



Very Long Baseline Interferometry with the SKA Observatory

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Very Long Baseline Interferometry (VLBI) is a fundamental technique that combines signals from telescopes separated by thousands of kilometres to obtain some of the highest-resolution images in astronomy. The Square Kilometre Array Observatory (SKAO) will provide sensitive elements to current VLBI arrays, enabling deep VLBI observations (including the first low-frequency VLBI capability in the Southern Hemisphere). This summary chapter outlines the science that the SKAO, when participating in a VLBI array, will achieve (such as AGN physics, explosive transient localisation, Galactic structure, and gravitational waves), and the current understanding of how VLBI with the SKAO will operate. Given that VLBI requires partnerships with other instruments, the chapter concludes with outstanding issues and considerations for the community needed to maximise the scientific return on investment in SKA-VLBI.

1 Introduction

Very Long Baseline Interferometry (VLBI) has been a cornerstone technique in radio astronomy for more than half a century, delivering the highest angular resolution observations in astrophysics (e.g., [Thompson et al., 2017](#)). By correlating signals from widely separated radio antennas across the globe and in space, VLBI achieves angular resolutions as fine as tens of microarcseconds at centi- and millimetre wavelengths, enabling science that probes some of the most extreme environments in the Universe. Landmark achievements include directly imaging the shadows of supermassive black holes (e.g., [Event Horizon Telescope Collaboration, 2019](#)), constraining jet-launching regions in active galactic nuclei (AGN) (e.g., [Lu et al., 2023](#)), and providing the astrometric precision that underpins the International Celestial Reference Frame (e.g., [Charlot et al., 2020](#)). VLBI has also proven a powerful astrophysical probe beyond continuum imaging: spectral line observations of Galactic masers have mapped the three-dimensional kinematic structure of the Milky Way (e.g., [Brunthaler et al., 2011](#)), while megamaser disks around AGN provide geometric distance measurements that yield some of the most precise, single-step determinations of the Hubble constant (e.g., [Pesce et al., 2020](#)). Pulsar astrometry with VLBI delivers microarcsecond-precision distances and proper motions that test theories of gravity and constrain neutron star populations (e.g., [Deller et al., 2016](#)). Outside of astronomy, VLBI plays a fundamental and societally important role in spacecraft tracking ([Gurvits et al., 2023](#), and references therein) and geodesy – the study of the Earth’s dynamic shape, size and gravity ([Petit and Luzum, 2010](#); [Nothnagel et al., 2017](#)).

The Square Kilometre Array Observatory (SKAO) will transform VLBI capabilities. Both SKA-Mid in South Africa and SKA-Low in Western Australia will support phased-array beamforming, allowing them to operate as ultra-sensitive elements in global VLBI networks ([Dewdney et al., 2009](#); [Paragi et al., 2015](#)). When phased up, SKA-Mid, operating at frequencies between 0.35–15.4 GHz, will offer a collecting area comparable to the largest existing radio telescopes, dramatically improving the sensitivity and imaging fidelity of current VLBI arrays. Its digital architecture will enable simultaneous participation in large-scale surveys and targeted long-baseline observations. SKA-Low, operating at frequencies below 350 MHz, will pioneer low-frequency VLBI in the Southern Hemisphere, opening a new parameter space for studies of, e.g., cosmic magnetism, galaxy evolution, pulsars, and ionospheric science.

VLBI will also transform the capabilities of the SKAO by providing the long baselines to probe astrophysical phenomena at the sub-arcsecond to milliarcsecond scale, something that the SKAO will not be able to do alone (see Figure 1). Imaging of AGN and relativistic jets at milliarcsecond scales will reveal jet-launching and collimation mechanisms, magnetic-field structure, and energy-dissipation processes across cosmic time (e.g., [Zensus, 1997](#); [Blandford et al., 2019](#)). Precision astrometry, enabled by SKAO’s multi-beam capabilities, will reach new frontiers, allowing accurate distance and proper-motion measurements for pulsars and maser sources throughout the Galaxy (e.g., [Reid and Honma, 2014](#)). These measurements will refine Galactic structure and rotation, measure black hole masses, and help detect gravitational waves by measuring pulsar parallaxes to high precision.

