15th EVN Symposium & Users Meeting, 11–15 July 2022, Cork, Ireland – POSTERS

1. *RadioAstron* space VLBI study of 3C 84 at 22 GHz

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Due to its brightness and proximity, the radio galaxy 3C 84 (NGC 1275, Per A) is one of the most frequently studied active galactic nuclei (AGN) on the northern sky. Very long baseline interferometric (VLBI) studies reveal a complex structure on parsec scales, composed of a faint, diffuse emission region originating from jet activity in the 1990's and a hotspot at the end of the re–started jet, the result of the latest activity starting in the early 2000's. The jet shows a limb–brightened structure (Nagai et al., 2014) that has been probed at the highest angular resolution by *RadioAstron* at 22 GHz in 2013 (Giovannini et al., 2018). The jet has a unique, quasi–cylindrical collimation profile, where the jet is confined by the pressure of the low–intensity cocoon surrounding it (Savolainen et al., 2021). The jet propagation was halted by the dense ISM, resulting in a period of frustration between 2016.7 and 2018.0 (Kino et al., 2021), when the jet broke out. We will present here a second epoch 22 GHz *RadioAstron* observation and will compare the new image with the one published in Giovannini et al. (2018). New data confirm the structures reported by Giovannini et al. (2018), and reveal morphological changes both in the jet and the hotspot region, as well as a wider, parabolic jet width profile. Simultaneous multi–frequency observations at 5, 8, 15 and 43 GHz with the VLBA and Effelsberg, as well as Medicina at 5 GHz enabled us to conduct spectral studies focusing on the hotspot, and to measure the core shift and infer the position of the jet apex, whose position has been the subject of debate in recent studies (Giovannini et al. 2018; Paraschos et al., 2021).

2. GMVA observation of BL Lacertae when the jet is flaring

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We present preliminary results of our ongoing project on BL Lacertae (BL Lac). BL Lac is the prototypical source of the BL Lac objects that is a subclass of *blazar*. With the exceptional brightness (>3 Jy even at ≤ 3 mm), proximity (redshift of $\sim$0.069), and mutual visibility suitable for the northern VLBI stations (Dec. $\sim +42°$), the relativistic jet of BL Lac is one of the best targets to study the inner part of the jet within sub-pc scales from the central supermassive black hole which is a region poorly understood. We use the Global mm-VLBI Array (GMVA) to observe the jet at 3 mm and report here the resultant image of a recent GMVA observing session (April 2021). Particularly, the phased array NOEMA was included in this session which is expected to improve the image quality largely. The μas-scale resolution of the GMVA (i.e., $\sim$50 μas) allows us to see the jet down to a scale of $\sim$4000 R_s; Schwarzschild radii. This region is thought to be either inside the acceleration/collimation zone (ACZ) where a large-scale helical magnetic field dominates, or the end of the ACZ with partially ordered magnetic fields. Previous studies found the structural complexity in the upstream of the jet such as multiple bends and stationary features that could be caused by variations of the external pressure and/or jet geometry. Furthermore, BL Lac is flaring since the late-2020 from radio to γ-rays (1 mm fluxes of the source reach $\sim$9 Jy in Apr. 2022), which makes the observation more interesting. In this study, we plan to investigate source polarization, jet shape/transverse patterns, and a connection with γ-rays to study the above-mentioned issues. Later, we will also include previous/recent GMVA datasets of BL Lac.

3. Double Synchrotron Self-Absorption Spectra of the Blazar 3C 454.3 and Its Magnetic Field Strengths

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The blazar 3C 454.3 is known for its strong outburst across the whole electromagnetic spectrum. Multi-wavelength radio observations enable us to study the spectral variability of relativistic radio jets in the source. In our work, we use multi-wavelength radio observations from 3GHz to 340GHz. From the spectral analysis using the multi-wavelength data we found two synchrotron self-absorption(SSA) features in the spectra for the compact variable emission regions in the source. One peak of the SSA spectral feature is found at a frequency range of 3-37GHz, and the other at 56-124GHz. By using the derived SSA physical parameters, we estimated magnetic field strength for both SSA(B_{SSA}) and equipartition(B_{EQ}) condition. The estimated magnetic field strengths in the assumption of equipartition are in range of 72-280mG for higher turnover frequency SSA feature. For about the SSA feature having lower turnover frequency, the estimated B_{SSA}(>7mG) is more strong than the estimated B_{EQ}(2-4mG) before Jun 2014 γ-ray flare. This may indicate that the emission region for lower turnover frequency SSA spectrum before the Jun 2014 γ-ray flare is recollimation shock.

