLBI Prospects (invited)

Eduardo Ros
Max Planck Institute for Radioastronomy, Germany

High-frequency VLBI is demonstrating its power with recent achievements such as imaging the shadow of black holes and the inner jet regions in active galactic nuclei. Ongoing developments in digital back-ends, calibration techniques and imaging methods, combined with the implementation of multi-band options, are dramatically extending the capabilities of VLBI at millimetre wavelengths. This will allow us to study fainter sources such as transients, radio quiet galaxies and galactic objects, to obtain previously inaccessible astrometric information, and to measure opacity and polarised emission in the collimation and acceleration regions of extragalactic jets to probe the strength and orientation of magnetic fields near the event horizon of the powering supermassive black hole. I will review current developments in high-frequency VLBI and present the prospects for the new science that will be possible with improved sensitivity, image fidelity, polarisation and astrometric capabilities. I will discuss synergies with multi-messenger astronomy, such as for very high energy gamma rays and neutrino associations, and show how mm-VLBI also paves the way for the high-resolution capabilities of the coming connected interferometers that will shape radio astronomy in the next decades.

Technical Advances in High-Frequency VLBI: A Focus on Multi-Frequency Receivers and Their Applications (invited)

Taehyun Jung
Korea Astronomy and Space Science Institute, Republic of Korea

High-frequency very long baseline interferometry (VLBI) observations have made remarkable progress in astrophysics and fundamental physics in recent years, owing to technical advances in receivers, digital backend, high-speed recording systems, and data processing methods. One critical advancement that has facilitated this progress is the use of multi-frequency receivers, such as the Korean VLBI Network (KVN), which allows for simultaneous reception of radio signals at multiple frequencies. Multi-frequency receivers have been particularly effective in millimeter VLBI, as they enable longer integration times up to hundreds of seconds at 130 GHz, demonstrated by KVN, by using fringe phase solutions at lower frequencies to calibrate high-frequency visibility data, known as frequency phase transfer (FPT). Moreover, multi-frequency receivers with FPT are facilitating submillimeter VLBI and space VLBI observatories. This presentation will discuss recent developments and technical aspects of high-frequency VLBI utilizing multi-frequency receivers, as well as scientific perspectives. These advances are promising to enable new discoveries and applications that can only be achieved with VLBI.

Steps towards a millimeter VLBI facility in Medicina and Noto

Alessandro Orfei
INAF - Istituto di Radioastronomia, Italy

In this talk I present an update about the implementation of the capability to observe up to 116 GHz at the 32m Medicina and Noto Italian radio telescopes: available receivers, upgrade of the overall surface accuracy and valuation of the performances.

VLBA technical developments

Walter Brisken
National Radio Astronomy Observatory, USA

The VLBA has been in operation for 3 decades. Over this time, it has seen several important upgrades that increase its sensitivity and capability. In this talk I will discuss some ongoing efforts to continue this trend of improvements. These include a new digital back-end system, transition to electronic transfer of data, including real-time correlation, and improved timing. Some desired, but currently unfunded, projects will also be discussed.

Major threats and challenges for present and future radio astronomical observations and VLBI techniques

Vincenza Tornatore
Politecnico di Milano, Italy

The highly increasing global connectivity has raised significant concerns on the impact of new technologies radio astronomy observations. An unprecedented effort is nowadays needed to protect and preserve astronomical research against old and new active radio services, in particular the telecommunication systems including large satellite constellations and 5G networks . In this context, the committee on radio astronomical frequencies (CRAF) has been involved in the protection of European radio astronomy observatories and research institutes since its foundation in 1988.

Today, large satellite constellations consist of thousands of low Earth orbit (LEO) satellites that are being deployed by companies such as SpaceX, OneWeb, and Project Kuiper (a project led by Amazon) having the potential to revolutionize the telecommunications industry by providing global connectivity. According to current plans, more than 50,000 satellites will be launched in the next decade. Of special interest to radio astronomer are the downlink frequencies on which the satellites transmit data to the user terminals. Current plans by the industry range from less than a GHz up to 100 GHz. This downlink signal can impact sensitive observations in the radio astronomy service (RAS) band, but can also affect such as band 5 of SKA- Mid or VGOS receivers. For this reason, in some European countries, licenses have been granted to constellation operators with the prohibition of transmitting in spot areas centred around radio observatories. In the meantime, a new hot topic has emerged – operating normal cell-phone base stations on satellites to connect normal smartphones to satellites.

Another very worrying development is currently seen in the preparation of the next World Radiocommunication Conference (WRC). Cell-phone stakeholders would like to get a significant part of the spectrum in the so-called mid-band. This would heavily impact observations of the methanol spectral line at 6650-6675.2 MHz. At the moment, it is unclear whether this band will be identified for cell-phone use at the ITU-R level, but many European countries are prepared to use the 6-GHz band for either cell-phone networks or high-bandwidth WiFi. CRAF was heavily involved in the discussions and also contributed several compatibility calculations, which we will present. Studies showed that the huge conducted power levels of cell-phone base stations would have high impact on any RAS operations, including VLBI and huge coordination zones (several 100 kilometers) would be required.

In conclusion, the deployment of large-scale satellites and 5G networks raises concerns for the astronomical community. The situation is difficult, but CRAF continues to work to incorporate the necessary regulations for the protection of radio astronomy from large satellite constellations or cell-phone networks. The interference caused by these active radio services can degrade the sensitivity and accuracy of scientific observations, which are critical to our understanding of the Universe. A special focus on spectrum management and monitoring activities at Italian VLBI stations will also be given while presenting some of the major challenges that need to be faced in the future.

Session: AGN II

The 40-yr History of 3C84 and Future Prospects with VLBI and ALMA (invited)

Hiroshi Nagai
National Astronomical Observatory of Japan, Japan

3C 84 is the bright, nearby radio source that is associated with a giant elliptical galaxy NGC 1275 (z=0.0176). Thanks to its proximity and brightness, 3C 84 has been studied using VLBI extensively in the context of jet formation, mechanism of high energy emission, jet interaction with circumnuclear gas, and so on. In this talk, I will look back the 40-yr history of 3C 84 study with VLBI. Then, I will present our recent ALMA+VLBI results on the study of inflow from galactic scale to parsec scale as well as AGN outflow in connection with the jet activity.

Cold gas in the heart of 3C84

Raffaella Morganti
ASTRON / University of Groningen - Kapteyn Institute, The Netherlands

One way to trace and study cold gas in the central regions of radio galaxies is by observing HI in absorption at the high resolution offered by VLBI. In this way, we can identify the location and properties of the gas. The presence of rotating structures (circumnuclear discs and tori) and of gas with disturbed or highly turbulent kinematics, are all key elements for understanding the evolution of both the AGN and the host galaxy. Here we focus on the case of 3C84, one of the most famous

radio galaxies, located in the central galaxy (NGC 1275) of the iconic gas-rich, cool-core Perseus cluster. Earlier, two HI absorption systems have been found in this object: one extremely narrow and highly redshifted, likely associated with a galaxy interacting with NGC1275, and one as broad as FWZI$\sim$800 km/s, centred around the systemic velocity of NGC1275. The latter has been the focus of our study. We have traced this HI component on multiple scales, from kpc (using the WSRT and VLA) down to pc scales using the VLBA. While the deep and broad absorption is clearly observed on the few hundred pc scales probed by the VLA - the surprising result obtained with the VLBA indicates that the HI in this radio galaxy is not located against the core or the jet of 3C84, but instead in a larger, disk-like structure of at least 100 pc, perpendicular to the jet. Indications for the presence of such a structure in radio continuum (i.e. the background that allows us to see the HI in absorption) was already found years ago in low-frequency VLBA observations while the presence of a cold molecular circumnuclear disc of similar size is confirmed by ALMA. The similarity of the velocities covered by the HI and the molecular gas indicate that neutral hydrogen should be present down to distances of 60 pc from the SMBH. The combination of the HI observed in absorption and the molecular gas (observed in emission) tells us about the structure of the circumnuclear disc and are essential information for obtaining a complete view of the complex nuclear region of AGN. We do not see signatures of the cold HI gas being affected by the interaction with the radio jet and we discuss the likely impact of the jet on the evolution of the radio source. If time allows, these results will be compared with what found from HI VLBI observations for other radio galaxies.

Gas morphology and kinematics of NGC4261: probing the AGN fuelling with VLBI

Satoko Sawada-Satoh
Osaka Metropolitan University, Japan

It is now widely accepted that active galactic nucleus (AGN) activity is powered by mass accretion onto a central supermassive black hole (SMBH). How the ambient environment of AGN drives mass accretion is one of the most important questions regarding the AGN fueling process. To date, VLBI has revealed the parsec- and/or sub-parsec-scale morphology and kinematics in the immediate vicinity of the SMBH. Moreover, millimeter and submillimeter interferometers such as SMA, ALMA and NOEMA can provide complementary information about the circumnuclear environment on sub-kiloparsec scales. In this talk, we present the recent results from our NOEMA and VLBI observations toward a nearby radio-loud AGN NGC 4261. We detected HCN and HCO^+ J=1-0 emissions representing a rotating circumnuclear disk with an outer radius of 100 pc. In addition, we imaged 22 GHz water maser emission, at the positions where the free-free absorption opacity was high on the receding jet. To explain all the observed characteristics, we propose a scenario of multiphase gas disk with ionized and molecular gases, as a reservoir of fuel for its SMBH.

A 20+ year overview of VLBI observations of the peculiar radio source 3C84

Georgios Filippos Paraschos
Max Planck Institute for Radioastronomy, Germany

The super-massive black holes (SMBH) located at the centres of AGN often launch highly relativistic jets. The main jet launching scenarios are either due to magnetic field lines anchored to the accretion disk (Blandford & Payne 1982) or directly connected to the black hole's (BH) ergosphere (Blandford & Znajek 1977), and are an ongoing, hot topic of active research. Very long baseline interferometry (VLBI), and specifically at millimetre wavelengths, offers an unparalleled view into the physical processes in action, in the close vicinity of BHs. Owing to its proximity and only moderate Doppler-boosting, the nearby radio-galaxy 3C 84 (NGC 1275) is a very suitable target for VLBI observations at the highest frequencies and spatial resolutions. Utilising archival and our own millimetre-VLBI observations of 3C 84 obtained over the past 20+ years, we can trace the VLBI jet of 3C 84 down to scales of $\sim$100 Schwarzschild radii, facilitating the study of jet formation and acceleration. Our observations reveal a limb brightened, double-rail structure reaching deep into the core region. As part of this analysis we also associate jet component ejection events with the multi-wavelength variability light-curves at radio frequencies and gamma-rays. Furthermore, by cross-correlating these light-curves, which span a time frame of 40+ years, we determine time-lags and draw conclusions regarding the location of the high energy emission at the jet base. Finally, we constrain the magnetic field strength and structure. In this talk I will give an overview of more than four decades of VLBI observations of 3C 84 and then present new results from recent global VLBI imaging campaigns.

The origin of Faraday rotation in 3C84 revealed by KVN and VLBA

Kam Minchul
Seoul National University, Republic of Korea

3C 84 is an active galactic nucleus (AGN) with a young radio jet located at the center of the elliptical galaxy NGC 1275. It is almost unpolarized at cm wavelengths, probably due to strong depolarization by Faraday rotation. However, the origin of the Faraday rotation has been a matter of debate for the past 20 years. To investigate this, we measured the rotation measure (RM) at the jet termination region (C3) of 3C 84 with the KVN and VLBA when C3 was at different locations over time. Surprisingly, the RM values ranging from 1 to 10 pc decrease with distance from the central black hole, following a single power law. Furthermore, RM values obtained with SMA, CARMA, and IRAM PdBI (for which 3C84 is a point source) appear to follow the same relation if we assume that the polarized emission at mm/sub-mm wavelengths likewise originates from C3. This strongly suggests that different RM values, previously thought to originate from different mediums, actually originate from the same medium. Based on these observations, we conclude that the ionized gas at the central region of AGN is the origin of the Faraday rotation in 3C84.

Session: Technology and methods II

New methods for VLBI observations and the associated science opportunities (invited)

Richard Dodson
UWA / The International Centre for Radio Astronomy Research, Australia

I will present the current progress and future potential for VLBI performance, with a focus on the current arrays but also for future observations with SKA and other next-generation interferometers. We are in a moment of great promise as the multiple next-generation radio facilities, on the point of or in construction, will provide a huge boost in sensitivity and frequency coverage. These advances are being matched by developments of next-generation methods that will ensure the current systematic limits can be overcome - to deliver on the potential and enabling transformational science.

Foremost among these new methods are MultiView and Source/Frequency Phase Referencing. The former has demonstrated an increasing number of astrometric measurements with outstanding performance, reaching the thermal noise limit of the current VLBI networks. We can expect an order of magnitude improvement for SKA-VLBI with per epoch errors of $\sim$10uas at 1.4GHz and per epoch errors of $\sim$1uas above 8GHz. The technological requirement for this is an upgraded network of antennas that match the SKA capabilities for multibeam observations. Source/Frequency Phase Referencing requires multifrequency observations, and this is particularly timely, given the equipping of three Italian stations with compact triple-band receiver technology that will enable global SFPR experiments. Initially these will mainly be with the Korean network that was a pathfinder for this method, but also with a rapidly increasing number of similarly equipped European stations. A recent development is that a similar approach will also be applied up to 340-GHz, with the ngEHT. Finally the long baselines of ngVLA will have multiple antennas at each station. We will discuss how these can be used to perform both of these style of observations, enabling astrometric applications upto 120-GHz.

With all of these new capabilities on the horizon the future, at 40, is burning as bright as a ruby.