In the time domain, the ability to rapidly localise fast radio bursts (FRBs) and other fast transients with sub-milliarcsecond accuracy will provide critical insight into their progenitors and host envi-

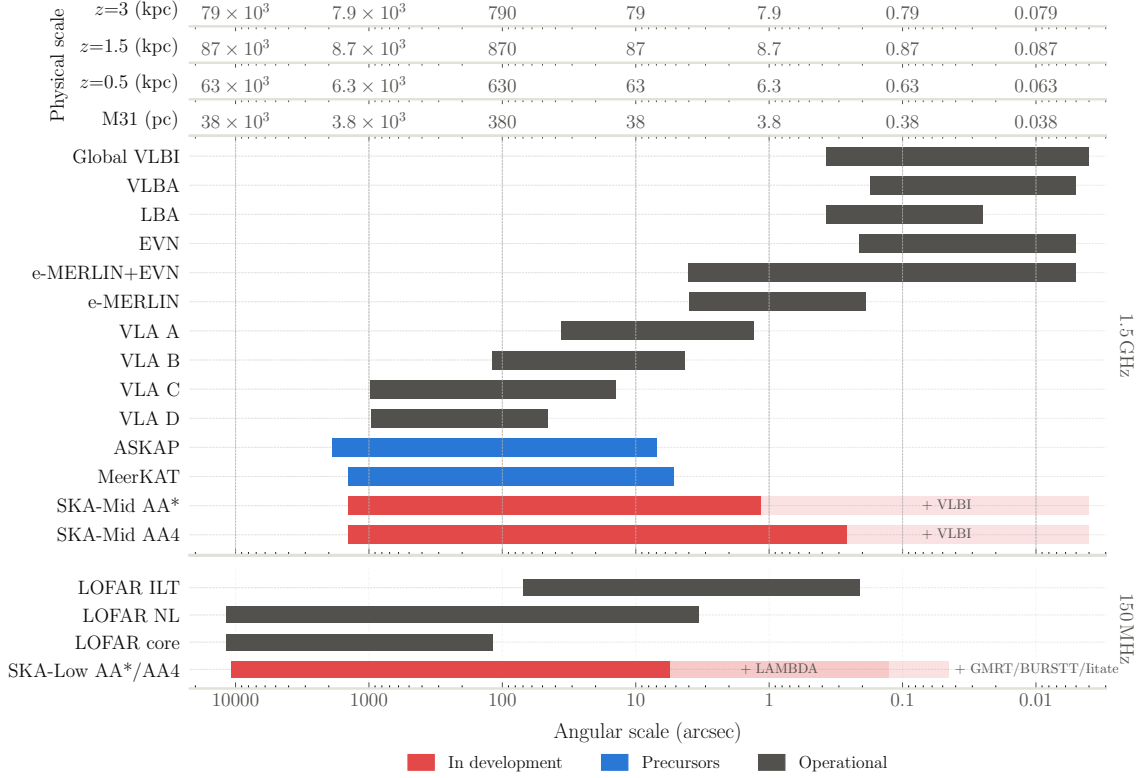


Figure 1: The range of angular scales probed by a selection of existing radio interferometric instruments, and the scales probed by the SKAO. The top panel shows SKA-Mid at AA* and AA4 at a central frequency of 1.5 GHz, including the SKAO precursors MeerKAT and ASKAP, while the bottom panel shows SKA-Low at AA*/AA4 at a central frequency of 150 MHz, including the core, Dutch (NL) and international (ILT) configurations of LOFAR. Both panels are drawn on the same angular scale, with all scales taken as λ/B from the shortest and longest baselines of each array, and the upper axis gives the corresponding proper physical scale at a range of distances (M31/780 kpc, and redshifts of 0.5, 1.5 and 3). Neither SKA telescope will be able to probe the milliarcsecond regime without the added VLBI capability. The pale extensions show the resolutions reached by adding VLBI partner stations: for SKA-Low, these include the prospective LAMBDA stations (see [Timmerman et al., 2026](#)) and then intercontinental baselines to the GMRT, BURSTT and Iitate.

ronments (e.g., [Chatterjee et al., 2017](#); [Marcote et al., 2017](#); [Kirsten et al., 2022](#)). Tidal disruption events, core-collapse supernovae, and gamma-ray burst afterglows will also be observed at the highest resolutions, tracing shock and jet evolution and energy injection on parsec scales.