4. The acceleration and collimation zone in the jet of 1928+738

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We studied the jet in the flat spectrum radio quasar (FSRQs) 1928+738, located at $z = 0.302$. The jet of 1928+738 is one of the most misaligned (13°) ones relative to the line of sight among known FSRQs. It provides an excellent opportunity to investigate the acceleration and collimation zone (ACZ), which is expected to exist in the vicinity of the central super massive black hole. The physical properties of ACZs, especially in FSRQs, are not well understood yet. We therefore explored the structural evolution and the kinematics of the 1928+738 jet, using various archival and our own VLBI observations. The multi-frequency observations made it possible to analyze the jet across a wide distance range, from < 1 to ~ 40 mas (corresponding to ≈ 800 pc in de-projection). We find that the jet is being collimated and accelerated continuously out to an angular distance of ~ 5 mas. We note that 1928+738 is the first FSRQ and only the fourth radio-loud AGN for which the presence of a spatially extended ACZ is now confirmed. In this talk, we will present our observational results of the jet of 1928+738. We will also discuss the physical properties of ACZ : the size of the zone, the terminated jet speed and the efficiency of the acceleration, etc.

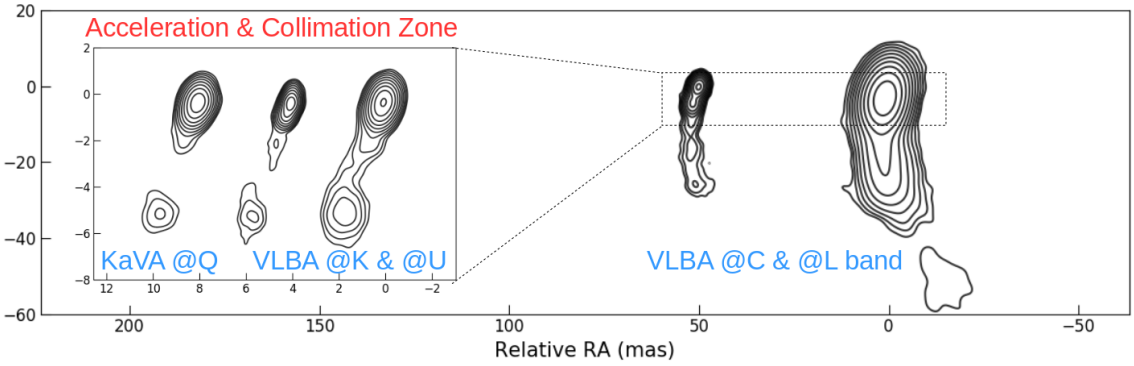

Figure 1: Total intensity maps of 1928+738 jet, observed with VLBA at different bands. The acceleration and collimation zone of the jet, which is discovered by our analysis, is successfully imaged using KaVA Q, VLBA K and U band observations. The jets observed with VLBA at C and L bands in larger scale, are also illustrated.

5. Modelling the flares in VLBI cores of blazars

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Core of the blazar jet observed with the VLBI at GHz frequencies is thought to be a photosphere due to the synchrotron self-absorption. Its position changes with frequency – this is well known core shift effect. However, even at a single frequency the core changes its position during the flares. Recent study of the core shift variability in a sample of blazars revealed that the emitting particles density increases while the magnetic field decreases at the core position during the flare. This is consistent with the previous modelling of the VLBI-core light curves and tempts to be interpreted as a magnetic reconnection powering the flares. However, simple analytical model were used for interpreting the data. We employ simulations of the multifrequency multi-epoch VLBI observations of a flaring relativistic jet to explore if such observations could in principle discriminate between the various flare models.

6. A study of bent jets in active galactic nuclei at parsec scales

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It is observed that some AGN jets exhibit bending even at parsec scales. In this work we perform an analysis of outflows in active galactic nuclei on the basis of publicly available multi-frequency VLBI images. Nearly 73 000 images of about 11 000 AGN are studied. Our analysis reveals that about 5% of them show significantly bent structure. We characterize the geometry of the jets by fitting stacked ridgelines with a set of simple models and suggest possible scenarios explaining observed bending.

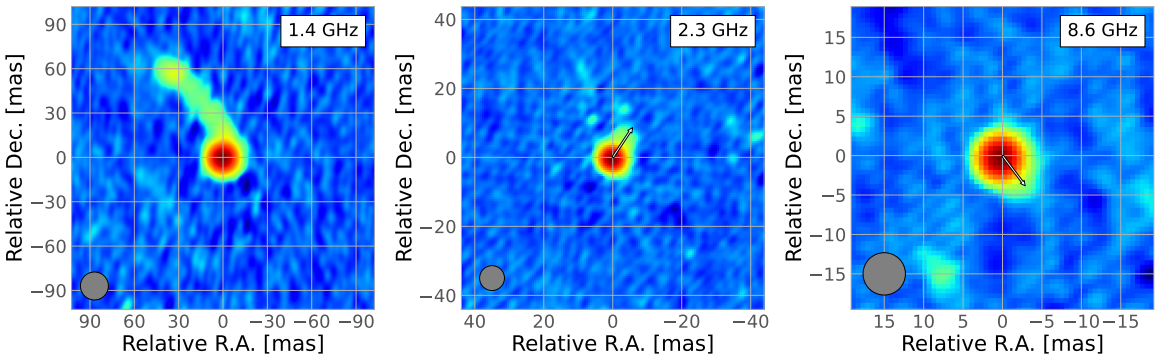

Figure 2: Quasar J1327+2210 (TXS 1324+224): an example of the source with significantly different jet directions probed at different scales by VLBI data at 1.4, 2.3 and 8.6 GHz. This represents a helix-shaped structure of the entire jet. The black arrows indicate corresponding jet position angle at a given frequency. Restoring beam at the half-power level is shown in the bottom left corners.