Celebrating 40 years of astrometric and geodetic VLBI data – a solid foundation for celestial and terrestrial reference frames (invited)

Hana Krasna
Technischen Universität Wien, Austria

Very Long Baseline Interferometry (VLBI) is a measurement technique at radio wavelengths, which is used - among others - for astrometric and geodetic purposes providing a unique source of data for the creation of global celestial and terrestrial reference frames. Furthermore, it is the only measurement technique that provides the full set of Earth orientation parameters, which describe the connection between the two reference frames. In this talk, I introduce the latest VLBI celestial and terrestrial reference frames VIE2022 computed at TU Wien which include VLBI data until December 2022. They can be seen as an extension of the current International Celestial and Terrestrial Reference Frames, the ICRF3-sx and ITRF2020, which incorporate the VLBI observations at the standard S/X band frequencies (2.3/8.4 GHz) until March 2018 (ICRF3-sx) and December 2020 (ITRF2020). In the framework of the K band collaboration, a celestial reference frame at the frequency 24 GHz is also estimated at TU Wien. Over 99% of the K band single frequency data are produced by the Very Long Baseline Array (VLBA), which induces challenges in the data analysis connected to the geometry of the telescopes placed in the territory of United States. Furthermore, the latest terrestrial reference frames incorporate data from the novel VLBI Global Observing System (VGOS) which is based on the broadband delay using several frequency bands in the range from 2.5 to 14 GHz. The first test sessions were run in December 2017 and the regular observations started in January 2019. The challenges adherent to the position estimation of the newly built VGOS telescopes are addressed.

Introduction of Jingdong 120-m radio telescope

Longfei Hao
Yunnan Observatories, CAS, People's Republic of China

In Jingdong County (101° E, 24.5° N), Pu'er City, Yunnan Province, the Yunnan Observatories Chinese Academy of Science will construct a 120-meter radio telescope dedicated to pulsar-related science. The telescope covers the frequency range from 100 MHz to 10 GHz (i.e., from the wavelength 3m to 3cm). Once finished, it will be the world's largest fully steerable single-dish decimetre-wavelength radio telescope. This topic introduces the scientific objectives and key technologies of JRT. The JRT will be driven by three major scientific goals, which include (1) long-term high-precision pulsar timing for time-frequency metrology and nanohertz gravitational wave detection; (2) pulsar astrophysics, fast radio bursts, gravity theory tests, and black hole physics; (3) deep space exploration, geodesy, and celestial reference system. We will also cover the engineering design aspects in this topic, and present current plan and design for the telescope mechanical structure, front-end, digital backend, and control system.

Synoptic Wide-field e-MERLIN EVN Programme

Célestin Herbe-George
University of Groningen - Kapteyn Institute, The Netherlands

The high angular resolution and sensitivity of VLBI offers a unique tool to identify and study AGN and star-formation activity over cosmic time. VLBI observations are crucial for identifying young radio sources and unveiling older restarted radio sources. Also, radio imaging over a large range of angular scales is needed to determine the role of black hole feedback and jet-induced star formation in galaxies. To answer these questions and to find rare radio sources, such as gravitational lenses and binary/dual AGN, all-sky VLBI surveys are needed. Despite recent technical advances, such as multiple phase centre correlation and multi-source self-calibration, only a limited part of the sky has been observed within a few well-studied fields (e.g. Lockman Hole, HDF, GOODS-N, COSMOS, SPARCS-N). To enter the realm of large statistical studies, a significantly larger area of sky must be observed, which would limit the VLBI available time for other single-target science projects.

SWEEPs (Synoptic Wide-field e-MERLIN EVN Programme) is a commensal survey mode for the e-MERLIN + EVN, where single-target PI-led observations are re-correlated at the position of all sources within 12 arcmin. The phase centres are selected using an e-MERLIN only wide-field image generated during the initial correlation (with additional correlations from LoTSS and VLASS). This program has the potential to observe up to 9000 radio sources per year, yielding an expected 1900 VLBI detections without any additional observing time. Here, we present preliminary results and methods from a pilot program, using a PI-led single target observation where we obtained 257 additional phase centres (127 in the calibrator field + 130 in the target field). From this study, we have investigated imaging methods for the multiple angular-scales of e-MERLIN + EVN, have tested robust pipelines to accurately detect sources and carried out an investigation into the correlation and data processing requirements of a new wide-field observing mode for the EVN (commensal multiple phase centre correlation) as part of SWEEPs. This understanding is important for its implementation as part of a future SKA-VLBI, a mode that will require significantly more phase centres (1000s) due to SKA's increased sensitivity.

Session: Spectral line

VLBI with ALMA in the field of maser studies (invited)

Liz Humpreys
ALMA / European Southern Observatory, Chile

Maser lines from species such as SiO, HCN, water, methanol and atomic hydrogen lie in the ALMA Bands. There are several reasons to study masers in the mm/submm in addition to study at longer wavelengths. These include higher angular resolution, the ability to potentially trace out different parts of targets and the possibility to probe regions for which emission from other maser transitions could be obscured. In this talk, I will discuss the implications of VLBI with ALMA for masers in evolved stars, star-forming regions, and the circumnuclear regions of AGN.

A Keplerian disk with a four-arm spiral birthing an episodically accreting high-mass protostar

Ross Burns
RIKEN, Japan

High-mass protostars ($M_\star > 8 M_\odot$) are thought to gain the majority of their mass via short, intense bursts of growth. This episodic accretion is thought to be facilitated by gravitationally unstable and subsequently inhomogeneous accretion disks. Limitations of observational capabilities, paired with a lack of observed accretion burst events has withheld affirmative confirmation of the association between disk accretion, instability and the accretion burst phenomenon in high-mass protostars.

Following its 2019 accretion burst, a heat-wave driven by a burst of radiation propagated outward from the high-mass protostar G358.93-0.03-MM1. Six VLBI (very long baseline interferometry) observations of the raditively pumped 6.7 GHz methanol maser were conducted during this period, tracing ever increasing disk radii as the heat-wave propagated outward. Concatenating the VLBI maps provided a sparsely sampled, milliarcsecond view of the spatio-kinematics of the accretion disk covering a physical range of $\sim$ 50 - 900 AU. We term this observational approach 'heat-wave mapping'. We report the discovery of a Keplerian accretion disk with a spatially resolved four-arm spiral pattern around G358.93-0.03-MM1. This result positively implicates disk accretion and spiral arm instabilities into the episodic accretion high-mass star formation paradigm.

Exploring Episodic Accretion in Star Formation with the INAF VLBI Network

Olga Bayandina
INAF - Osservatorio Astrofisico di Arcetri, Italy

New high-frequency tri-band (K, Q, and W) receivers will soon be installed to the telescopes of the INAF VLBI network (the Sardinia, Medicina, and Noto Radio Telescopes). The upgrade promises to open new horizons for studying many astronomical phenomena and, in particular, massive star formation. Disk-mediated accretion with episodic accretion bursts is the leading theory of star formation. However, in the case of massive young stellar objects (MYSOs) it has found little practical evidence yet - to date, only four accretion bursts have been detected. An excellent indicator of accretion bursts in MYSO are masers: from maser flares at the onset of a burst to maser-traced bow shocks in the aftermath of a burst. VLBI observations of masers are critical as they reveal the overall picture of the bursting region and unfold the place of masers in it. However, accretion burst associated maser flares are extremely short-lived and require great deal of flexibility from a VLBI array to catch the burst onset. In turn, studying the origin and evolution of bow shocks traced by high-frequency masers consumes a lot of VLBI array's time, which has led to a very limited sample of studied sources. To solve these problems, a fast-response and scheduling flexible VLBI array equipped with cutting-edge high-frequency receivers is required - exactly what the INAF VLBI network upgrade will provide.

EVN monitoring of the polarized H2O maser emission around the massive protostars W75N(B)-VLA 1 and W75N(B)-VLA 2

Gabriele Surcis
INAF - Osservatorio Astronomico di Cagliari, Italy

Several radio sources have been detected in the high-mass star-forming region W75N(B), among them the massive young stellar objects (YSOs) VLA 1 and VLA 2 are of great interest. These are thought to be in different evolutionary stages. In particular, VLA 1 is at the early stage of the photoionization and it is driving a thermal radio jet, while VLA 2 is a thermal, collimated ionized wind surrounded by a dusty disk or envelope. In both sources 22 GHz water masers have been detected in the past. Those around VLA 1 show a persistent linear distribution along the thermal radio jet and those around VLA 2 have instead traced the evolution from a non-collimated to a collimated outflow over a period of ∼20 years. We further monitored the polarized emission of the 22 GHz H2O masers around both VLA 1 and VLA 2 over a period of six years with the European VLBI Network (EVN), including the Medicina radio telescope, for a total of four epochs separated by two years from 2014 to 2020. I will present the results of our monitoring project by focusing on the evolution of the maser distribution and of the magnetic field around the two massive YSOs.

Extragalactic maser VLBI studies: past, present and future

Andrea Tarchi
INAF - Osservatorio Astronomico di Cagliari, Italy

Since three decades, VLBI studies of extragalactic (water) maser sources have incontrovertibly proved that they are unique tools to derive fundamental physical quantities of the host galaxies. Indeed, galactic distances of members of the Local Group can be measured through maser proper motion studies. Furthermore, in nearby and distant Active Galactic Nuclei, masers allow to obtain the geometry of accretion disks around super-massive black holes, precise black hole masses and galactic distances, and detailed information on the interaction region of nuclear jets/outflows with the interstellar medium.

However, so far, extragalactic maser searches have yielded detection of few percent, and only relatively few maser sources have been found.

In addition, although currently extragalactic maser science can take profit of a number of excellent VLBI networks, particularly in the Northern Hemisphere (e.g., the VLBA and EVN), capable to provide detailed measurements of maser sources, only the closest and brightest objects can be successfully imaged in sufficient detail.

Luckily, because of their unprecedented sensitivity, new upcoming facilities, like Meerkat, the ngVLA, and the SKA, will allow to significantly increase the number of known (water) maser sources, with the chance of performing statistically-relevant studies of the maser phenomenon (and its occurrence). Even more important, fostering the implementation of long(er)-baselines options for the future interferometers and a close synergy between the different VLBI arrays throughout the world will offer the chance to perform the detailed studies described above for larger samples and up to cosmological distances.

In this talk, we will provide a brief outline of the most relevant achievements of past VLBI studies of extragalactic masers, together with an outline of ongoing research programs targeting particularly promising megamaser galaxies, with special reference to their contribution at our understanding of the Unified Scheme for AGN. In addition, we will illustrate a preview of the potential offered by new observational facilities for a substantial advance in extragalactic maser science.

IC485: Towards a new maser disk galaxy!?

Elisabetta Ladu
INAF - OAC / Università degli studi di Cagliari, Italy

Megamasers are unique tools for investigating the nuclear regions of the Active Galactic Nuclei (AGNs) and for better understanding the Unified Model. In addition, the detailed studies of the three known AGN water megamaser classes (disk-, jet-, and outflow-masers) provide information on the different physical aspects of AGNs according to the observed typology. An important and fundamental contribution is also provided by the Very Long Baseline Interferometry (VLBI) technique.

Indeed, the high angular resolution observations of disk masers allow to trace the disk geometry, to estimate the BH mass and to measure accurate distances to their host galaxies. Jet(s)/outflow masers produce important information about the interaction regions of the jets/outflow with the interstellar medium.

Despite their importance, detections of maser sources are rare, so every new source become a goldmine to understand the physics behind these objects. Here, we present our results in continuum and in spectral mode of high-sensitivity, multi-epoch campaign with the VLBA and EVN of the nuclear region of the megamaser galaxy IC485. The outcome of our analysis indicates that the radio continuum emission is dominated by star formation process, with a weak contribution from the AGN. The detection of two complexes of maser emission offset by 472 km/s in velocity and about 0.2 pc at the distance of IC485 (122 Mpc) suggests, instead, an association with an edge-on disk accreting onto a SMBH of $\sim 10^7 M_\odot$. This maser nature is also supported by recent ALMA observations of water maser emission at 183 GHz. A set of new, ongoing interferometric follow-ups will eventually be outlined.

Wednesday, May 24th

Session: Technology and methods III

Black hole morphology using closure invariants in VLBI

Nithyanandan Thyagarajan
Commonwealth Scientific and Industrial Research Organisation, Australia

The Event Horizon Telescope (EHT) has released the first event horizon scale images of black holes residing at the centres of M87 and our Milky Way. Since then, attempts by various groups to independently infer the morphological features of these black holes have generated intense discussions and even a few controversies. The challenges to imaging from an extreme version of planet-scale Very Long Baseline Interferometry (VLBI) like the EHT primarily arise from a combination of various factors such as sparse aperture coverage, low signal-to-noise, calibration, limitations in imaging algorithms, and any prior assumptions. While the EHT collaboration has reportedly taken extreme care in their analysis to avoid systematic effects from these factors, it is nevertheless important that such pathbreaking experiments require independent verification using orthogonal approaches not subject to such potential systematic biases. VLBI has historically relied on interferometric invariants like closure phases and closure amplitudes which are invariant to antenna-based calibration and errors therein, and therefore contain true morphological information about the objects of interest. However, a direct correspondence between the closure invariants directly and detailed morphological features towards image reconstruction has not been established to date. I will describe recent work using machine learning that successfully estimates parameters of various morphological classes, and subsequently reconstructs images using closure invariants alone without employing any prior assumptions unlike many existing imaging techniques.

High-fidelity wideband VLBI polarimetry

Iván Martí-Vidal
Universitat de València, Spain

We will discuss about wideband and multiband VLBI observations taken with linear-polarization feeds (the simplest hardware polarimetry for wide bands), and how these observations can be calibrated and fringe-fitted with special software, in order to produce full-polarization images with a high fidelity. We will show results from real observations, taken with the VGOS array, and discuss about future applicability of these algorithms in future VLBI arrays.