Beyond astrophysics, SKA-VLBI will strengthen global geodesy and navigation. Its Southern Hemisphere location and frequency coverage will improve the geometric distribution and sensitivity of geodetic VLBI networks, improving the stability of terrestrial and celestial reference frames and supporting planetary missions. Dedicated surveys of the Southern sky will reach sources that are inaccessible to Northern Hemisphere arrays, extending the celestial reference frame southwards and densifying the catalogue of compact calibrators on which differential astrometry depends ([Xu et al., 2026a](#)). SKA-VLBI may also contribute to fundamental physics by constraining Lorentz

invariance, testing General Relativity in the strong-field regime, and probing gravitational wave backgrounds through high-precision pulsar timing and astrometric microlensing studies (Gwinn et al., 1997; Manchester et al., 2013; Deller et al., 2019).

This chapter provides an overview of SKA-VLBI capabilities and the science they enable. In Section 2, we summarise the main science themes emerging from the VLBI-focused chapters of this book, and the small set of capabilities that almost all of them require. In Section 3, we describe how VLBI will be implemented at the SKAO, covering tied-array beamforming and data output, the dedicated data path to an external correlator, and the staged delivery of the capability through science verification to Cycle 0. In Section 4, we set out the principal challenges that remain – from the need for a coordinating body for global VLBI participation, through the bandwidth and image fidelity limitations imposed by current partner arrays, to the shortage of long-baseline stations, particularly for SKA-Low – together with our recommendations to the wider community. We present our conclusions in Section 5.

2 Science with SKA-VLBI

Across all the VLBI-focused chapters, a common theme runs through them: many astrophysical questions require compact structures to be resolved or small motions to be measured, and current arrays can do neither at the required sensitivities. SKA-VLBI addresses this on three fronts at once, combining sub-milliarcsecond imaging with microarcsecond astrometry and the ability to respond on transient timescales, all at microJansky (μJy) sensitivities. It also brings these capabilities to the Southern Hemisphere, where high-sensitivity VLBI has been scarce and where much of the accessible SKAO sky lies. VLBI is therefore better understood as a **core SKAO capability** than as an addition, since it provides the link between small-scale physics and the large-scale processes the observatory is built to study.

The chapters consistently highlight VLBI’s role in multi-messenger surveys. Coordinated efforts across optical, X-ray, gamma-ray, gravitational-wave, and neutrino observatories rely more on high-resolution data, including proper motions, shock structures, and jet morphology. Without accompanying high-sensitivity and high-resolution VLBI observations, transient alerts and long-term monitoring are difficult to interpret. This point is especially true for transients and accreting compact objects. In these cases, the radio band traces non-thermal particle populations and magnetic field structure in a way no other band does, and allows us to constrain source geometry, which breaks degeneracies that otherwise leave the physical parameters governing the emission of the ejecta poorly constrained (e.g., Shu et al., 2026; Giarratana et al., 2026; An et al., 2026a).

We summarise the main scientific themes below, and refer the reader to the individual chapters for the details.

2.1 Key science themes

Accreting black holes and relativistic jets. This theme accounts for more VLBI chapters than any other. How jets are launched, collimated, and ultimately dissipated remains poorly understood, and will stay that way until the flow can be imaged directly across the full range of scales involved,

from the innermost accretion flow out to the kiloparsec-scale feedback regions (Baczko et al., 2026; Pathak et al., 2026). The SKAO with a VLBI capability, together with higher-frequency VLBI observations, will span this range of spatial scales, as shown in Figure 1.