7. Rotation Measure studies of the quasar 3C 345 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. The formation of jets and what collimates them on parsec scales is still poorly understood and debated to date. Many jet launching scenarios predict the existence of helical magnetic fields in the jet, potentially being one of the jet collimation mechanisms and manifesting themselves in polarisation structure and transverse Faraday rotation gradients.

Therefore, studying the magnetic fields on the smallest possible scales in AGN jets can give crucial insight into the physics of jet launching, acceleration and collimation. This is one of the main aims of the RadioAstron mission, which operated from 2011 to 2019. The 10 m anenna onboard the *Spektr-R* spacecraft on a highly ellipical orbit with major axis of 350,000 km complemented a ground-array of telescopes, including the EVN, at observing frequencies of 0.32, 1.6, and 22 GHz with full polarisation capabilities.

The powerful flat-spectrum radio quasar (FSRQ) 3C 345 is one of those archetypical AGN that underwent several flaring episodes in the optical, γ-rays and at radio wavelengths. Observed with VLBI over several decades, it shows a compact jet closely aligned with the line of sight with components exhibiting apparent superluminal motion.

We observed 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 $\sim$300 μas. 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 from the same epoch, as well as newer observations with the VLBA made in 2019. We test for possible Faraday rotation gradients and study the evolution of the EVPAs.

8. Multi-wavelength VLBI observations of the quasar 3C 345

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We study the innermost 5 mas of the compact jet of the quasar 3C 345, which is known for a complex structure of rapidly moving and shocked components, as well as gamma ray emission driven by the relativistic outflow. Additionally, we probe the magnetic field structure by analyzing the polarized emission. For this endeavor, we use observations of 3C 345 at ten epochs from 2017 to 2019, at 23, 43 and 86 GHz. From the jet kinematics, we first determine Doppler and Lorentz factors, providing information about ejection time and evolutionary stage of the individual jet components. Images at different frequencies are combined to obtain spectral index maps and estimates for the synchrotron spectrum to investigate the origin and nature of the emission, as well as the spectral evolution. We find e. g. multiple individual, persistent jet components moving at apparent superluminal speeds, which can be cross-identified between epochs and frequencies.

9. Radio jet proper motion analysis of 9 distant quasars at redshift above 3.5

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At high redshifts (e.g. $z > 4$), the radio jets of quasars are more difficult to detect because the sources are weaker and typically less extended. Up to now, there are only 4 radio quasars having measured jet proper motions at $z > 4$, with the help of the high-resolution very long baseline interferometry (VLBI) technique. The small sample significantly limits our knowledge of high-redshift jets, which can provide key information for understanding the jet nature and the growth of the black holes in the early Universe. In this presenting work, we selected 9 radio-loud quasars at $z > 3.5$ which display milliarcsec-scale jet morphology, presented VLBI images of the sample at 8.4 GHz frequency, and made spectral index maps. We also consider Gaia optical positions that are available for 7 out of the 9 quasars, for a better identification of the jet components within the radio structures. By involving multi-epoch archival VLBI data, we obtained jet component proper motions of the sample and estimated the jet kinematic and geometric parameters (Doppler factor, Lorentz factor, viewing angle). Based on the above results, we find that 6 out of the 9 sources can be classified as core–jet blazars. The remaining 3 objects are more likely young jetted radio sources, compact symmetric objects. Our results show that at $z > 3.5$, the jet apparent speeds do not exceed 20 times the speed of light (c). This is consistent with earlier high-redshift quasar measurements from the literature and the tendency derived from low-redshift blazars that fast jet speeds ($> 40\,c$) only occur at low redshifts.

10. High-resolution Imaging of Two Radio Quasars at the End of Reionization

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There are approximately 250 quasars discovered at redshift $z \geq 6$, of which only a handful were detected in radio bands, and even fewer were imaged with the highest resolution very long baseline interferometry (VLBI) technique. Here we report the results of our dual-frequency observations with the Very Long Baseline Array (VLBA) of two such recently discovered quasars, VIKING J231818.35–311346.3 at $z = 6.44$ and FIRST J233153.20+112952.11 at $z = 6.57$. Both extremely distant sources were imaged with VLBI for the first time. The radio properties of the former are consistent with those of quasars with young radio jets. The latter has an UV/optical spectrum characteristic of BL Lac objects, of which no others have been found beyond redshift 4 so far. Our VLBA observations revealed a flat-spectrum compact radio source.