VLBI data processing in CASA

Mark Kettenis
Joint Institute for VLBI ERIC, The Netherlands

Over the past years VLBI data processing in CASA has become a reality. It is now a supported alternative to AIPS for EVN continuum observations and has established itself as one of the two official calibration pipelines for the EHT. It can also be used for (EVN) spectral line observations, many VLBA observations and observations by other arrays such as LOFAR-VLBI, e-MERLIN and GMVA. A comprehensive CASA-based VLBI pipeline that supports many of these arrays is available in the form of rPICARD. This presentation will give an overview of VLBI functionality in CASA, as well as current and future developments that are needed to make sure data processing software keeps track with other technical and scientific developments in VLBI and future developments like the ngVLA. Particular areas of interest that will be discussed are support for observation that use multi-band receivers and supporting observations below and above the traditional VLBI spectrum (i.e. LOFAR-VLBI and EHT).

Source-frequency phase-referencing for low-luminosity AGN

Wu Jiang
Shanghai Astronomical Observatory, People's Republic of China

The source-frequency phase-referencing (SFPR) technique has been demonstrated to have great advantages for mm-VLBI observations. I will report some successful experiments with SFPR, such as the detections of mm-VLBI cores of LLAGNs M81*, M84* and M104*, as well as positioning the black hole M87*. I will also present it as a promising technique for probing supermassive black hole binaries.

No need for special VLBI hardware?

Anastasios Tzioumis
Commonwealth Scientific and Industrial Research Organisation, Australia

Apart from the VLBA, all other VLBI networks around the world utilise radio telescopes (single dishes or arrays) built and operated as single instruments. Traditionally, VLBI observations have been facilitated by specialised VLBI equipment attached independently to the receiver front-end output (RF or IF). Such equipment has been expensive, often difficult to operate and maintain, and led to VLBI being viewed as a "pioneering adventure" led by "black belt" trained VLBIers and inaccessible to the rest of the astronomy community. It can be argued that this has constrained the adoption and use of VLBI by the wider community. Technology has changed drastically since the early days of VLBI and has already changed the way we do VLBI correlation i.e. no more hardware correlators and the new software correlators can run on any of the modern supercomputer clusters. The digital technology on modern radio telescopes (new antennas or just new receiver systems) has now progressed to the state that digital data at baseband can be directly delivered from the receiver to a GPU cluster, with nanosecond timing accuracy. Often called a "universal back-end" system. Such data are VLBI-ready or can be re-packaged by relatively simple software. So, modern VLBI operations could be streamlined to be just a simple change in mode on a universal back-end. The VLBI observing will be much easier to setup and operate, and should attract a lot more astronomers to use the VLBI technique for their science. I would report on recent progress on implementing such systems and open discussion on how VLBI can transition to this more universal operation mode.

Session: Global VLBI Alliance

Testing the event horizon paradigm with VLBI probes of magnetic field

Andrei Lobanov
Max Planck Institute for Radioastronomy, Germany

Arguments put forth so far for the existence of cosmic black holes have been largely based on various types of enclosed mass measurements and observations of relativistic effects arising in matter and photons moving near the event horizon. The GRAVITY observations of stellar motions near Sgr A* and the EHT imaging of M87 and Sgr A* illustrate well the success of these approaches for testing the black hole and event horizon paradigm. Further effective tests of the event horizon paradigm can be carried out with VLBI probes of magnetic fields around black holes on scales below several thousands gravitational radii. This possibility is recognized and explored by our project M2FINDERS focusing on multifrequency polarization VLBI imaging of compact radio emission in selected AGN in which linear scales below about 10000 gravitational radii can be probed. These imaging yields a combined information on linear polarization, Faraday rotation, and synchrotron spectrum and opacity, which provides a robust framework for estimating the strength and reconstructing the three-dimensional morphology of the magnetic field in the vicinity of putative supermassive black holes in AGN. Current progress and first results from the M2FINDERS measurements will be presented in this contribution.

Accretion and ejection in AGN: a VLBI view

Francesca Panessa
INAF - Istituto di Astrofisica e Planetologia Spaziali di Roma, Italy

The accretion-ejection mechanism acting in Active Galactic Nuclei(AGN) is one of the main astrophysical open issues, being connected to the role of AGN feedback in galaxy formation evolution studies. In Radio Loud AGN, radio emission is essentially all produced by synchrotron emission from a relativistic jet. In contrast, in Radio Quiet AGN the absence of luminous jets allows us to probe radio emission from a wide range of possible mechanisms, from the host galaxy kpc scale down to the innermost region near the SMBHs: star formation, AGN driven wind, free-free emission from photo-ionized gas, low power jet, and the innermost accretion disc coronal activity. All these mechanisms can now be probed with unprecedented precision and spatial resolution, thanks to the current and forthcoming generation of highly sensitive radio arrays. The origin of radio emission in RQ AGN at milli arcsecond spatial scales will be discussed together with its connection to the X-ray emission and its variability properties.

New insights into the Universe from strong gravitational lensing and very long baseline interferometry

Simona Vegetti
Max Planck Institute for Astrophysics, Germany

Strong gravitational lensing is a powerful tool to investigate a broad range of astrophysical phenomena: from the nature of dark matter to the physic of high-redshift galaxies and cosmic magnetism. In this talk, I will present which insights we have gained into the physics of the Universe by combing strong gravitational lensing with very long baseline interferometry and discuss what we can expect from future observations and the new hundreds of thousands of lenses that will soon be discovered.

Snapshot of a magnetohydrodynamic disk wind traced by water maser observations

Luca Moscadelli
INAF - Osservatorio Astrofisico di Arcetri, Italy

The formation of astrophysical objects of different nature, from black holes to gaseous giant planets, involves a disk-jet system, where the disk drives the mass accretion onto a central compact object and the jet is a fast collimated ejection along the disk rotation axis. Magnetohydrodynamic disk winds can provide the link between mass accretion and ejection, which is essential to ensure that the excess angular momentum is removed and accretion can proceed. However, up to now, we have been lacking direct observational proof of disk winds. This work presents a direct view of the velocity field of a disk wind around a forming massive star. Achieving a very high spatial resolution of 0.05 au, our water maser observations trace the velocities of individual streamlines emerging from the disk orbiting the forming star. We find that, at low elevation above the disk midplane, the flow co-rotates with its launch point in the disk, in agreement with magneto-centrifugal acceleration. Beyond the co-rotation point, the flow rises spiraling around the disk rotation axis along a helical magnetic field. We have performed (resistive-radiative-gravito-) magnetohydrodynamic simulations of the formation of a massive star and record the development of a magneto-centrifugally launched jet presenting many properties in agreement with our observations.

Imaging of more than 730 K-band celestial reference frame sources at up to 87 epochs

Aletha de Witt[1], Marisa Nickola[1], Christopher Jacobs[2], Michael Bietenholz[3], David Gordon[4]
[1]*South African Radio Astronomy Observatory, South Africa,* [2] *Jet Propulsion Laboratory, California Institute of Technology, USA,* [3] *York University, Canada,* [4] *United States Naval Observatory, USA*

We present an overview of high-resolution images of more than 730 AGN sources from the K-band (24 GHz) celestial reference frame (CRF), which is based on observations made with the VLBA (supported through the USNO's 50% timeshare allocation) from 24-hour sessions observed between 2015 and February 2023. Many of these sources are imaged for the first time at frequencies above X-band (8 GHz) with sub-mas resolution. The K-band images provide information about the source properties and for sources observed over multiple epochs they provide insights into the temporal behaviour of the sources. The use of K-band was motivated by the opportunity to access more compact intrinsic source morphology at that higher frequency as well as to leverage the factor of three improvement in interferometer resolution relative to the historically standard S/X-band (2.3/8.4 GHz) used for much reference frame and calibrator work. As most of the sources imaged here are in the K-band component of the 3rd International Celestial Reference Frame (ICRF-3), these images serve to characterize the objects used in that IAU standard. Lastly, we also compare images and astrometry from S (2.3 GHz), X (8.4 GHz), K (24 GHz) and Q-band (43 GHz) in order to study the astrophysical differences and determine the optimal frequency band for celestial reference frame observations.

PANTERAs: Revealing extreme stellar wind shocks from massive binaries

Benito Marcote
Joint Institute for VLBI ERIC, The Netherlands

Massive binary systems are known to exhibit strong interaction between the winds of their constituent stars, resulting in the production of energetic shocks that emits radiation from radio wavelengths to very high energy gamma-rays. These systems are called colliding wind binaries (CWBs), and despite their potential significance, only a small number has been identified to date. The regions of wind collision within CWBs are highly efficient environments for the production of high-energy particles, and the high angular resolution capabilities of very long baseline interferometry (VLBI) offer an unprecedented opportunity to study these systems in great detail.

While only a few CWBs displaying particle-accelerating, radio-emitting wind collision regions have been discovered to date, recent exceptional examples such as HD 93129A and Apep – in addition to the well-known Eta Carinae – have highlighted the importance of these systems. In particular, for the understanding of the dynamics and efficiency of relativistic shocks, dust production, the evolution of possible progenitors of gamma-ray bursts, and even to the possible contribution of CWBs to the Galactic cosmic-ray background.

However, the most suitable high-energy binaries have periods of the order of years, and these systems are often overlooked in (optical) surveys due to their small orbital motions. Targeted radio observations utilizing VLBI imaging can be instrumental in detecting and characterizing a significantly larger number of CWBs, enabling us to determine orbital parameters and properties of the constituent stellar winds.

To obtain a general understanding of the population of gamma-ray binaries, it is necessary to study low-luminosity systems on a large scale rather than relying solely on the most extreme and exceptional systems. The dynamics and physical conditions necessary for efficient particle acceleration in CWBs remain unclear, and the PANTERA-Stars (Particle Acceleration and Non-Thermal Emission of Radiation in Astrophysics - Stars) collaboration is working towards achieving these goals.

Thursday, May 25th

Session: Transients I

Many needles in the haystack– on the contribution of VLBI to cracking the FRB puzzle (invited)

Franz Kirsten
Chalmers University of Technology, Sweden

It has been a little over fifteen years since the discovery of Fast Radio Bursts (FRBs) and we are still unsure about what type of object generates these enigmatic millisecond-duration bursts. The phenomenon is extremely common – we expect several thousands of bursts per sky per day – and we find roughly a dozen of new bursts each week. The bursts' properties tell us that they originate from cosmologic distances and that the emission must be coherent in nature. Broadly speaking, there are two types of FRBs: the repeating ones and those that apparently do not repeat. It is an open question whether the two populations share a common origin; some statistical studies indicate that this might not be the case. Amongst aspects such a the burst structure, bandwidth, duration and polarisation properties, a key ingredient required to solve the FRB puzzle is the local environment FRBs reside in. In combination with high-resolution optical data, VLBI-localisations of FRBs allow us to draw robust conclusions about the physical properties in the immediate surroundings of these sources and thus obtain clues about the possible progenitors. In this talk I will review our current understanding of FRBs with a particular focus on the contribution of VLBI in this endeavour.

The local radio environment of fast radio bursts and their progenitor implications

Shivani Bhandari
ASTRON / JIVE, The Netherlands

Fast Radio Bursts (FRBs) are millisecond-duration transient sources of intense, coherent radiation originating in distant galaxies that are signposts of extreme astronomical environments. Telescopes all over the world are used to conduct searches for FRBs, localise them, and study their host galaxy and local environment. The European VLBI Network in particular is a prime instrument to study the radio environment of FRB sources in their host galaxies at milli-arcsecond scales. Such VLBI observations are needed to characterise the nature of radio emission caused by star formation or a compact persistent radio source (PRS), as well as to constrain the size of any radio nebulae. In this talk, I will present radio observations of the local environment of repeating and non-repeating FRBs, as well as the implications for FRB progenitor models.

A VLBI search for pulsars without pulsations

Pikky Atri
ASTRON, The Netherlands

The last few years have witnessed a surge in the discovery of exotic radio transients, expanding the realm of known transient classes owing to the increase in the sensitivity of radio surveys. Previous surveys revealed an excess of steep spectrum sources in the Galactic plane. The compact nature of these targets in the GMRT and the VLA surveys suggested that these were likely a new population of pulsars. However, unsuccessful detection of timing signatures from these targets led to the question: are all these steep spectrum sources extragalactic or are they an unexplored sub-population of pulsars without detectable pulsations? In this talk, I will give an overview of how we are using VLBI to determine if these confusing sources are indeed pulsars using a combination of measuring scatter-broadening in the image plane and proper motion using astrometry.

Dynamic response to transients with e-MERLIN

David Williams
JBCA - University of Manchester, UK

The e-MERLIN array is a set of 7 telescopes across England that form an interferometer capable of sub-arcsecond resolution and micro-Jansky sensitivity at centimetre wavelengths. It now regularly participates in the EVN, as well as having its own peer-reviewed science programme. In recent years, e-MERLIN has been used for a wide variety of science cases including to study AGNs, masers, galaxy clusters and transients, to name a handful. In order to improve access, the e-MERLIN operations team has improved data and processing channels through a new pipeline and has included a new "rapid response time" (RRT) mode to further enable transient studies. The rapid response time enables dynamic scheduling of transient sources to obtain early detections and positions of evolving radio sources.

In this talk, I will give an overview of the preliminary transient science results that have come from the rapid response time data. This includes the 2021 outburst of the recurrent nova RS Oph, the long-lived radio jets from an X-ray binary in a young stellar cluster, rapid follow up observations of the brightest GRB of all time and a late-time radio detection of a type 1a supernova. I will discuss the need for rapid and dynamic scheduling capabalities offered by the RRT observations for VLBI science for the next decade. Finally, I will discuss further planned upgrades to e-MERLIN which will improve the impact of VLBI transient science long into the future.