At high redshift ($z > 0.5$), VLBI population studies will probe black-hole growth and galaxy formation, provided that the first powerful radio sources can be resolved and characterised individually (Spingola et al., 2026). At lower redshift, the emerging class of high-energy-emitting radio galaxies will provide laboratories for misaligned jets and for particle acceleration operating across several spatial scales simultaneously (Bruni et al., 2026). Compact FR0 systems and radio-quiet AGN pose the opposite problem: their cores are weak, and their outflows carry little power, so detecting them at all will require the sensitivity that the SKAO provides (Baldi et al., 2026; Panessa et al., 2026). Neutral hydrogen absorption offers a complementary view of the same feeding and feedback cycle, as milliarcsecond mapping will resolve the kinematics and morphology of the circumnuclear gas (Pandey-Pommier et al., 2026).

Compact binaries and stellar endpoints. In X-ray binaries, the inflow-outflow coupling evolves over hours to days, so resolving the jets and their polarisation will require sensitive VLBI observations, with improved uv coverage, at a correspondingly high cadence (An et al., 2026a). Colliding-wind and gamma-ray binaries need similar resolution to resolve their shock structures and locate the non-thermal particles, and the same applies to surveying the population rather than revisiting a few well-studied systems (Marcote et al., 2026). Magnetar proper motions will test formation scenarios by tying individual objects back to their parent supernova remnants (Akahori et al., 2026), while precise orbital measurements of black-hole-neutron-star binaries and intermediate-mass black-hole candidates will constrain both strong-field gravity and the evolutionary channels that produce such systems (Lin et al., 2026).

Time-domain explosive transients. For fast transients, the key factors are the SKAO’s quick responsiveness and VLBI’s ability to measure ejecta sizes directly. Milliarcsecond imaging of tidal disruption events will distinguish a collimated jet from a wide-angle wind, constrain the magnetic field structure, and establish whether the emission is genuinely nuclear (Shu et al., 2026). Gamma-ray burst afterglows must be observed while they are still expanding if the measurements are to discriminate between jet geometries and circumburst environments (Giarratana et al., 2026). For supernovae, VLBI remains the only practical way to resolve the ejecta at early times and to connect progenitor properties to the outcome of the explosion (An et al., 2026b).

Precision astrometry and Galactic structure. Astrometry serves as both a core scientific focus and a foundational capability for other research areas. In the southern sky, astrometric and geodetic surveys will enhance the celestial reference frame, especially in regions where it is currently weakest (Xu et al., 2026a). Maser astrometry will enable the creation of a three-dimensional map of spiral structures in the Milky Way, and place constraints on the Galactic bar and overall Galactic parameters (Xu et al., 2026b). Surveys of the Galactic Centre using large OH-maser proper-motion observations will reveal the spatial and kinematic properties of the nuclear stellar disk (Imai et al., 2026). Achieving microarcsecond accuracy in such large surveys will rely heavily on calibration strategies, along with sensitivity, with multi-beam and MultiView techniques making this routine

(Rioja et al., 2026). This level of precision will also allow the detection of planetary companions and the radio emissions from low-mass stars and ultra-cool dwarfs, providing insights into their magnetospheres (Curiel et al., 2026).

Fundamental physics and gravitational-waves. This precision extends to tests of gravity as well. Measuring how Solar System bodies bend light will improve constraints on relativistic parameters and, over time, on higher-order gravitational effects (Li et al., 2026). Pulsar timing arrays depend on precise measurements of distances and positions to interpret the nanohertz gravitational-wave signal, and accurate localisation is especially the limiting factor for continuous-wave sources (Takahashi et al., 2026). Electromagnetic counterparts of dual and binary supermassive black holes form part of the same gravitational background, and a systematic radio census would link these two views of the population for the first time (D’Amato et al., 2026). Large single-dish facilities will also play a role by conducting timing programs that increase the sensitivity of pulsar timing arrays (Chen et al., 2026).

Low-frequency VLBI. Low-frequency VLBI remains the least developed among these areas. Precise low-frequency source catalogues are essential for Epoch of Reionisation experiments, as inaccuracies in foreground-source positions can persist in residuals after subtraction (Kobayashi et al., 2026). Longer baselines covering 50–350 MHz will also provide the resolution needed for steep-spectrum sources, pulsar astrometry, scintillometry, and the low-frequency counterparts of transients (Timmerman et al., 2026). Achieving this requires technological advancements alongside the scientific efforts, pointing toward next-generation extensions of SKA-Low such as LAMBDA.