11. Multifrequency simultaneous VLBA view of the radio core in 3C111

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This work presents the results of the analysis of multi-wavelength (6, 3.5, 2, 1.3, 0.7, 0.35 cm) observations of the active galaxy 3C111, obtained with the Very Long Baseline Array (VLBA). 3C111 contains one of the brightest cores at the cm/mm millimeter wavelengths among radio galaxies and exhibits variable emission of spanning several Jy. On pc scales, a one-sided jet is observed, consistently with substantial relativistic beaming and apparent superluminal motion. Given its proximity, 3C111 (z = 0.049), is an excellent object to study the physics of jets with mm-VLBI. We present images in total intensity, spectral index, polarization and rotation measure. The brightness distribution in each band is modeled with a set of circular Gaussian components. For each of them, we computed the brightness temperature (with $T_{B,max} \approx 1.3 \times 10^{12}$ K) and the equipartition magnetic field (in the range between 0.1 and 57 mG). Clear correlations between the measured/inferred quantities define the physics of an expanding bubble of relativistc plasma and of the magnetic field (geometry/topology) within the jet(s).

12. Imaging ICRF3 sources at K band with the European VLBI Network

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We explore the capabilities of the European VLBI Network (EVN) to image radio reference frame sources at K band (22 GHz). The EVN includes long East-West and North-South baselines (from Europe to Asia and from Europe to South Africa) along with baselines of shorter and intermediate lengths within Europe, making it worthwhile to study its potential for snapshot imaging. To this end, we use a 20-telescope experiment carried out as part of the JUMPING JIVE project in October 2020 whose primary goal was to measure the geodetic positions of non-geodetic EVN antennas (i.e. antennas not equipped with the proper dual-frequency S/X (2.3/8.4 GHz) receivers traditionally used for geodesy). The network comprised 16 EVN telescopes along with three e-MERLIN out-telescopes (in the UK), and was augmented by the Hobart 26 m antenna (in Australia), who kindly agreed to join the experiment. Scheduling was accomplished by using sub-netting (ensuring a minimum of four stations per sub-net) to optimize the sky coverage at each telescope, as in standard geodesy experiments. A total of 80 sources belonging to the third realization of the International Celestial Reference Frame (ICRF3) were observed in the course of this experiment. Because the primary scope of the project was geodesy, all of these sources were chosen in the pool of ICRF3 defining sources. The resulting images may be used to further assess their compactness – and hence their astrometric suitability – at a frequency and a resolution higher than probed by the standard S/X observations that formed the basis for selecting those sources as ICRF3 defining sources.

13. The Appearance of a Possible New Jet Feature in a Seyfert 1 Galaxy Due to Accretion Rate Change

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Variability of the optical and X-ray emissions from the nuclei of Seyfert galaxies on timescales shorter than the viscous timescale in a standard thin-disk model is usually explained by either variations in the obscuration or sudden changes in the accretion rate. In stellar-mass black hole systems, the complex variability of the X-ray luminosity and the hardness ratio is explained by changes in the accretion disk structure. Synchrotron self-absorbed core-jets are ubiquitous in the hard state and they are responsible for the X-ray–radio correlation in such systems. However, it is still unclear whether and how the disk–corona system of X-ray binaries can be scaled up to describe the optical-UV emissions of the accretion disks of active galactic nuclei (AGN). The Seyfert 1 galaxy, KUG 1141+371 has been showing a steadily increasing X-ray flux since 2007, and exhibited variability behavior similar to the state transitions observed in X-ray binaries. It was hypothesised to undergo a rapid boost of mass accretion. If the X-ray binary analogy holds then the appearance of jet emission can also be expected in KUG 1141+371. While the source was not detected in the Faint Images of the Radio Sky at Twenty-centimeters in 1994, it appears in the VLA Sky Survey in 2019 and at 22 GHz in a VLA observation in 2018 at mJy flux density level. Here we present the results of our high-resolution very long baseline interferometry observations of KUG 1141+371 conducted with the EVN+e-MERLIN array at 1.7 and 5 GHz in 2021 to reveal whether the radio emission originates from a compact feature at the center of the host galaxy, and whether it is from a newly started jet in the source.

14. The twin-jet system in 3C 452

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The radio galaxy 3C452 displays a unique combination of symmetric double-jet morphology, large black hole mass, and vicinity (z=0.081). It is a rare example of a powerful Fanaroff-Riley II source which can be imaged at high resolution through high-sensitivity VLBI observations. Here we present the first-ever VLBI images of this source on sub-parsec scales, which revealed a highly symmetric twin-jet system. We performed a pixel-by-pixel analysis of the innermost $\sim 10^3$ - 10^4 Schwarschild radii, aiming at identifying the centre of symmetry and pinpointing the core location. Through a jet to counter-jet analysis, we obtained the speed profile and set an upper limit of $\sim 80^\circ$ on the jet viewing angle. The jet orientation close to the plane of the sky makes 3C452 a prime target to test the existence of a thick obscuring torus surrounding the supermassive black hole, as predicted by the standard model of active galactic nuclei. To this end, we performed an X-ray analysis using XMM-Newton data. The X-ray spectrum appears to be dominated by Compton reflection off cold matter, indicating a highly absorbed source with intrinsic hydrogen column density of $\sim 6 \times 10^{23}$ cm^{-2}.