The role of VLBI observations in the context of multimessenger science (invited)

Om Sharan Salafia
INAF - Osservatorio Astronomico di Brera, Italy

The Advanced LIGO ground-based interferometric gravitational wave (GW) detectors revolutionized our view on the Universe by demonstrating for the first time in 2015 the very existence of GW with properties in agreement with the predictions of General Relativity and the feasibility of their detection. In 2017, in a network with the Advanced Virgo detector, they detected and localized the first ever GW + photon source, the binary neutron star (BNS) merger GW170817, opening a new era in multi-messenger science. VLBI observations proved fundamental and complementary in the characterization and understanding of that source: they settled the debate on whether a narrow, relativistic jet was produced after the BNS merger, with important implications on the equation of state of neutron star matter; they allowed for breaking the inherent distance-inclination degeneracy in the GW signal, allowing for the first several-percent-precision multi-messenger determination of the Hubble constant. The O4 observing run of the ground-based GW detector network is about to start, with an increased projected detection rate of BNS mergers and also, potentially, black hole - neutron star mergers. VLBI observations will likely play again an important role in unveiling the secrets of these systems.

Constraining jets from gravitational wave mergers with VLBI: challenges and opportunities

Kelly Gourdji
Swinburne University of Technology, Australia

Short gamma-ray bursts (SGRBs) offer an opportunity to study extreme examples of transient jets, providing insight into both the jet physics and the merger progenitors. While SGRBs have traditionally been seen only on-axis and at typically high redshift, the advent of gravitational-wave merger (GWM) detections means that much closer, off-axis events can also be identified and studied. The prototypical example of this new category was the landmark detection of the multiwavelength counterpart to binary neutron star merger GW170817, which provided an unprecedented view of an SGRB. In particular, its relative proximity enabled very long baseline interferometric (VLBI) observations that identified superluminal proper motion of the merger's relativistic outflow, breaking the degeneracy between competing afterglow models and setting much tighter constraints on key jet parameters. However, VLBI data typically includes systematic sources of uncertainty that can be difficult to quantify, and will often be of low signal-to-noise for typical GWM jets. These two challenges complicate the estimation of jet parameters and especially the associated uncertainty. In this talk, I will discuss the main model-fitting challenges we face and present possible solutions toward more robust results.

Studying the dynamics and the structure of Gamma-Ray Bursts with the VLBI

Stefano Giarratana
INAF - IRA / University of Bologna, Italy

Some massive stars end their lives with a catastrophic explosion which leaves behind a spinning, stellar mass black hole or a highly magnetised neutron star. Regardless of the nature of the remnant, this central engine launches a jet of ionised matter which eventually interacts with the circum-burst medium through external shocks, producing the so-called Gamma-Ray Burst (GRB) afterglow, which can be detected from the very-high energy throughout the whole electromagnetic spectrum. Radio observations, and in particular VLBI, are fundamental to measure the apparent superluminal expansion (on-axis GRB) and proper motion (off-axis GRB) of the GRB outflow, to constrain its structure and to characterise the circum-burst medium. In this talk I will present two representative cases for radio studies of GRBs: GRB 201015A and GRB 221009A. For the former, interferometric observations were crucial to characterise the density profile of the circum-burst medium; on the other hand, VLBI observations of the brightest GRB of all time, GRB 221009A, allow us to constrain the expansion and the proper motion of the centroid. Finally, I will discuss how combining the SKA sensitivity and surveying capabilities with the VLBI resolution will affect GRB science.

SN 2014C: Shell structure and deceleration reveal details of ejecta colliding... with a dense circumstellar medium

Michael Bietenholz
Hartebeesthoek Radio Astronomy Observatory / SARAO, South Africa

The unusual supernova 2014C, in the nearby galaxy NGC 7331, was initially of the H-poor Type Ib. Over the course of $\sim$1 yr, however, it developed bright H-alpha lines, implying strong interaction with H-rich circumstellar medium (CSM). The expanding shock-front collided with a dense, H-rich shell of CSM at age of $\sim$1 yr. Since then, the shock has emerged from the dense shell, and is now expanding into the lower density CSM beyond. I report on new VLBI measurements of SN 2014C made with the European VLBI Network $\sim$5 yr after the explosion, as well as VLA and Chandra-NuSTAR X-ray observations. The VLBI observations, at 8.4 GHz, reveal a shell structure and continued expansion, with deceleration that appears to get stronger at the latest times. Since the first year after explosion, SN 2014C has shown an unusual, almost constant flux density as well as a relatively flat powerlaw spectrum. X-ray observations support the implications of the ejecta colliding with a dense CSM.

Session: Synergies II

Introduction to FAST VLBI System (invited)

Haiyan Zhang
National Astronomical Observatories of CAS, People's Republic of China

Since the beginning of routine observations in 2020, the Five-hundred-meter Aperture Spherical radio Telescope (FAST) has achieved several outstanding scientific outputs on the studies of Fast Radio Bursts (FRBs), Pulsars, Spectral line of Hydrogen, etc. As one of the scientific cases of FAST, the research on radio sources with Very Long Baseline Interferometry (VLBI) has also been discussed, such as Astrometry of pulsars & FRB, Active Galactic Nucleus (AGNs), OH masers and so on. In this presentation, the recent progress of FAST and VLBI system will be intro-

duced briefly. During the commissioning stage, the FAST VLBI system had been established. The first VLBI fringes of FAST was obtained in 2019 between FAST and Tianma 65 meter radio telescope (TM65) in Shanghai. Then the VLBI experiments with FAST, TM65 and Urumqi 26 meter radio telescope (UR26) had been carried out. Moreover, in past two years, thanks for the efficient collaboration of the domestic and international VLBI teams, serval VLBI experiments with FAST, Long Baseline Array (LBA) and European VLBI Network (EVN) had been performed successfully. Based on the results of FAST VLBI tests, the ability of FAST VLBI system has been proved and it is ready for scientific observations in future.

Enabling VLBI for the upgraded GMRT

Visweshwar Ram Marthi
National Centre for Radio Astrophysics, India

The GMRT, despite being one of the most sensitive low-frequency imaging instruments, had not been able to fully realise its potential for Very Long Baseline Interferometry (VLBI). This was partly because of engineering challenges in the pre-upgrade avatar including clock stability issues, frequency coverage and analog and digital receiver electronics. The upgraded GMRT has addressed many of these constraints and has unlocked the potential for global VLBI at low radio frequencies. Specifically, the adoption of the most up-to-date time-frequency standards, a modern, highly flexible digital receiver design and software-enabled signal processing instrumentation allows for harnessing the full VLBI potential of GMRT.

Earlier last year, the GMRT participated separately in successful VLBI fringe test experiments with a subset of telescopes of the European VLBI Network (EVN) and the Australian Long Baseline Array (LBA). So far we have been able to demonstrate that all baselines to the GMRT, in all the three fringe test experiments with the EVN, have shown excellent phase and delay stability at a level that is better than sufficient for production-level correlations. The new VLBI capability has been made possible by unlocking new modes in the GMRT Wideband Backend (GWB) and the implementation of a sequence of signal processing steps. In the immediate term, several pilot experiments are being proposed to study the suitability of the GMRT for specific scientific investigations such as small-scale neutral Hydrogen in the Milky Way and VLBI Scintillometry of interesting pulsars. This will pave the way for the GMRT to integrate seamlessly with the SKA-VLBI observations in the future, an outlook that is even more promising.

The GMRT has an indispensable role to play in the future of VLBI, particularly in the SKA era, being favourably located with respect to both SKA-Low (in Australia) and SKA-Mid (in South Africa) and having good frequency overlap with both these facilities. As the GMRT gears up its offline and real-time VLBI signal processing capabilities, we are exploring pathways to engage more meaningfully with other VLBI partners. In the near future, VLBI will be a regular observing mode offered by the GMRT, with many feature additions and signal processing upgrades being planned within the next 1-2 year timescale.

VLBI astrometry in the epoch of Gaia (invited)

Laurent Loinard
The Institute of Radio astronomy and Astrophysics - UNAM, México

Gaia and phase-referenced VLBI observations deliver similar levels of astrometric accuracy - of order 20 micro-arcseconds on trigonometric parallax measurements. The two types of measurements, however, are affected by different sources of error and have different limitations. Gaia, of course, provides results for more than a billion objects while VLBI astrometric observations exist only for a few hundred sources. On the other hand, VLBI observations are largely immune to dust extinction, enabling observations deep into the Galactic disk. Also, the angular resolution of VLBI observations is more than a hundred times better than Gaia's, enabling the resolution of tight binary systems that cannot be resolved with Gaia. In this talk, I will present a comparison between Gaia and VLBI emphasizing the complementarity between the two techniques.

Long Baseline Bistatic Radar

Simon Garrington
JBCA - University of Manchester, UK

Long-baseline Bistatic Radar combines existing radar transmitters and sensitive radio telescopes to improve the capabilities of radar for space debris, space domain awareness, calibration satellites and potentially more distant objects such as asteroids. The enhanced sensitivity from using large radio telescopes with cryogenic receivers is especially relevant at GEO and beyond. We have demonstrated the technique at L-band using transmitters at MIT (Haystack, US) and TIRA (Bonn) and radio telescopes in Europe, including e-MERLIN, WSRT and SRT. Results include precision differential measurements of satellite clusters and micro-Doppler characterisation of tumbling debris objects, allowing image reconstruction for rocket bodies in 20,000km orbit. Other applications and extensions of the technique will be discussed.

A study of solar wind propagation using the Planetary Radio Interferometry and Doppler Experiment (PRIDE) technique

Md Said
Joint Institute for VLBI ERIC, The Netherlands

We investigated the propagation of solar wind using the radio signal transmitted by the Mars Reconnaissance Orbiter (MRO) spacecraft at a frequency of 8.4 GHz (X-band) and observed with the European VLBI Network in June 2018. The solar wind speed was calculated by performing cross-correlations between the EVN baselines of the phase fluctuations of the spacecraft's signal. Our analysis of interplanetary scintillation (IPS) using this method shows how this method can help improve our understanding of the solar corona.

Session: Transients II

Multi-wavelength studies of X-ray binaries: the role of VLBI in understanding accretion and feedback around stellar-mass compact objects (invited)

Sara Elisa Motta
INAF - Osservatorio Astronomico di Brera, Italy

The inflow of matter onto astronomical objects is connected to the generation of outflows throughout the Universe on a variety of scales, from proto-planetary disks, to merging neutron star systems and gamma ray bursts, to stellar mass and supermassive black holes. The matter inflow/outflow processes scale predictably with mass, and proceeds according to the same basic principles around all collapsed objects. Super-massive black holes have driven the evolution of galaxies and regulated star formation through accretion and feedback. In accreting binaries - the low-mass counterparts of super-massive black holes - a stellar mass black hole or a neutron star feeds from an accretion disc that is formed by the material stripped from a stellar companion. I will give an overview of the phenomenology ascribed to the accretion process and to the generation of outflows in low-mass X-ray binaries, and I will show how these processes can be understood only if studied together. I will particularly focus oil the role that VLBI has in the understanding of the properties of the radio jets observed in XRBs in specific accretion states.

While the focus of this talk will be on black hole systems, I will also show how neutron stars are ideal laboratories to study the accretion-ejection processes.

Filming the evolution of symbiotic novae with VLBI

Marcello Giroletti
INAF - Istituto di Radioastronomia, Italy

In symbiotic novae, the material ejected from the surface of the white dwarf (WD) after the thermonuclear runaway drives a strong shock through the dense circumstellar gas produced by the red giant (RG) wind. Recurring symbiotic novae such as V407 Cyg and RS Oph are perfect real-time laboratories for studying physical processes as diverse as accretion, thermonuclear explosions, shock dynamics and particle acceleration; in many ways they are like supernova remnants on fast forward. In this talk, I will present the results of two intensive VLBI campaigns carried out for the two high energy symbiotic novae V407 Cyg and RS Oph, after their explosions in 2010 and 2021, respectively. These campaigns provided a resolved view of the structure of the ejected material and of its evolution, setting unique and independent constraints on the emission mechanisms, the physical processes at work, the presence and location of shock acceleration, the geometry of the system, and the density profile of the RG wind.

Evidence of a radiation belt around a radio-emitting brown dwarf

José Carlos Guirado
Universitat de València, Spain

Radio observations of ultracool dwarfs, objects comprising brown dwarfs and the very lowest mass stars, have mainly focused on analyzing their light-curve and spectral energy distributions providing valuable insights into their magnetic fields. However, spatially-resolved studies of such magnetospheres have been elusive so far. We report milliarcsecond-scale VLBI images of a nearby, radio emitting brown dwarf which reveals a morphology strikingly similar to the well-known radiation belts of Jupiter and Earth, consisting of energetic particles confined via magnetic mirroring. Our finding represents the first observational evidence of radiation belts in objects other than those of the Solar System.

40 Years of Studying the Evolving Compact Radio Sources in M82

Tom Muxlow
Jodrell Bank Centre for Astrophysics, UK

For over 40 years the EVN has been fundamental in the investigation of the bright supernova remnants in M82 including the nominal super nova remnant (SNR) 41.95+57.5 - for many years the brightest single compact radio object within M82. VLBI imaging has confirmed the unusual double-lobed structure of 41.95+57.5 which is unlike the more typical shell-like SNR found in M82. The lobe separation historically increased at a rate of $\sim$0.24mas/yr, yielding an upper limit derived expansion age of $\sim$100 years. 41.95+57.5 has decreased in flux density at $\sim$8.8%/yr since L-Band monitoring began in the early 1970s until the late 1990s, indicating a potential birth 1.4GHz flux density of $\sim$170Jy - with a luminosity approaching that of radio afterglows of long-duration gamma-ray bursts, suggesting that 41.95+57.5 may be a late stage GRB radio afterglow.

Global VLBI confirms the double-lobed structure continues to fade, however more recently an evolving partial ring-like structure has begun to appear within the existing fading double lobes. L-Band monitoring from 1993 onwards has shown that the rate of change in total flux density of the remnant has slowed to $\sim$6.4% / yr. In addition, e-MERLIN imaging in 2014 shows the 1.5 - 6.2GHz spectral index has flattened to $\sim$-0.5 from -0.8 over around a 10- year period, suggesting an emerging flatter spectrum central nebula is beginning to appear, consistent with a Pulsar Wind Nebula (PWN).