Infrastructure, and technical developments. All these scientific cases rely on parallel technological advancements. Space-VLBI will enhance angular resolution and uv coverage beyond what any ground-based array can achieve, with SKA-Mid serving as the sensitive core of such a network and southern targets gaining the most (Kovalev et al., 2026). On Earth, new stations across Africa will provide the north-south baselines that the southern array currently lacks, directly improving image fidelity (Bempong-Manful et al., 2026). Additionally, new large dishes and demonstrator facilities will boost sensitivity, scheduling flexibility, and contribute to science in their own right (Wongphecaxson et al., 2026; Chen et al., 2026). Despite this, uv coverage will remain sparse, requiring ongoing improvements in imaging and deconvolution to translate sensitivity into improved dynamic range (Zhang et al., 2026). Interoperability with EVN, LBA, VLBA, and ngVLA will also influence how much scientific progress is realistically achievable (Kadler et al., 2026b).

2.2 SKA-VLBI drivers

To finish this section, we summarise the overall set of capabilities required by almost every one of these science cases:

- Milliarcsecond to microarcsecond angular resolution for resolving compact jets, shocks, and binaries (e.g., Bacsko et al., 2026; Spingola et al., 2026; D’Amato et al., 2026).
- μ Jy-level sensitivity and polarimetry to detect weak non-thermal components and constrain magnetic fields (e.g., Kadler et al., 2026a; Shu et al., 2026).

- High-cadence, rapid-trigger VLBI for transient evolution on hours-to-days timescales (e.g., [Giarratana et al., 2026](#); [An et al., 2026a](#)).
- Wide-band, multi-beam tied-array operation and MultiView calibration to suppress systematics and enable microarcsecond astrometry (e.g., [Rioja et al., 2026](#); [Curiel et al., 2026](#)).
- Global baselines, including ground networks, space-VLBI, and partner arrays, to deliver dense uv -coverage and high-fidelity imaging (e.g., [Kovalev et al., 2026](#); [Bempong-Manful et al., 2026](#); [Kadler et al., 2026b](#)).
- Simultaneous multi-scale, multi-frequency imaging, in which the compact structure recovered on VLBI baselines is placed in the context of the extended emission around it, as needed for fast-evolving novae and for complex jet systems such as NGC 1068 (e.g., [Marcote et al., 2026](#); [Panessa et al., 2026](#)). This requires that the SKAO interferometric data taken alongside the tied-array beams be made available to VLBI users, and that observations be configured with multiple sub-arrays to retain short-baseline (< 160 km for SKA-Mid and < 75 km for SKA-Low) coverage.

Together, the chapters outline a broad array of science cases that depend on VLBI – covering topics from jet origins and particle acceleration physics, to galaxy and black hole formation, the Milky Way’s structure, and fundamental physics tests. These cases all require high angular resolution and precise astrometry. Without VLBI-scale baselines alongside the SKAO, many of these scientific goals will remain unattainable.

3 VLBI with the SKAO: capabilities & implementation

In this section, we summarise the current operational knowledge of how the SKAO will be incorporated into a global VLBI array. Incorporating SKA-Mid and SKA-Low into global VLBI networks requires a dedicated signal path that is distinct from the standard interferometric imaging pipeline. Because the data rates and computational demands of full VLBI correlation are incompatible with routing all SKA antennas through either the SKA correlator or an external VLBI correlator, the SKAO will support VLBI through a tied-array beamforming approach: a sub-array of antennas is phased up into one or more high-sensitivity pencil beams, each of which then serves as a single VLBI “station” for correlation with other telescopes in the global network (see Figure 2).