15. Exploring connections between the VLBI and optical morphology of AGN and their host galaxies

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The main aim is to analyse VLBI and optical images of AGNs and their host galaxies and look for statistical correlations between the shape and orientation of the galaxy and the direction of the jet. We utilise the Astrogeo catalogue, which has over 9000 sources. Many sources have a clear core-jet like structure that allows for the jet position angle to be reliably determined. We then used the VLBI source positions to search for optical images within the SDSS survey. In order to parameterise the orientation and shape of the host galaxy, we fitted an ellipse to the optical image. Then, the angle between the semi-major (and minor) axis of the host galaxy and the direction of the jet was compared. If a correlation is seen, it could shed light on the interplay between the galactic nucleus and its host galaxy. In this presentation we will show some early results from this analysis.

16. Methanol and excited OH masers in HMYSOs at a milliarcsecond scale

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Using the European VLBI Network, we have imaged the excited OH maser line at 6.035 GHz in seven targets known as high-mass young stellar objects (HMYSOs) since they contain the 6.7 GHz methanol masers (Bartkiewicz et al. 2009). The excited OH spectra were found in a survey of a large sample of OH counterparts of methanol masers that has been carried out since 2018 with the Torun 32-m telescope (Szymczak et al. 2020). Radial velocities of spectral features of methanol and excited OH overlap in the majority of sources, suggesting that both lines arise in the same volume of gas. The high-angular resolution data are needed to verify this hypothesis. The excited OH spectra are highly polarized, and we evaluate the sources as potential targets for future full polarization observations to identify Zeeman pairs and estimate the strength of the magnetic field.

17. VLBI observation results of two variable sources from Irbene CH_3OH maser monitoring programme

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Irbene telescope monitoring programme of 42 objects began in March 2017 to study the variability of CH_3OH 6.7 GHz maser emission. More than 70% of sources are variable, but only one or two spectral features often vary significantly. Three of them were VLBI imaged by the EVN network to derive structures of these sources and identify the positions of regions responsible for changes in flux density. Here we report the results for two of them, G90.92+1.49 and G94.602–1.796.

We detected 47 methanol maser spots in G90.925+1.486, forming seven cloudlets. The maser emission appeared in the velocity range from -71.3 to -68.3 km s^{-1} and covers 108 mas$\times\times$100 mas area corresponding to 637 au$\times$590 au. We also note that the overall structure of the maser region has persisted at least during the time elapsed since previous high-resolution observations seven years ago, although the variability of the spectrum.

For G94.602$-$1.796 we found 61 methanol maser spots that formed seven cloudlets in the velocity range of -40.6 to -44.4 km s^{-1}. Spots are distributed over 33$\times$115 mas corresponding to 150 au$\times$520 au. There is a clear major axis of the emission along the north-south direction with a velocity gradient of 0.008 km s^{-1} au^{-1}. The ratio of velocity-integrated flux density S_{int}(EVN)/S$_{int}$(Ir) equals 0.42. The mean FWHM of the seven cloudlets is 0.37 km s^{-1}. Interestingly, the velocity gradient in the N-S direction appears in all cloudlets except one. There is a hint that the N-S elongated structure in this source has been stable over at least the last two decades compared with an earlier VLBI image of this source.

18. Proper motions along the Sagittarius spiral arm

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3D velocities of high-mass star-forming regions and O-type stars can give us insights into the kinematic structure of the star-forming molecular gas in spiral arms. Notable differences between high-mass star-forming regions and short-lived O-type stars are not expected. However, if detected these would be interesting to high-mass star-formation theory as evidence of star-formation in shocks. The Sagittarius spiral arm is the first spiral arm from us towards the Galactic Centre. This arm is, due to its vicinity and the availability of VLBI maser astrometry of high-mass star-forming regions from the BeSSeL programme (Reid et al. 2019, ApJ 885, 131) and the O-type star eDR3 astrometry from *Gaia* (Xu et al. 2021, A&A 645, L8) together spanning about 140 degrees in Galactic azimuth, a good candidate for such kinematic studies. In this poster I will present the 3D velocities of the high-mass star-forming regions and O-type stars in the Sagittarius spiral arm, investigate their possible differences and search for trends along Galactic azimuth, Galacto-centric distance and across the spiral arm.

19. Exploring radio continuum emission in megamaser galaxies with the EVN

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The origin of nuclear radio continuum emission in radio quiet AGN, differently from their radio loud counterpart, may be due to multiple physical mechanisms. Indeed, in addition to syncrothron emission from relativistic (or sub-relativistic) particle in low-power jets, it might be produced by accretion disk winds and/or coronae, as well as by nuclear star formation. The study of the radio emission in radio quiet AGN, although they constitute the great majority of the AGN population, is challenging due to their intrinsic weakness.