The recent wide-field C-Band Western EVN + e-MERLIN programme (EM148, 20B013), has investigated the detailed structure of 41.95+57.5 at $\sim$5-10mas resolution together with other compact shell-like SNR within the central 30 arcsec of the M82 nuclear region. With the additional short-spacing coverage provided by e-MERLIN antennas, the expansion of such fading shells has allowed an extension to the expansion timeline to further constrain the expansion velocity evolution of these SNR which are beginning to become highly resolved with VLBI-only investigations. New expansion velocity constraints are presented for the classical shell SNR 43.31+59.2.

VLBI architecture of a compact binary with exoplanet

Gisela Leon-Ortiz
Instituto Nacional de Astrofísica, Óptica y Electrónica, México

Very Long Baseline Interferometry (VLBI) offers astrometric precision of tens of micro-arseconds, which is comparable to that offered by the Gaia mission. Using the six-dimensional information (position and velocity) delivered by the two instruments for hundreds of young stars, it has been possible to investigate the three-dimensional structure of star-forming regions and the internal kinematics of their stellar members. The advantage of VLBI is that it can see through the dense material of molecular clouds, reaching the youngest and most embedded stars. In addition, VLBI astrometry of various types of masers now allows the derivation of distances as far as tens of kilo-parsecs, thus proving the structure of the Galaxy at spiral-arm scales. In this talk, I will revisit key results from VLBI and Gaia astrometric studies, and their synergies, in pursuit of constructing a six-dimensional view of the star-formation in our Galaxy.

Friday, May 26th

Session: Future

The future of the EVN (invited)

Zsolt Paragi
Joint Institute for VLBI ERIC, The Netherlands

The European VLBI Network is a major radio astronomical facility that extends well beyond Europe. In its 40+ years of existence, it has proven to be a fundamental facility serving generations of radio astronomers, one that was continuously able to renew itself as challenges emerged. How to address new challenges in the changing astronomical landscape is an important question. I will review what we have learned from the EVN Science Vision process and share my views on possible ways forward.

ngVLA for the 2030s ICRF (invited)

Megan Johnson
United States Naval Observatory, USA

The next generation Very Large Array (ngVLA) is proposed for the 2030s time-frame and, if approved, will include long baselines to replace the current Very Long Baseline Array (VLBA). We present an overview of the goals and plans for the ngVLA long baselines to support the International Celestial Reference Frame (ICRF) in the 2030s and beyond. Integrating and sustaining the ICRF at multiple radio frequencies in the coming decades will be challenging. We explore some of these challenges and describe our goals for advancing this field of fundamental radio astronomy and discuss how ngVLA might be realized to support these ambitions. We will also present some recent results towards this effort using data collected with the VLBA and showcase the USNO Fundamental Reference Image Data Archive (FRIDA), a repository of ICRF multi-frequency radio images.

Future Science with the Long Baseline Array

Cormac Reynolds
Commonwealth Scientific and Industrial Research Organisation, Australia

The Long Baseline Array (LBA) is the only astronomical VLBI array operating in the southern hemisphere. There has been a significant focus in recent years on efforts to increase the sensitivity of the array by allowing bandwidths in excess of 1 GHz. In addition there is also interest in providing a multi-beam capability for the more sensitive telescopes in the array. Multi-beam technologies will provide the basis for the next generation of ultra-precise VLBI astrometry enabled by multiview calibration techniques. The heterogeneous nature of the array provides significant challenges for the coordinated development of new wideband systems, but through a disparate set of activities these efforts are now coming to fruition. I will give a brief update on the current status of the LBA and the latest VLBI developments in Australia. These

include:

- the Parkes Ultra-wideband Low receiver, which provides continuous frequency coverage from 700 MHz to 4.5 GHz.
- the BIGCAT correlator upgrade for the Australia Telescope Compact Array (ATCA) which will provide a significantly enhanced tied array capability, with up to 8 GHz of instantaneous bandwidth and multi-beaming capabilities.
- the deployment of DBBC3 (Digital Baseband Converters) and wideband Callisto feeds on the AuScope antennas.
- the CryoPAF system for Parkes which will permit multi-beam observations with the Parkes telescope.
- the planned Parkes Ultra-wideband High receiver which will provide continuous frequency coverage between 5 and 22 GHz.
- the planned development of a tied-array system for the ASKAP telescope which will also permit multi-beam observations.
- a common gpu-based digital backend system which will enable many of these developments with minimal duplication of effort.

The Long Baselines of the Next-Generation Very Large Array

Lucas Hunt
National Radio Astronomy Observatory, USA

The next-generation Very Large Array (ngVLA) is currently being designed by the National Radio Astronomy Observatory (NRAO) to address the high priority goals of modern astrophysics at radio frequencies from 1.2-116 GHz. It will replace both the Very Large Array (VLA) and the Very Long Baseline Array (VLBA). The current design for the long baselines (ngVLA-LONG) has multiple 18-meter antennas located at both current VLBA sites and new locations across North America, with the option to include antennas from different parts of the telescope to improve sensitivity and UV-coverage as part of a tailored science subarray. This talk will cover the technical aspects of ngVLA-LONG and highlight some of the envisioned science use cases.

New developments in SETI Long baseline Interferometry

Michael Garrett & Kevin Wandia
University of Manchester, UK

Interferometry offers some significant advantages for SETI research that single dishes and beam-formed arrays do not. We have been developing a SETI capability using the EVN, building on short observations of radio sources in the Kepler field made at 21cm. Several scans were correlated at JIVE (expt RSG12) with very high spectral resolution (16k channels over a 8 MHz band). One of these scans includes J1926+4441 - this VLBA calibrator is located close to the exoplanet Kepler-111b. We detected a highly unusual feature in the data that is observed in both the autocorrelation and (very surprisingly) also the cross-correlation data. The feature is also seen in low spectral resolution data but is much less obvious and would probably be disregarded in a conventional data analysis. We believe this feature is not real but is an artifact in the data that is associated with HI filling the beam of the EVN antennas and raising their system temperatures. We have confirmed this by observing sources within and outwith the galactic plane (RSW02). At the time of our observations, we detect no transmitters associated with Kepler 111b with an Equivalent Isotropically Radiated Power (EIRP) $>$ 3.75E15 Watt. This work represents an important step forward in using the EVN (and VLBI in general) for SETI follow-up observations.

VLBI surveys en route to the SKA (invited)

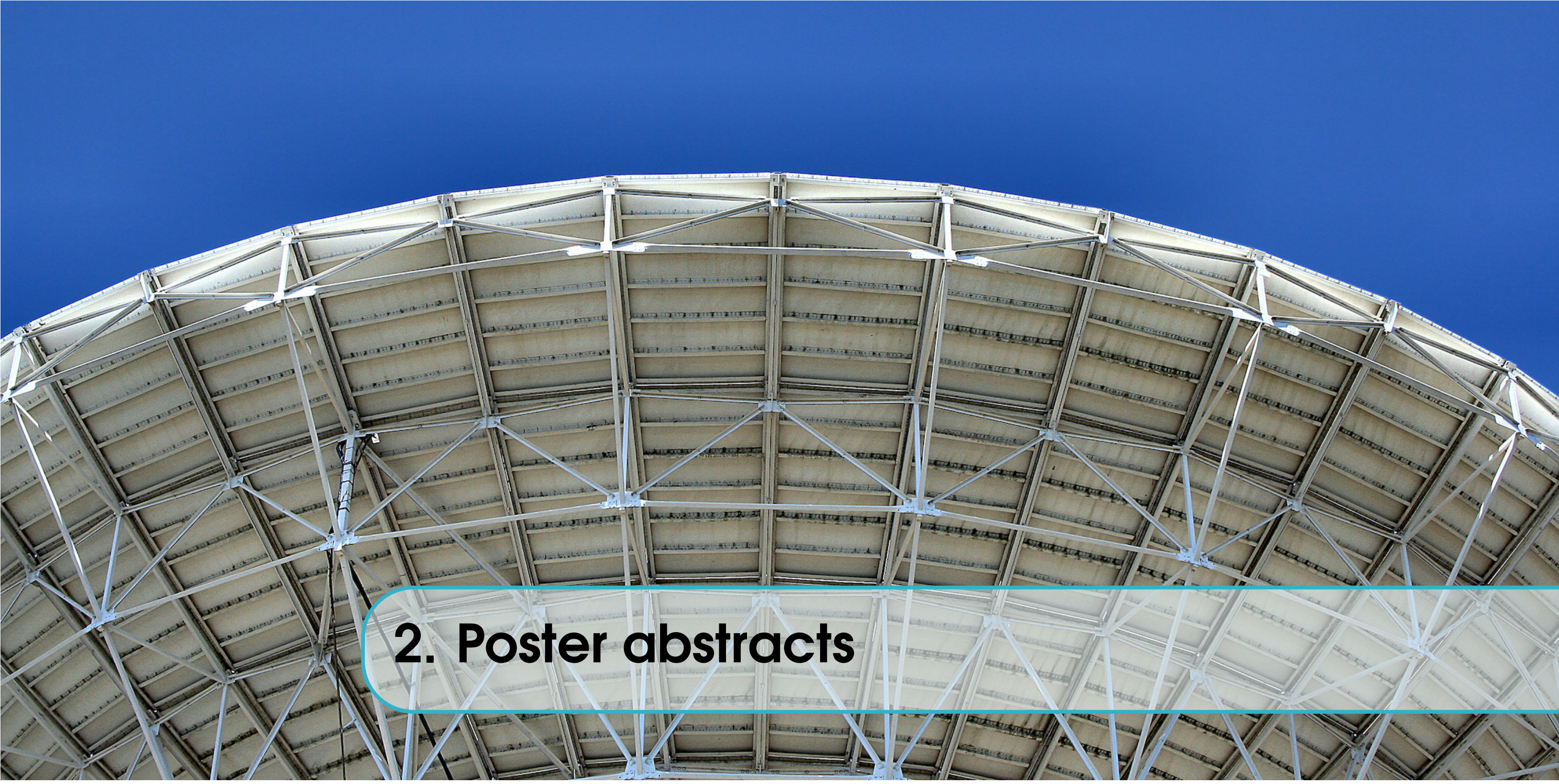
Roger Deane
University of the Witwatersrand / University of Pretoria, South Africa

High angular resolution radio astronomy has undergone several major advancements over the past decade at metre, cm, and mm wavelengths through the Very Long Baseline Interferometry (VLBI) technique. Increased VLBI sensitivity, capabilities, and algorithm development enable wider area surveys that detect orders of magnitude more sources, while sophisticated imaging and Bayesian modelling enable higher and more robust scientific yield from individual sources of interest. This is set to dramatically accelerate over the course of the next decade as new stations are added and as the SKA-MID and LOW arrays become operational. Expanded wide-field VLBI survey programmes are timely given the survey-driven focus of SKA pathfinders and, more generally, the impetus on wide-area synoptic surveys across the electromagnetic spectrum. In this talk, I present the design, processing, and basic data products of several wide-field VLBI surveys over legacy extragalactic fields, and their synergies with the MeerKAT MIGHTEE survey, in particular. Novel survey design, imaging, and source-finding approaches will help broaden the discovery space for future wide-field surveys with upcoming arrays like Square Kilometre Array (SKA-VLBI).

Entering the Era of Black Hole Cinema with the Next Generation Event Horizon Telescope (invited)

Sara Issaoun
Center for Astrophysics | Harvard & Smithsonian, USA

Using a network of eight radio telescopes at six geographic locations spanning the Earth, the Event Horizon Telescope (EHT) produced the first images of supermassive black holes in 2019 and 2022, launching the field of direct horizon-scale study of the spacetime and environments around black holes via direct imaging. The next-generation Event Horizon Telescope (ngEHT) is a project to double the number of telescopes in the current EHT and quadruple the recorded bandwidth. The resulting global interferometric array will have the capability to make detailed high-dynamic range millimeter and sub-millimeter polarimetric movies of M87, SgrA*, and other black hole targets – tracing the dynamical processes underlying black hole accretion and jet launching while zeroing in on stationary horizon-scale features that reveal the imprint of general relativity. I will provide an introduction to the ngEHT concept and array design, and highlight some of the scientific goals of the project.



2. Poster abstracts

P1 - Interferometric Polarimetry using Closure Traces

Ezequiel Albentosa Ruiz
Universitat de València, Spain

Polarization calibration of interferometric observations is a costly procedure and, in some cases, it can even be impossible to be applied, due to observational limitations. To avoid this worst-case scenario and expand the possibilities for the interferometric polarimetry, it might be possible to use a new set of quantities, the closure traces, proposed by Broderick & Pesce (2020), that encode information related to the intrinsic polarization of the observed sources in a way independent of instrumental effects. This poster shows the first results from the application of the closure traces to VGOS data from the ultrawideband observations, from 3 to 13GHz, conducted on July 2022. We show a spectral and temporal evolution of the closure traces, which may account for changes in the differential polarization across the source structure. We also explore the results from a set of parameter-fitting approaches to apply the closure traces to the brightness modelling of data.

P2 - Multi-band study of a potential gravitational lens system at milliarcsecond scales

Diego Alvarez-Ortega
Institute of Astrophysics - FORTH, Greece

Subgalactic dark matter (DM) halos ($< 10^{11} M_{\odot}$) have great relevance in unveiling the nature of DM, as distinct viable models make significantly different predictions on the abundance and density profile of halos in these scales. Given their low masses, and the fact that they are more DM dominated, it is hard to detect them observationally, and in some cases their presence could be only revealed through gravitational lensing.

Carried out in 2021, the pilot study of the SMILE (Search for Milli-LEnses) project, explored 13828 sources from the Astrogeo VLBI FITS image database, looking for potential strong gravitational lenses of active galactic nuclei at milli-arcseconds scales, where the lens is supposed to be a compact object with mass in the range $10^6 - 10^9 M_\odot$. A list of 40 milli-lens candidates, which exhibited multiple compact features at mas-scales and met the surface brightness preservation criterion, was presented in a recent publication (Casadio et al., 2021).