3.1 Tied-array beamforming and data output

The Central Signal Processor (CSP) Correlator and Beamformer (CBF) of each telescope first forms tied-array beams from a flexible selection of sub-arrays. For SKA-Mid, up to 16 such beams can be produced simultaneously, and for SKA-Low, up to 8 beams are available. Each beam can, in principle, be drawn from a distinct sub-array of antennas (up to 16 independent sub-arrays for SKA-Mid by Cycle 1), enabling simultaneous multi-field VLBI observations or the commensal use of different sub-arrays for imaging and beamformed science.

The tied-array beam data are then converted into the VLBI Data Interchange Format (VDIF), the international standard for VLBI station data streams. For both SKA-Mid and SKA-Low, this

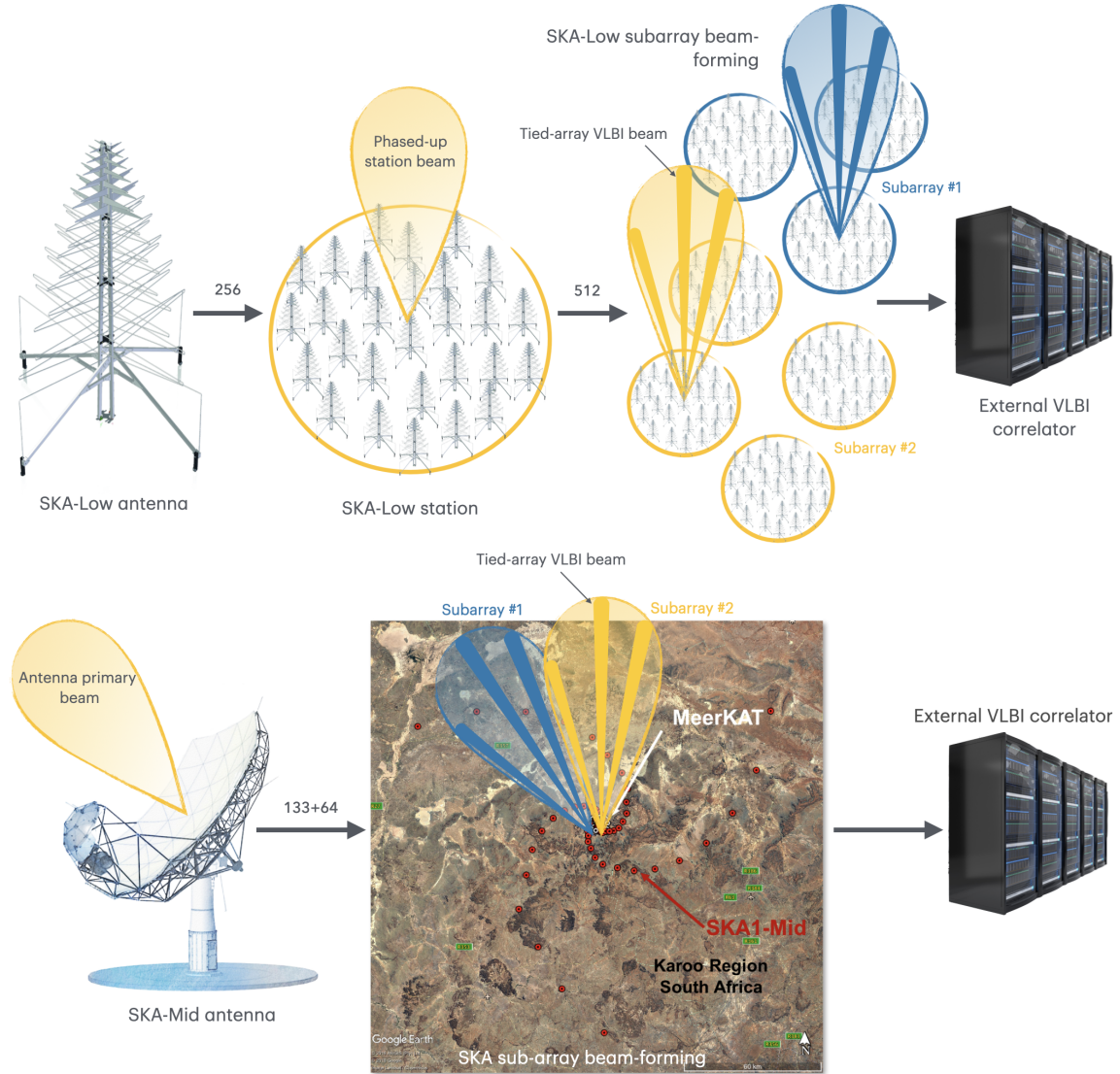


Figure 2: The operational diagram of how SKA-Low (top) and SKA-Mid (bottom) will operate as a VLBI instrument. For both instruments, subarrays will be phased up from a subset of SKA-Low stations (which have 256 phased-up SKA-Low antennas per station) or SKA-Mid dishes to form a tied-array/pencil beam. Each pencil beam will be recorded in a VLBI-compatible format and transferred to an external correlator for combination with other radio telescope data.

conversion is performed on the Pulsar Timing (PST) beam servers rather than on dedicated CBF hardware. This architectural decision reuses the existing PTUSE-based data acquisition and signal processing software, extended to produce VDIF-formatted output. An analogous approach was adopted for SKA-Mid, enabling early availability of VLBI beams before the AA* milestone and ahead of the full deployment of CBF-based VLBI firmware. In both cases, the beam allocations are shared between VLBI and pulsar timing (PST) observations, with the allocation between the two modes determined during scheduling. A 100 Gbps link carries the aggregated VLBI data products from the PST output switch to the wider network.

3.2 Data path and external correlation

The VLBI data stream follows a dedicated signal path that bypasses the standard SKAO data products pipeline and the SKA Regional Centre Network (SRCNet). From the PST beam servers, the VDIF-formatted data are transferred to VLBI recorders at the telescope sites and then transmitted, either in real time (*e*-VLBI) or via recorded media, to an external VLBI correlator for joint processing with the other network stations. The resulting correlated data products are returned to the observer via the operating network’s standard VLBI post-processing and imaging workflows.

3.3 Operational timeline