Being preferentially found in radio quiet objects (e.g. Seyfert or LINER galaxies), water megamasers offer a powerful complementary way to shed light on the origin of the radio continuum emission in these AGN. In fact, beside accretion disks, H_2O masers may also trace nuclear ejecta in the form of jets or winds providing estimates of the shock speeds and densities of the outflowing material, and improving our understanding of its interaction with the ISM.

Here, we present multi-frequency VLBI radio continuum observations of two Seyfert galaxies hosting luminous water maser emission presently under thorough investigation by our group: IRAS 15480-0344 and IC485. These observations allow us to reveal the possible presence of compact radio jets and to associate the position of the maser spots with sources of activity in the nuclear region of the galaxies. These information provide relevant clues on the origin of the maser emission and, as a side-product, may help us to disentangle the mechanisms underneath the nuclear radio continuum emission.

20. A multi-frequency and wide-band absorption line study using the KVN+Effelsberg+Yebes (KEY) array

Dong-Jin Kim[1,2], Thomas Krichbaum[2], Jan Wagner[2], Alex Kraus[2], Uwe Bach[2], Yoon Kyung Choi[2], Helge Rottmann[2], Taehyun Jung[3], Do-young Byun[3], Javier Gonzalez[4]

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Atomic or molecular absorption lines seen by continuum radio jet emission are unique probes to study the circumnuclear gas in radio AGN. For instance, VLBI observations at cm-wavelengths have revealed the Jet-ISM interactions within a few hundred parsecs of radio AGN via H I absorption. Plenty of molecular lines available at higher frequencies can provide better angular resolutions than reachable through HI absorption. However, such observations require flexible frequency setup and wide-band capabilities. As a preparatory study, we have attempted to searching for multiple molecular absorption lines with a small VLBI array equipped with wide-band backend and/or multi-frequency receiver system. This poster introduce the KEY project with preliminary results.

21. Resolving stellar wind shocks of massive binary stars

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Binary systems comprising massive stars (of typically O, B, or WR spectral types) in relatively close orbits allow the presence of strong interaction between the two winds of the components. When the distance is close enough, an energetic shock is produced due to the collision of the two stellar winds, which can shine at radio wavelengths. These regions have proven to be extremely efficient environments to accelerate particles up to relativistic energies, involving higher mass, photon, and magnetic energy densities than their analogue processes in supernova remnants or interstellar bow-shocks.

The radio emission would arise from synchrotron emission produced along the region where the two winds collide, typically describing a bow-shaped structure that can be only resolved with VLBI. In this poster I would focus on the discovery of two exceptionally powerful colliding wind binaries, HD 93120A and Apep, thanks to VLBI observations. These two binaries can compete with Eta Carinae in the most extreme ones ever discovered. These exceptional cases have actually been hypothesized to be able to emit up to high-energy gamma-rays.

On the other size, these are exceptional and thus rare cases. A general comprehension of the population of gamma-ray binaries can only come from large-scale studies of the low-luminosity systems. The dynamics on the average energy range of the population is poorly understood. And the limits on the physical conditions required for efficient particle acceleration to be produced remains unclear. To fulfill this goals, we have set the PANTERA-Stars (Particle Acceleration and Non-Thermal Emission of Radiation in Astrophysics - Stars) collaboration.

22. VLBI detection of refractive scattering in the quasar 2005+405

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Analyzing scattering properties of the interstellar medium of our Galaxy based on VLBI observations of about 9 000 active galactic nuclei jets at frequencies ranging from 1.4 to 86 GHz, we have identified a set of sources with extreme angular broadening at long wavelengths. A few of them seen through the Galactic plane manifest evidences for a rare phenomenon of anisotropic refractive-dominated scattering. Early results for one of such sources, the quasar 2005+405, taken from quasi-simultaneous multi-frequency VLBA observations will be presented and discussed.