We focused on one of the most promising candidates, J1143+1834, by performing new EVN observations at 5 and 22 GHz, and collecting VLBA multi-epoch data-sets at different frequencies from the archive. We test physical quantities that are expected to be preserved in a gravitational lens system, like surface brightness, flux density ratio over epochs, and spectra. The source passed all tests, reassuring its position as a favourable milli-lens candidate.

P3 - Exploring the hearts of radio quiet quasars

Tao An
Shanghai Astronomical Observatory, People's Republic of China

Radio-quiet active galactic nuclei (RQAGN) occupy the bulk of the AGN population, but the nature of their radio emission remains unclear. This problem is due to the complex origins of the radio emission from RQAGN and the mixing of multiple emission mechanisms, which makes understanding the radio structure and nature of the emission difficult. We have completed VLBI observations of an optically selected sample of nearby AGN. The high-resolution images completely resolved the contribution of star formation to the radio emission, and the compact emission detected in VLBI images is entirely driven by AGN. We have analysed the nature of the radio emission through multi-frequency, multi-epoch observations, identifying evidence that the pc-scale radio emission in this flux-density-limited sample is mainly from jets. This work provides insight into the physical nature of radio-quiet AGN and the radio-loud/quiet AGN dichotomy.

P4 - The collimation of AGN jets with large inclination angles

Anne-Kathrin Baczko
Chalmers University of Technology / Onsala Space Observatory, Sweden

Even after decades of astronomical research the physical mechanism behind the collimation and acceleration of jets in Active Galactic Nuclei (AGN) is still not fully understood. To narrow down possible theoretical models all types of AGN jets have to be studied at all scales, from close to the central engine until their interaction with the intergalactic medium. In this talk I will present our first VLBI results, including jet collimation studies, from a pilot study of a sample of AGN jets with large inclination angle, many of which show a double-sided jet structure. This is a highly under-represented class of sources in comparison to the amount of Blazar jets for which properties as their magnetic field and expansion profile have been studied in detail. Furthermore, the studies of AGN jets with large inclination angle are much less biased by relativistic effects such a differential Doppler-boosting. For most sources in our sample extended jet structure have been detected for the first time at VLBI frequencies above 8GHz.

P5 - From VLBI to Fermi-LAT: a multiwavelength analysis of 3C 111 during a gamma-ray flare

Vieri Bartolini
Max Planck Institute for Radioastronomy, Germany

Radio galaxies (RGs) are a class of Active Galactic Nuclei (AGN) with a viewing angle large enough ($> 10°$) to resolve their jet structure. Thanks to this characteristic, RGs are an excellent laboratory to study the nature of relativistic jets under different conditions. The two different classes of RGs i.e. High Excitation (HERGs) and Low Excitation (LERGs) can emit at gamma-ray frequencies with different behavior, namely, it is thought that HERGs are detected usually during a flaring activity while LERGs have a more steady emission at these frequencies. The typical double hump Spectral Energy Distribution (SED) of AGN suggests that the emission at high energy, generated by the inverse Compton mechanism, and the radio emission, generated by the synchrotron process, are related to the same electron-photon population. Consequently, studying the radio emission with the Very Long Baseline Interferometry (VLBI) technique could provide insights on the jet structure at the scale in which the gamma-ray emission is believed to be originated (i.e parsec/sub-parsec scales).

Our work fits in this context with the aim of studying the HERG 3C 111 during a gamma-ray flare that took place in November 2013 with the help of VLBI observations at 15 GHz and 43 GHz, respectively from the MOJAVE and BU-BLAZAR group monitoring programs. We perform a multi-epoch (20 VLBI epochs) analysis from August 2012 to September 2014. Our light curves study, which covers the frequencies of 15 GHz, 43 GHz, 225 GHz (with the SMA telescope), 15-50 KeV (with the BAT instrument), and 0.1-100 GeV (with the Fermi-LAT instrument), suggests a time coherence between the peak in the gamma-ray and the peak at 225 GHz while the one at 43 GHz appears $\sim$ 40 days later. Moreover, our analysis on the evolution of the spectral index between the two VLBI frequencies suggests a changing spatial distribution of the optically thick regions with time. Thanks to the modelfit analysis, we modeled the visibilities with different Gaussian components and we followed them through the various epochs. Our results seem to point towards a connection between the passage of certain knots through stationary components at $\sim$ 0.5 pc from the core, and the gamma-ray flare. It is notable that not every knot that passes through this region cause an enhancement in the 43 GHz light curves or the gamma-ray one. Future observations and numerical simulations of 3C 111 and/or similar sources could confirm this scenario.

P6 - TANAMI monitoring of TeV detected AGN at 13 cm

Petra Benke[1], Eduardo Ros, Roopesh Ojha, Matthias Kadler, and Florian Rösch on behalf of the TANAMI team
[1]*Max Planck Institute for Radioastronomy, Germany*

TANAMI aims at VLBI monitoring of active galactic nuclei on the rarely targeted southern sky at X and K band since 2007, and in S band since 2020. Radio-gamma multiwavelength campaigns have been carried out since the start of the program, and in recent years the source sample has been extended to accommodate the emerging field of neutrino astronomy as well. Focusing on the connection between the gamma-ray and radio variability, we investigate objects affected by the Doppler crisis and we attempt to locate the origin of the gamma-ray emission from VLBI imaging at parsec scales. Since most sources detected at very high energies are faint in the radio bands (S_2GHz<100 mJy), new S band observations were added to the TANAMI monitoring to observe TeV detected AGN on the southern sky. I present first results of the S band imaging program together with spectral studies of extended jets of very high energy detected AGN.

P7 - Synergy between VLBI and Gaia: towards a multi-waveband celestial reference frame

Patrick Charlot
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A new IAU working group entitled "Multi-waveband ICRF" has been established in 2021. This working group takes over two former working groups: (i) the working group on the "Third Realization of the International Celestial Reference Frame (ICRF3)", terminated in 2018 with the realization and adoption of the ICRF3, and (ii) the working group entitled "Multi-waveband realizations of the International Celestial Reference System (ICRS)", terminated in 2021 after the adoption of the Gaia-CRF3 as the optical realization of the ICRS. The objective of the new working group is to work toward the realization of a multi-waveband celestial reference frame, incorporating positions in both radio and optical bands and ensuring their consistency over the various bands. The end goal of the working group will be to produce the next generation VLBI frames at the S/X, K, and X/Ka bands, or at any other radio band that may emerge in the coming years, to match these with the optical realization from the Gaia space mission, and to place all such positions on a common grid guaranteeing consistency of the source positions over the different bands. Before this can be accomplished, a number of questions relating to the construction of such a multi-waveband frame are to be addressed. These include dealing with non-uniform sky distributions, agreeing on a consistent treatment of Galactocentric acceleration, establishing common practices to align reference frames in different bands, and considerations regarding wavelength and time-dependent source positions. A proper terminology for referring to the individual (per band) components of the reference frame must also be defined. This future multi-waveband ICRF should be a valuable asset to further improve our understanding of the physics of the underlying extragalactic objects.

P8 - VLBI Astrometry of two Radio Stars HD 199178 & AR Lacertae

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To accurately link the radio and optical Celestial Reference Frames (CRFs) at optical bright end, i.e., with *Gaia* G band magnitude < 13, increasing number and improving sky distribution of radio stars with accurate astrometric parameters from both Very Long Baseline Interferometry (VLBI) and *Gaia* measurements are mandatory. We selected two radio stars HD 199178 and AR Lacertae as the target for a pilot program for the frame link, using the Very Long Baseline Array (VLBA) at 15 GHz at six epochs spanning about 1 year, to measure their astrometric parameters. The measured parallax of HD 199178 is 8.949 $\pm$ 0.059 mas and the proper motion is $\mu_\alpha \cos\delta = 26.393 \pm 0.093$ and $\mu_\delta = -0.950 \pm 0.083$ mas yr^{-1}, while the parallax of AR Lac is 23.459 $\pm$ 0.094 mas and the proper motion is $\mu_\alpha \cos\delta = -51.906 \pm 0.138$ and $\mu_\delta = 46.732 \pm 0.131$ mas yr^{-1}. Our VLBI measured astrometric parameters have accuracies about 4-5 times better than the corresponding historic VLBI measurements and comparable accuracies with those from *Gaia*, validating the feasibility of frame link using radio stars. With the updated astrometric parameters for these two stars, there is a $\sim$ 25% reduction of the uncertainties on the *Y* axis for both orientation and spin parameters.

P9 - VLBI imaging of a nearby galaxies sample at 5 GHz

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Low luminosity AGNs are dominant in the present-day universe. The mechanism by which energy and radiation are produced in the center is still in debate. The radio emission is dominated by jet or ADAF, or a combination. An important discriminant is to probe the size of the radio emission in parsec-scales. We present our new VLBI results of a sample of LLAGNs at 5 GHz. Twenty-three of the 36 sources are detected and imaged. The origin of the radio emission in pc scales is discussed in the present work.

P10 - RADIOBLOCKS: Applying Cutting-Edge Technology to Enhance the Entire Data Chain, from Receiver to Final Output

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RADIOBLOCKS is a 10 M€ Horizon Europe project that will develop common building blocks for technological solutions to enable a broad range of new science and enhance European scientific competitiveness. RADIOBLOKS is coordinated by JIVE and includes major European research infrastructures for radio astronomy, together with partners from industry and academia. I will describe the project and its ambitious goal to develop the common blocks that European radio facilities will use to enable exciting scientific results.

P11 - Digital Object Identifiers and Metadata for VLBI Datasets and Products

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The time and effort required to discover, visualise and analyse large quantities of information and research data for research, monitoring and decision making present a great challenge to VLBI and Earth science investigation. Existing data and information systems support experienced users but present difficulties for new and novice users unfamiliar with the variety of formats and structures in which data, metadata and information are stored. To address these challenges, innovative data services, cloud-based tools, Application Programming Interfaces (APIs), data discovery tools and support approaches have been developed to assist specialised and general user communities in discovering, visualising and analysing VLBI data and products. The realisation of the importance and potential use of unique persistent identifiers in support of Wilkinson's FAIR principles, has led to the attribution of Digital Object Identifiers (DOIs) to data, and products derived from data, becoming best practice for research data management. Data discovery is largely dependent upon proper and encompassing metadata, metadata standards and repositories. In this presentation, we discuss DOIs and best practices for the attribution of DOIs to VLBI datasets and products, as well as the importance of complete and reliable metadata and metadata repositories. We present an initiative by a regional data service provider to mint DOIs for its data and products, and make recommendations for the establishment of a user-friendly metadata repository for the South African Radio Astronomy Observatory (SARAO) in the near future.

P12 - The LOFAR-VLBI view of Abell 2255

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The LOw Frequency Array (LOFAR) is an interferometer that operates at frequencies between 10 and 240 MHz. The facility actually consists of 52 stations spread throughout Europe. 38 of these are located in Netherlands: 24 "core" stations, located within a radius of 2 km, and 14 "remote" stations with baselines of up to 120 km. Nowadays it is routine to calibrate these Dutch stations in order to achieve 6″ resolution maps in a 20 deg2 field of view at 150 MHz. However, the LOFAR array presents also 14 "international" stations spread throughout Europe: 6 in Germany, 3 in Poland, and one each in UK, France, Sweden, Ireland, and Latvia. Other two are expected to be built also in Italy and Bulgaria. This configuration provides baselines of up to 1989 km, which yields an angular resolution of 0.27″ at 150 MHz. Such high-resolution capability is unique for low-frequency instruments, even for future era of the Square Kilometre Array (SKA).

Using the full International LOFAR Telescope (ILT) is however technically challenging in terms of both calibration and data volumes: these difficulties caused the

ILT to be not intensively used in the previous years, and so just a small number of publications was produced. The turning point is represented by the development of a pipeline by Morabito et al. (2022) which allows the calibration and imaging of targets within LOFAR's field of view at sub-arcsecond resolution.

In the poster we show the preliminary results from the ILT observations of the galaxy cluster Abell 2255. In particular, we focus on the "tails" of the three main radio galaxies that characterize the cluster environment, namely the "Original Tailed Radio Galaxy (TRG)", the "Goldfish", and the "Beaver". These head-tails, that have a narrow angle tail (NAT) morphology, show extended synchrotron radio emission on 100s kpc-Mpc scales at 144 MHz up to resolutions of $5.0'' \times 3.8''$ (Botteon et al., 2020). But, at this moment, no LOFAR-VLBI observations have been used to observe, at sub-arcsecond resolution, these head-tail radio galaxies.

The goal of our work is then to use LOFAR long-baselines data to study the structure of the main tails observed in A2255. These preliminary results have been obtained with just a small number of observations with respect to the huge amount of data that will be available and will be put together (around 250h of observations), with the aim to show a unique view of these sources at arc-second and sub-arcsecond resolution.

P13 - A deep pilot VLBA survey in COSMOS: radio-faint AGN in typical galaxies at cosmic noon

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The radio window offers a unique, dust-unbiased view of star formation and active galactic nuclei (AGN) accretion. Yet, we have no observational clues at $z>0.3$ on the occurrence of radio-faint (i.e. <100 uJy) AGN in "typical" star-forming galaxies (SFGs), due to poor sensitivity or galaxy contamination in the radio band. Current VLBI follow-ups are aimed at either sparse samples or radio-brighter AGN (>100 uJy). This not only limits our knowledge of the global AGN duty cycle, but also prevents us from taking a clean census of "pure" star formation in the distant Universe. I will present the preliminary results of a deep (rms ~ 4.5 uJy/bm in L-band) pilot Very Long Baseline Array (VLBA) survey at the center of the COSMOS field, which capitalizes on exquisite multi-wavelength ancillary data already in-hand. By targeting a representative sample of >150 massive SFGs, this VLBA programme enables us to: (i) quantify radio-faint AGN contamination in typical SFGs; (ii) constrain the duty cycle and evolution of radio-faint AGN in massive high-z galaxies. These are crucial steps for making realistic predictions of the composite nature of the uJy radio population with the upcoming ngVLA and SKA.

P14 - Probing the Jet Collimation Profile of M84

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How the jet in active galactic nuclei (AGN) is collimated has been a longstanding issue in astrophysics. Recent high-resolution VLBI analysis for an increasing number of AGN jet sources has greatly improved our observational understanding of jet collimation properties near the supermassive black hole. However, past jet collimation studies were exclusively based on bright and powerful jet sources. Here we focus on the nearby radio galaxy M84, a prototypical source of low-luminosity AGN (LLAGN), which allows us to examine the jet collimation property at the lower end of the jet activity. We analyzed the detailed jet morphology of M84 using the Very Long Baseline Array and archival Very Large Array data to probe the jet geometry from $\sim 10^2$ Schwarzschild radii (r_s) up to $\sim 10^7\ r_s$. The well-fitted jet structure exhibits a transition from a semi-parabolic, $W(r) \propto r^{0.72}$, to a conical shape, $W(r) \propto r^{1.17}$, at about $10^4\ r_s$. The distance of the collimation break is significantly shorter than those typically seen in more powerful jets, suggesting that the collimation of the low-power jet is less efficient. In addition, we measure the frequency-dependent core shift effect using phase referencing observations and discuss the jet physical properties such as the magnetic field strength.

P15 - Zooming into the heart of a double-double radio galaxy with the EVN and e-MERLIN

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The radio source J0028+0035 is a recently discovered double-double radio galaxy at redshift z=0.398. The relic outer lobes are separated by about 1 Mpc while the collinear inner lobes span less than 1 kpc projected onto the sky. In the arcsec-resolution radio images, there is also a central radio feature that offers the intriguing possibility of being resolved into a pc-scale, third pair of innermost lobes. This would make J0028+0035 a rare triple-double source where traces of three distinct episodes of radio activity could be observed. To reveal the compact radio structure of the central component, we conducted observations with the European VLBI Network (EVN) and the enhanced Multi-Element Remotely Linked Interferometer Network (e-MERLIN). Here we present our high-resolution 1.7-GHz image of the core in J0028+0035 that consists of a single mJy-level component. As a bonus, a nearby compact radio source, 5BZU J0028+0035, a coincident object seen in the background, with an angular separation of only ~15 arcsec from our primary target was also studied by employing multi-phase-centre correlation.

P16 - VLBI analysis of the potential high-energy neutrino emitter blazar, CTD 74

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Recent studies suggest that high-energy neutrinos can be produced in the jets of blazars, radio-loud active galactic nuclei (AGN) with jets pointing close to the line of sight. Follow-up of possible high-energy neutrino counterpart objects is essential in the electromagnetic regime due to the relatively poor angular resolution of current neutrino detectors. Since the Very Long Baseline Interferometry (VLBI) technique provides the highest angular resolution to study the radio jets of blazars, a growing number of investigations are conducted to connect individual blazars to given high-energy neutrino events. We analysed more than 20 years of available archival VLBI data of the blazar CTD 74, which has been listed as a possible counterpart of the neutrino event EHEA2012-05-23. Using cm-wavelength data, we studied the apparent speed of jet components, and we investigated the jet structure and core flux density before and after the neutrino event. Our results indicate a significant brightening of the core after the neutrino event.

P17 - Preliminary study on the clock comparison using high-frequency VLBI

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It is essential to transfer and compare atomic clocks distributed internationally to prepare for the upcoming redefinition of the second. In particular, state-of-the-art optical clocks have higher accuracy than the precision of GPS-based clock comparison, which is currently the only way for intercontinental comparison. Therefore, we launched a new project for the intercontinental optical clock comparison using broadband high-frequency VLBI. We first investigated the delay residual from 22-GHz VLBI measurements in Korea. As a long-term goal, we plan to compare optical clocks in Korea and Italy using broadband VLBI equipped with CTRs (compact triple-band receivers) which will be installed in Yonsei, Pyounchang (Korea), and Medicina(Italy) near future.

P18 - Investigating the parsec-scale jet structure of TeV-detected blazars

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Blazars are found to cover a broad range in luminosity and the lowest-luminosity objects turn out to be the ones whose spectral energy distribution extends to the highest energies. In the most extreme cases their spectral energy distribution can peak at very high gamma-ray energies above 10 TeV. These extremely high peaked BL Lac objects typically are very faint radio sources and thus make up a poorly studied source sample, especially at high radio frequencies. Due to their relatively low redshifts, VLBI observations of such sources can achieve a very high linear resolution. This makes it possible to look for hints of limb brightening and/or spine-sheath structures on the smallest scales. This is of particular interest as they might explain the origin of the seed photons for high-energy processes. To test these models, observations with the highest possible resolution at the highest possible frequencies are necessary. Here, we present first results of the parsec-scale jet morphology in a sample of GMVA observed extreme blazars.

P19 - Constraining relativistic beaming model for γ-ray emission of blazars

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In this paper, we use the correlation between radio core-dominance (R) and γ-ray properties of a sample of blazars to investigate the hypothesis that γ-ray emissions of blazars are strongly beamed. Distribution of R shows that FSRQs are more core-dominated than BL Lacs, with mean values of 0.71 $\pm$ 0.05 and 0.63 $\pm$ 0.03 on logarithm scales for FSRQs and BL Lacs respectively. The scatter plots yield 7 $\leq \gamma \leq$ 17 values of Lorentz factor which correspond to the mean beaming angles (ϕ_{m}) of 140 for the whole sample. We find a strong upper envelope correlation (r $\approx$ 0.75) between R and γ-ray dominance (Dg) defined as the ratio of γ-ray to radio luminosity with Lorentz factor of $9 \leq \gamma \leq 25$ and corresponding mean angle, $\phi_{\mathrm{m}} \approx 30$. Further analyses show that the Fermi quasars and Fermi BL Lacs sub-samples yield 3 $\leq \gamma \leq 5$, $\phi_{\mathrm{m}} \approx 160$ and $3 \leq \gamma \leq 5$, $\phi_{\mathrm{m}} \approx 110$ of the values of Lorentz factors and mean beaming angles respectively, suggesting that both radio and γ-ray emissions from blazars are beamed. The results are in good agreement with the proposition that γ-ray emissions from blazars are strongly beamed.

P20 - Study of Jet Collimation Profile in TeV Blazar Markarian 501

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Probing the detailed structure of the inner part of the relativistic jets is a fundamental issue for understanding jet launching and collimation mechanisms. High-resolution VLBI observations have revealed the limb-brightened structure and allowed to study the jet collimation profile of the representative radio galaxy M87. Recently the study has been extended to not only nearby radio galaxies but also quasars and blazars. However, it was difficult to probe the innermost jet structure for TeV blazars due to the small viewing angles. We selected the nearby representative TeV blazar Markarian 501 as our target. This source also has properties similar to M87, such as the limb-brightened structure and the jet power, except for the jet viewing angle. Multi-frequency VLBI analysis have revealed parabolically collimated structure at the inner region, while conical structure at outer region. We will discuss the footpoint of the relativistic jet, and further compare the jet launching mechanism with M87. We will also present our future prospects with the Event Horizon Telescope observations.

P21 - Jet proper motion in two z$>$3 blazars

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Relativistic jets of active galactic nuclei (AGN) in the early Universe provide important clues for understanding the cosmological evolution of supermassive black holes. At high redshift, beyond z=3, we have a very limited sample of jets with sufficiently long observational history which can provide information to extend our knowledge. Studying the apparent proper motion of jet components, using the milli-arcsecond scale resolution very long baseline interferometry (VLBI) technique, can reveal important information on the physical and geometrical properties of AGN. Here we present two blazars at $3 < z < 4$ that show prominent jet structure with multiple moving components. In both sources, J0805+6144 (z=3.03) and J1658-0739 (z=3.74), the apparent proper motion of each component could be derived using archival and new 8-GHz VLBI datasets covering time periods of almost two decades. The low apparent speeds of the jets are similar to earlier measurements of other high-redshift jetted AGN found in the literature and are consistent with the current cosmological paradigm.

P22 - Zooming in toward FRBs

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The origin of fast radio bursts remains unknown. Significant progresses have been made in the last few years, particularly in characterizing the environment of active repeating FRBs. VLBI, scattering analysis, the time series of pulses, RM, etc. have all provide valuable constraints of the FRB environments, some down to pc scales. A unifying picture is emerging, where more active repeaters are located in more complex plasma.

P23 - Offsets between VLBI and Gaia DR3 positions of extragalactic sources: global and individual characteristics

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Previous comparisons of VLBI catalogs against the Gaia data revealed large-scale differences of a few tenths of mas as well as significant offsets for about a hundred of sources. We study the positional differences of ICRF sources as obtained from a special VLBI solution and the Gaia Data release 3 (DR3). We used data from the permanent geodetic VLBI program at 8 GHz restricted to the observational time span used for the DR3 astrometric solution (August 2014 to May 2017) to determine the positions of radio sources through a standard geodetic VLBI data reduction scheme. Then we compared the estimated positions for sources in common with the Gaia DR3 solution. The preliminary results suggest some systematics in the determination of the angular separation: the angular separation is generally overestimated by some tenth of mas for sources having a poor VLBI observational history (that are also sources with large VLBI positional error), and for fainter sources in the optical band (that are also sources with large DR3 positional error).

P24 - Unravelling the link between multi-scale structure and star formation of Local U/LIRGs

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This work is part of the large i-LINK+LIRGI collaboration that aims to understand star formation in nuclear regions of local galaxies and how structures emerge from the intense activity triggered by interacting and merging processes giving origin to luminous and ultra-luminous Infrared galaxies, U/LIRGS. We are building a comprehensive legacy set of data from MHz to mm with high-resolution instruments (e-MERLIN, JVLA, the EVN and LOFAR-VLBI), for a multi-frequency and multi-scale view of the physical processes at $\lesssim 100$ mas, covering structures from ~ 10 pc to the kpc range. We are sampling 33 LIRGs and 9 ULIRGs from the statistically significant LIRGI Sample (e-MERLIN Legacy Project Luminous Infra-red Galaxy Inventory), a northern sub-set of the GOALS sample (Armus et al. 2009). Science objectives are to study the relations between star formation, AGN accretion, feedback mechanisms, establish how the energy/material flow, and how the distribution of these components shape the structures in these galaxies. These VLA observations are a key element of this programme which, when combined with our already available e-MERLIN data, will complete our radio view across multiple frequencies, enabling physically important scales to be reached whilst providing the surface brightness sensitivity to recover extended structures.

P25 - Detailed Analysis of Parsec-Scale Jet Kinematics in 3C 84 Monitored with the VLBA at 43 GHz

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We present detailed analysis of the parsec-scale jet kinematics of 3C84 from 2003 November to 2022 June monitored with the Very Long Baseline Array (VLBA) at 43 GHz. Our study focuses on a bright feature, named "C3", which has been moving at an average apparent velocity of 0.273c in the direction of 176 degrees. We find that the apparent velocity of C3 varies abruptly several times throughout this period, probably due to changes in the jet direction. For example, the apparent velocity changes from 0.15c in 2012-2016 to 0.39c in 2017-2022. This suggests that the intrinsic velocity of C3 should be larger than 0.37c and the viewing angle should be smaller than 30.9 degrees. In addition, we identify the emergence of four new jet components at C3, each with apparent velocities larger than that of C3. The fastest component shows an apparent velocity of 2.05c, which is larger than any other reported values in 3C84. This cannot be explained by a change in the viewing angle alone, unless the average viewing angle of C3 becomes smaller than 5 degrees. Our findings suggest that the new components are intrinsically faster than C3. We discuss possible mechanisms for the production of these new components at C3.

P26 - HartRAO VLBI: 50 Not Out!

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The Hartebeesthoek Radio Astronomy Observatory (HartRAO), which forms part of the South African Radio Astronomy Observatory (SARAO), operates as both an astronomical and fundamental geodetic observatory. HartRAO has its roots in NASA's Deep Space Station 51 (DSS 51), established in South Africa in 1961 to track deep space probes with a 26 m radio telescope. By the time NASA withdrew from South Africa in 1974, the 26 m had been conducting single-dish radio astronomy observations for more than a decade already. It had also participated in its first astronomical VLBI observations by 1970. HartRAO itself saw the light in 1975, now operating as a radio astronomy observatory. Soon the astronomical VLBI projects on the 26 m were being joined by astrometric/geodetic counterparts, the first geodetic VLBI on the 26 m taking place in 1980. A critical bearing failure on the 26 m in 2008 necessitated the conversion of a 15 m SKA prototype radio telescope to an operational geodetic VLBI antenna in 2012 in order to signficantly reduce the 26 m's geodetic workload. A VGOS antenna is waiting in the wings and, as soon as it has been equipped with a receiver, it will enter the geodetic VLBI fray, hopefully by the first half of 2024. We provide an overview of HartRAO trials and tribulations over the past 50 years and our VLBI aspirations for the next innings.

P27 - HST-1 in M87: Quad-frequency analysis of quasi-simultaneous VLBI observations

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The M87 jet has always been a great candidate for a relativistic outflow laboratory. However, there are areas of the jet, which are not been investigated in great detail, such as the HST-1 feature 70 pc downstream from the core. At subarcsecond angular resolution, HST in the optical and VLA in radio can spatially resolve it from the core, but can not provide information on its substructure. However, the superior angular resolution of VLBI has also some limitations, since it struggles with the sensitivity and smearing effects, not allowing it to observe it at all, especially with high frequencies. Our new analysis overcomes these limitations and we are glad to present the first Quad-frequency analysis (1.6-5-8-15 GHz) of quasi-simultaneous observations, made in the spring of 2009 by the VLBA and the EVN telescopes.