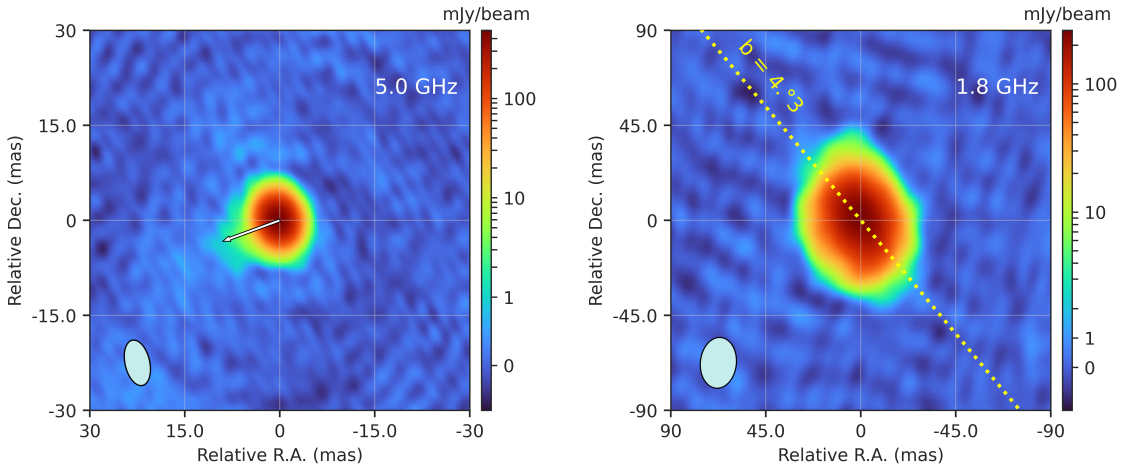

Figure 3: VLBA image of the quasar 2005+405 at 5.0 GHz (left) shows a typical AGN morphology represented by a bright core and one-sided jet propagating along the PA = 110° and at 1.8 GHz (right) shows an unusual brightness distribution, which is a result of multiple imaging of the source. The de-magnified secondary images are induced by scattering and stretched along the direction of constant Galactic latitude at PA = 40° depicted by the dotted yellow line. The white arrow indicates the jet direction. Cyan ellipse in the bottom left corner represents the FWHM of the restoring beam.

23. Modality analysis in the radio light curves of intra-hour quasars: PKS 1257−326 and J1819+3845

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We investigate the modality of flux density distributions of two intra-hour variable radio quasars, PKS 1257−326 and J1819+3845, whose variations are due to interstellar scintillation occur along the line of sight between observer and source. The statistical analysis performed using the Pearson's *S-K* difference test shows that the flux density distributions of these sources are bimodal and non-normal. The comparison of these intra-hour variable radio sources to our previous statistical analysis of intra-day variable BL Lac object PKS B1144−379 supports our hypothesis that physical changes in radio light-curve modality correlate with intrinsic evolution of the blazar. These findings also demonstrate that our approach provides a robust technique for improving our understanding of the underlying process and would help in the modelling of flux density distribution.

24. VLBI in Malaysia: Current status and future plans

Juan Carlos Algaba[1], Zamri Zainal Abidin[1]

[1] Universiti Malaya

The community of astronomers is growing Malaysia and organizing their first steps towards a solid Malaysian Astronomical Society. The area of radioastronomy is growing on par, and so it is in particular the VLBI field. Here we present the Malaysian current VLBI status and future plans. Our local community is raising VLBI experts both from the scientific as well as from the technical and engineering points of view. Malaysian VLBI researchers are active in fields involving, but not limited to, AGN physics, masers, solar astronomy, clusters of galaxies, or dark matter, among others. Scientific collaboration and partnership with other (south) east asian regions and the East Asian Observatory (EAO) has also started. Malaysia has moved forward in the signing of a Memorandum of Agreement with the Shanghai Astronomical Observatory (SHAO) and Xiamen University Malaysia (XMUM) for the acquisition and operation of a VGOS radio telescope which will be expected to start its construction in the location of Jelebu in the near future. Malaysia is moving towards its readiness by finalizing VLBI tests with the UPSI pathfinder antenna.

25. Overview of the current activities from the University of Tasmania in astronomy, geodesy and space.

Guifré Molera Calvés[1]

[1] University of Tasmania, Hobart, Australia

The University of Tasmania is running a continent-wide array of radio telescopes for radio astronomy, geodetic, and spacecraft and satellite tracking purposes. This array includes the 3 geodetic-type 12-m dishes at Hobart (Tasmania), Yarragadee (WA), Katherine (NT), the 30-m dish at Ceduna (SA) and the 26-m dish at Hobart. The antennas are participating regularly in the global geodetic observations as part of the IVS and to the Long Baseline Array. In addition, the antennas are used by UTAS students for a variety of exciting research areas.

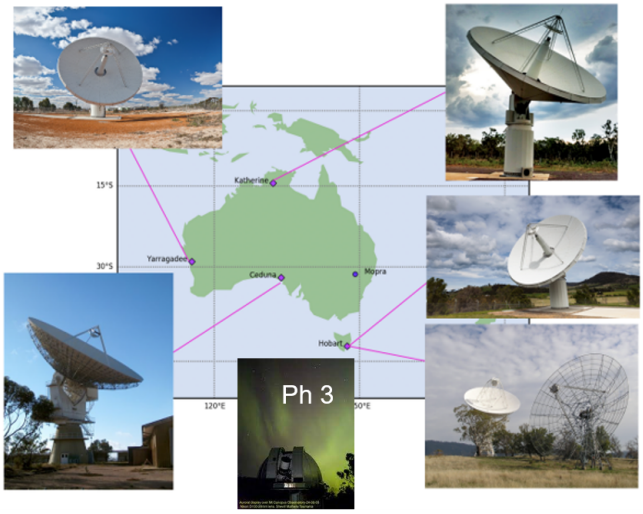

Figure 4: UTAS network of sensors

In this talk, I will give an overview of the current capabilities of the UTAS network, the technical details of our antennas and current observing capabilities, the reparation process of the bearing failure of the Hobart-26 m that occurred in 2021, the future plans for the receiver upgrade at Yarragadee and Ceduna, the construction of a new 7.3 m antennas for satellite bi-static radar tracking activities, and future plans for space craft and satellite tracking.

26. Spacecraft Doppler tracking (SDtracker) software.

Guifré Molera Calvés[1] , Marina Buttfield-Addison[1]

[1] University of Tasmania, Hobart, Australia

The first release of the Spacecraft Doppler tracking (SDtracker)[1] software was written over 13 years ago in collaboration between JIVE and Aalto University. The software, precursor of the current software correlator (SFXC) in used in JIVE, was developed to track and analyse the landing of Huygens to the Titan moon. In that experiment, telescopes around the globe tracked the probe in 2004 and the post-processing JIVE calculated with ultra precision its state vectors. The first release of SDtracker in 2008 was used for the initial detection test of the ESA's Venus Express (VEX) space mission. Since then the software has been updated regularly to adjust to different radio telescope settings, newer VLBI data formats, different hardware architectures, etc. The methods and algorithms were recently published in Molera Calvés, G. et al. 2021 (PASA, 38, e065. doi:10.1017/pasa.2021.56). Recently, a PhD student from the University of Tasmania has released a major upgrade to address a number of recent issues.

This newer version eases the installation process with an automated script. The dependencies have been minimised to make the installation optimal for a multi-core 64 bit machine (e.g. standard Flexbuff). It uses the latest Intel Integrated Performance Primitive (IPP) libraries, and do not rely on legacy functions. It benefits from the latest mark5libraries available from the DIFX repository. Subroutines and scripts have been upgraded to work on Python 3.6 and above. Finally, several functions have been improved to optimise performance and clean unused sections.

SDtracker software has been extensively used in a number of space missions over the past decade, in collaboration with ESA. More recently we have used the software in the current missions like MEX, BebiColombo, Juno and Tianwen, at X-band and Ka-band. In addition, new applications have been exploited, such as flare monitoring of spectral lines of methanol emissions; RF characterisation and pattern of life of Earth-based satellites; bi-static radar tracking of asteroids and of space domain awareness. This presentation covers the scientific achievements and present its features.

[1] https://gitlab.com/gofrito/sctracker/

27. Single-band absolute astrometry

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[1] NASA Goddard Space Flight Center

The ionospheric contribution affects path delay. When simultaneous dual-band observations are used for absolute astrometry, the residual contribution of the ionosphere is at a level of several picoseconds. But there are two cases when we need to process single band group delays: a) some observations provided usable data only for one band; b) an entire experiment used only one band. I have developed a novel approach to utilize GNSS TEC maps to get the best solutions for these two cases and provide realistic estimates of residual errors. Applications of this technology is discussed. In particular, the impact of residual ionospheric path delays at K-band on estimates of source positions is quantitatively evaluated and conclusions about advantages and disadvantages of high frequency absolute astrometry are made.

28. Polarization angle calibration using the Crab nebula for the Korean VLBI Network

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The instruments using circular polarization (CP) receiver cannot directly measure polarization angles because of an offset in the angle introduced by part of the CP receiver system. To calibrate the offset, it is necessary to observe a polarization angle calibrator. The Crab nebula is widely usd as the calibrator for single-dish radio observations because of its brightness and high degree of linear polarization. However, it cannot be directly used as a polarization angle calibrator for the instruments such as the Korean VLBI Network (KVN), of which the beam size is smaller than the size of the nebula. One way to find the polarization angle of the Crab nebula seen by KVN is using 3C 286, a compact source with stable polarization. Using KVN, we observed both the Crab nebula and 3C 286 in each session from February 2017 to February 2021 and found the polarization angles at the total intensity peak and the pulsar position of the Crab nebula seen by KVN at 22, 43, 86, 94, and 129 GHz.

ν [GHz]	$\chi_{\rm peak}$ [°]	$\chi_{\rm pulsar}$ [°]
22.4	154.4 ± 0.9	157.1 ± 0.9
43.0	151.0 ± 1.1	150.7 ± 1.2
86.2	149.4 ± 1.6	148.4 ± 1.6
94.0	149.6 ± 2.2	148.6 ± 2.2
129.4	149.0 ± 1.6	150.2 ± 2.0

Table 1: The polarization angles at the total intensity peak (peak) located at equatorial coordinates (J2000) R.A. = $05^{\rm h}34^{\rm m}32.3804$s and Dec = 22°00'44.0982" and at the pulsar position at RA = $05^{\rm h}34^{\rm m}31.971$S and Dec = 22°00'52.06" seen by KVN

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