P28 - Unveiling particle acceleration regions in the hotspots of radio galaxies

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Hotspots are bright and compact regions that are usually observed at the edge of powerful radio galaxies. Although they mainly radiate in the radio band, it has been established that many of them emit up to X-rays. The discovery of hotspots

with diffuse optical and likely X-ray synchrotron emission requires a revision of the standard scenario of particle accelerated by a single strong shock generated at the jet termination. The X-ray emission may be explained with an additional synchrotron component originating in compact regions, provided that efficient particle acceleration is ongoing. In this contribution we present results on multiwavelength high-resolution observations of the hotspots of 3C227 and 3C445. These hotspots were target of JVLA, VLBI, VLT, and multi-epoch Chandra observations. We discuss the pc-scale structure and magnetic field of these hotspots and investigate the particle acceleration mechanisms at work at the edges of radio galaxies.

P29 - New digital backend for ATCA - small-N GPU correlator

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Commonwealth Scientific and Industrial Research Organisation, Australia

The ATCA is a 6 element interferometer in Australia with a frequency coverage of 1-105 GHz. Currently the facility has a 4 GHz bandwidth digital backend using traditional FPGA based digital processing. In late 2023, all digital components will be replaced with the new "BIGCAT" backend, based on Xilinx RFSoC digitisers and GPU based processing. The system will double the bandwidth to 8 GHz. As a GPU based system there will be much greater flexibility for new astronomical modes such as spectral line setups, pulsar binning options and RFI mitigation approaches. The core GPU processing is being written with an open source licence, and the processing is "VLBI friendly" (ie no short baseline assumptions have been made). Current benchmarking show we can easily processes 512 MHz of dual polarisation voltage data for 6 stations in realtime on a a single Nvidia RTX3080 GPU.

P30 - Multi-wavelength view of the quasar 3C 345 beyond λ18 cm with RadioAstron

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A fraction of supermassive black holes in the centres of active galactic nuclei (AGN) produce powerful jets emitting across the electromagnetic spectrum. However, their formation and collimation mechanisms remain poorly understood to date. Probing the small physical scales involved can be achieved with Very-Long-Baseline Interferometry (VLBI) at radio wavelengths. Many jet launching scenarios predict the existence of helical magnetic (B-)fields in the jet, potentially being one of the jet collimation mechanisms and manifesting themselves in polarisation structure and transverse Faraday rotation gradients. The RadioAstron mission, operated from 2011-2019, aims at utilising a 10-m antenna onboard the Spektr-R spacecraft on a highly elliptical orbit with major axis of 350,000 km in conjunction with a ground-array of telescopes, including the EVN. It observed at frequencies of 0.32, 1.6, and 22 GHz with full polarisation capabilities, and thus maximises the angular resolution even at lower radio frequencies. We observed the powerful flat-spectrum radio quasar 3C 345 with RadioAstron at 1.6 GHz on March 30, 2016, resulting in the highest-resolution

image of this source at this frequency to date (see. Pötzl et al. 2021) with a resolution along the jet direction of 300 microarcseconds. In addition to the published results, we will present studies of the spectral index and the rotation measure in the source. These were obtained with the aforementioned RadioAstron data in conjunction with ground-VLBI data at different frequencies from the same epoch. We test for possible transverse Faraday rotation gradients, study the evolution of the EVPAs, and discuss these quantities in the context of viable physical models.

P31 - Numerical study of the jet acceleration in NGC 315-like sources

Luca Ricci
MPIfR / Julius-Maximilians-Universität Würzburg, Germany

Relativistic jets launched by Active Galactic Nuclei (AGN) are able to propagate up to scales of hundreds of kiloparsec, largely outgrowing their host galaxies. One of the main elements behind their ability to extend through such remarkable distances is their inertia, achieved by investing their initial energy into accelerating the jet bulk flow. In the last decades, the mechanisms behind the jet acceleration phenomena have been largely studied and substantial progress has been made.

However, both theoretical and numerical studies have been mostly focused on the magnetic component of the acceleration, assuming thus cold flows. In our work, we want to explore whether the thermal acceleration, expected to be relevant only on very compact scales, can be effective on sub-parsec and parsec scales as well. We aim at doing that by relaxing the assumption of cold jets and by simulating different outflows with different initial conditions, either magnetically or thermally dominated, in order to explore the role of both acceleration mechanisms. Along with this aspect, we aim at reproducing the main properties of the acceleration region in NGC 315, a prototypical Fanaroff-Riley I radio galaxy chosen as a template for our simulations since its acceleration properties have been exhaustively studied by means of Very Long Baseline Interferometry (VLBI) observations. Our results suggest how the thermal acceleration via the Bernoulli mechanisms is still relevant on parsec scales when the internal energy is comparable, or larger, with respect to the magnetic one. Moreover, a number of our simulated models are able to reproduce the different Lorentz factor profiles inferred for NGC 315 across different epochs, showing how small changes in the jet physical condition at injection, which can take place over time-scales of few months, may lead to important variations in the observed speed profiles. Finally, in the simulated region, we recover half-opening angle values of 1-3 deg, in agreement with the average values for AGN jets.

P32 - Status of the KVN/E-KVN and the EAVN

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The Korean VLBI Network (KVN) comprises three 21 m radio telescopes located in Seoul, Ulsan, and Jeju Island, equipped with the world's first 4-channel receiver capable of simultaneous observations at four different frequencies (e.g., 22, 43, 86, 129 GHz). Recently, KVN's multi-frequency receiver has been further enhanced with a compact triband receiver (CTR), which has been widely adopted. In 2020, the extended KVN project (E-KVN) began, which involves the construction of a new radio telescope in Pyeongchang, South Korea, almost identical to the current KVN telescope, but with better surface accuracy to extend the operating frequency up to 230 GHz. This new telescope allows for the simultaneous observation of a maximum of five radio frequency bands (18-26, 35-50, 86-116, 125-175, 210-275 GHz). The construction and commissioning of the E-KVN are expected to be completed by the end of 2023, and KVN will operate as a 4-element array from 2024. In this presentation, we will introduce the current status and activities of KVN and E-KVN, and discuss the activity of the East Asian VLBI Network (EAVN).

P33 - Morphology Study of GHz-Peaked-Spectrum Radio Galaxies

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A morphological VLBI study of GPS radio galaxies suggests that these objects may have different evolutionary paths, which likely depend on the relevance of precession in the radio jet.

P34 - Probing the Heart of Active narrow-line Seyfert 1 Galaxies with VERA wideband Polarimetry

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We explored the parsec-scale nuclear regions for a sample of radio-loud narrow-line Seyfert 1 galaxies (NLSy1s) using the VLBI Exploration of Radio Astronomy (VERA) wideband (with a recording rate of 16 Gbps) polarimetry at 22 and 43 GHz. Our targets include 1H 0323+342, SBS 0846+513, PMN J0948+0022, 1219+044, PKS 1502+036 and TXS 2116-077, which are all known to exhibit γ-ray emission indicative of possessing highly beamed jets similar to blazars. For the first time we unambiguously detected Faraday rotation towards the parsec-scale radio core of NLSy1s. The RM magnitudes of NLSy1s are significantly larger than those seen in the core of BL Lac objects (BLO; a dominant subclass of blazars), suggesting that the nuclear environment of NLSy1s is more gas-rich than in BLOs. Remarkably, the observed parsec-scale polarimetric properties of NLSy1s (low core fractional polarization, large core RM and jet-EVPA misalignment) are similar to those of flat-spectrum radio quasars (FSRQs). Our results are in accordance with the scenario that NLSy1s are in an early stage of AGN evolution with their central black hole masses being smaller than those of more evolved FSRQs.

P35 - Chasing the disappearing knots in the blazar 3C 454.3

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The quasar 3C 454.3 (also known as "Crazy Diamond") presents a curved parsec-scale jet that has been exhaustively monitored across the electromagnetic spectrum over the recent years. Here, we present a multiwavelength study during the period 2013-2017. Very-Long-Baseline Interferometric (VLBI) observations at 43 GHz and 86 GHZ in total intensity and polarization enabled us to reveal the magnetic field topology in spatial scales up to 0.4 parsecs in projected distance. Kinematic analysis revealed the abrupt vanishing of at least four new superluminal jet features in the historical jet region located approximately 0.6 milliarcseconds from the VLBI core, where a quasi-stationary feature is located. In this work, we examine several possible scenarios that can explain this phenomenology.

P36 - 3.5 years of ESCAPEism

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On 31 January 2023 the 15M€/3.5 year European Commission funded ESCAPE project finished after starting on 1 Feb 2019. It brought together the largest European astronomy and particle physics ESFRI landmarks (CTA, KM3Net, SKA) and pan-European research infrastructures such as CERN, ESO, and JIVE with the ambitious goal of "Implementing the European Open Science Cloud" (EOSC); specifically the bits relevant to the communities served by the participating research infrastructures.

The EOSC is the EC's vision on making the European Research Area more consolidated and federated by letting partners from different/adjacent domains (=a cluster) find and share solutions to common problems - such as (more user friendly, federated) access to storage, compute, and data resources ("archives"). Another important goal is to make the science data, products, and results more FAIR (Findable, Accessible, Interoperable, Reusable). The EC put money where their mouth is by funding user facing as well as infrastructural software - and service development for the EOSC in the The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructure (ESCAPE) project.

In the presentation I'll briefly introduce the project and describe how the ESCAPE-funded developments at JIVE towards e.g. the Virtual Observatory and Jupyter notebooks may have an impact on European VLBI Network users and possibly for certain aspects of radio astronomy in general.

P37 - Introduction to the East Asian VLBI Network and Future Growth into the Global VLBI

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The poster presentation describes an introduction to the project overview of the East Asian VLBI Network (EAVN) and recent active collaborations with non-EAVN arrays/telescopes for future growth into the Global VLBI Alliance (GVA). EAVN, consisting of 16 active radio telescopes and 3 correlators in China, Japan, and Korea, provides opportunities of VLBI observation of more than 1100 hours in a year at 6.7, 22, and 43 GHz with the longest baseline length of 5000 km. Among these EAVN sessions, 27% (about 300 hours) of whole EAVN time is served to VLBI observations with inviting non-EAVN telescopes. As of the first half of 2023, EAVN has conducted VLBI observations with 12 non-EAVN telescopes from 5 countries (Australia, Germany, Italy, Russia, and Spain). It is notable that the highest angular resolution of 250 microarcseconds at 22 GHz can be obtained with a series of EATING VLBI (East Asia To Italy: Nearly Global VLBI) observations with the longest baseline length of longer than 11000 km. These experiments are a good demonstration for considering practical coordination of GVA, including creation of a governing body of GVA, data transfer from each telescope to a correlator, and discussion on potential science cases with GVA.

P38 - Providing a new data set: the dual frequency and broadband VLBI visibility data on the range between 2 and 10 GHz

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Federal Agency for Cartography and Geodesy, Germany

The goal is to represent the availability of the dual frequency and broadband VLBI visibility data at the BKG Data Center. The BKG Data Center (BKG DC) is hosted by the German Federal Agency for Cartography and Geodesy (BKG) as one of the three primary IVS Data Centers on terms defined by the International VLBI Service for Geodesy and Astrometry (IVS). Since the last year so-called SWIN files (as short for Swinburne) are received for the currently observed sessions. The SWIN data is the product of the the DiFX correlator and contains the visibility data, which the IVS Community refers to as the Level 1 Data. The IVS conducts the legacy VLBI observations on the dual frequencies of about 2.2 and 8.6 GHz (also referred to as S/X bands in IVS Community) of the bandwidth depending of the session type with 6 and 8 recording channels each correspondingly. Additionally, the broadband VLBI observations are conducted in four bands, each with a width of 512 MHz of the next central frequencies: 3.3, 5.5, 6.6, and 10.5 GHz (A, B, C, and D-bands, respectively), resulting in a total of 32 recording channels. We provide a general overview of the available sources in the VLBI observations conducted by IVS. Here we are aiming to give an introduction to the commonly used IVS terms and definitions such as the VLBI sessions and the common session types with focus on the description of the source observation strategies.

The SWIN files provide the potential to be exploited far beyond the geodetic IVS community. We present here how to access the data at BKG Data Center. The other official IVS Data Center – CDDIS - has the SWIN files in their repositories as well. The official IVS Data Centers are designed by IVS to be the mirror of each other. This becomes a challenge with the SWIN files as their demand of the disk space exceeds drastically the needs of any other VLBI data at the Data Center. Besides, the data transfer of the historical data stored at the Haystack correlator has been initiated from the "cold data storage" to the CDDIS. The total amount reaches up to 60TB, where about a half of the data are available at the correlator in Bonn. Because of the technical demands, we are interested in the discernible use of these data. Driving by these reasons we look for the relevant communities to announce and advertise the availability of the new data. The BKG Data Center team is eager to improve our services. Following our goals, we work on the support and facilitation of the barrier free data access, thus the feedback is essential to us.

P39 - Exploring Deeper into the Acceleration and Collimation Zone of Radio Quasar 1928+738 with HSA Polarimetric Multifrequency Observations

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Supermassive black holes in the center of active galactic nuclei (AGNs) often produce highly collimated relativistic jets. The standard magnetohydrodynamic (MHD) models of AGN jets predict the existence of the acceleration and collimation zone (ACZ) in their inner region. We have explored the ACZ in the jet of a radio quasar 1928+738 (a.k.a 4C 73.18). We recently performed follow-up observations using the High Sensitivity Array (HSA) at 1.6, 2.3, 4.9, 8.4, 15, 24 and 43 GHz. We investigate the magnetic fields and the external medium surrounding the 1928+738 jet, and thus the two main ingredients of the MHD processes in the ACZ. Our multi-frequency polarimetric observations enable studies of the evolution of magnetic field structures and the Faraday rotation over a wide range of scales. In this talk, we present the preliminary results.

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