The staged delivery of VLBI capability follows the broader SKAO science verification and early-operations schedule. For SKA-Mid, a single VLBI beam is expected to be available during the AA2 Science Verification phase (2029), providing the first opportunity for commissioning the end-to-end VLBI signal chain. By AA* (2031), this will grow to four simultaneous VLBI beams, and full basic VLBI capability – with the complete 16-beam pool available across up to 16 sub-arrays – is planned for Cycle 0 (2032). For SKA-Low, a broadly analogous timeline is anticipated, with early single-beam VLBI capability in the first science verification cycles growing to a potential eight multi-beam operation by Cycle 0. The SKAO **guarantees** only four simultaneous VLBI beams for SKA-Mid and SKA-Low, and the 16- and 8-beam capability described earlier for SKA-Mid and SKA-Low is on a best-effort basis. These milestones are illustrated at <https://www.skao.int/en/science-users/timeline-science>.

The number of VLBI beams available at any given time is a shared resource with pulsar timing, and the practical allocation will depend on the concurrent observing programme. Several key SKA-VLBI science cases (e.g., multi-field astrometry, multi-source monitoring) require more than four simultaneous beams, and three of the seven identified Low-frequency VLBI science cases need up to eight VLBI beams. The flexibility afforded by the PST-based architecture, where the VLBI and PST beam pools can be dynamically partitioned, is therefore an important operational asset and is expected to be further exploited as the telescope matures.

4 Challenges and recommendations to the wider community

In this section, we outline upcoming challenges and open questions for SKA-VLBI. The scientific community will need to participate actively to resolve them.

Given SKA-VLBI’s different operational model and the partnerships with external telescopes and arrays it requires, several of these challenges follow directly from the available array geometry. Figures 3 and 4 show the telescopes that could realistically participate in SKA-Mid and SKA-Low VLBI observations, together with the fraction of the sidereal day over which each shares sky with the SKAO as a function of source declination.

Key recommendation: A coordinating body for global VLBI participation in SKAO. A coordinating body for VLBI needs to be established and is empowered to negotiate policy and provide a single voice to SKAO from the VLBI community. This body would need to include all the key stakeholders for both SKA-Mid and SKA-Low VLBI-capable stations, and would need to

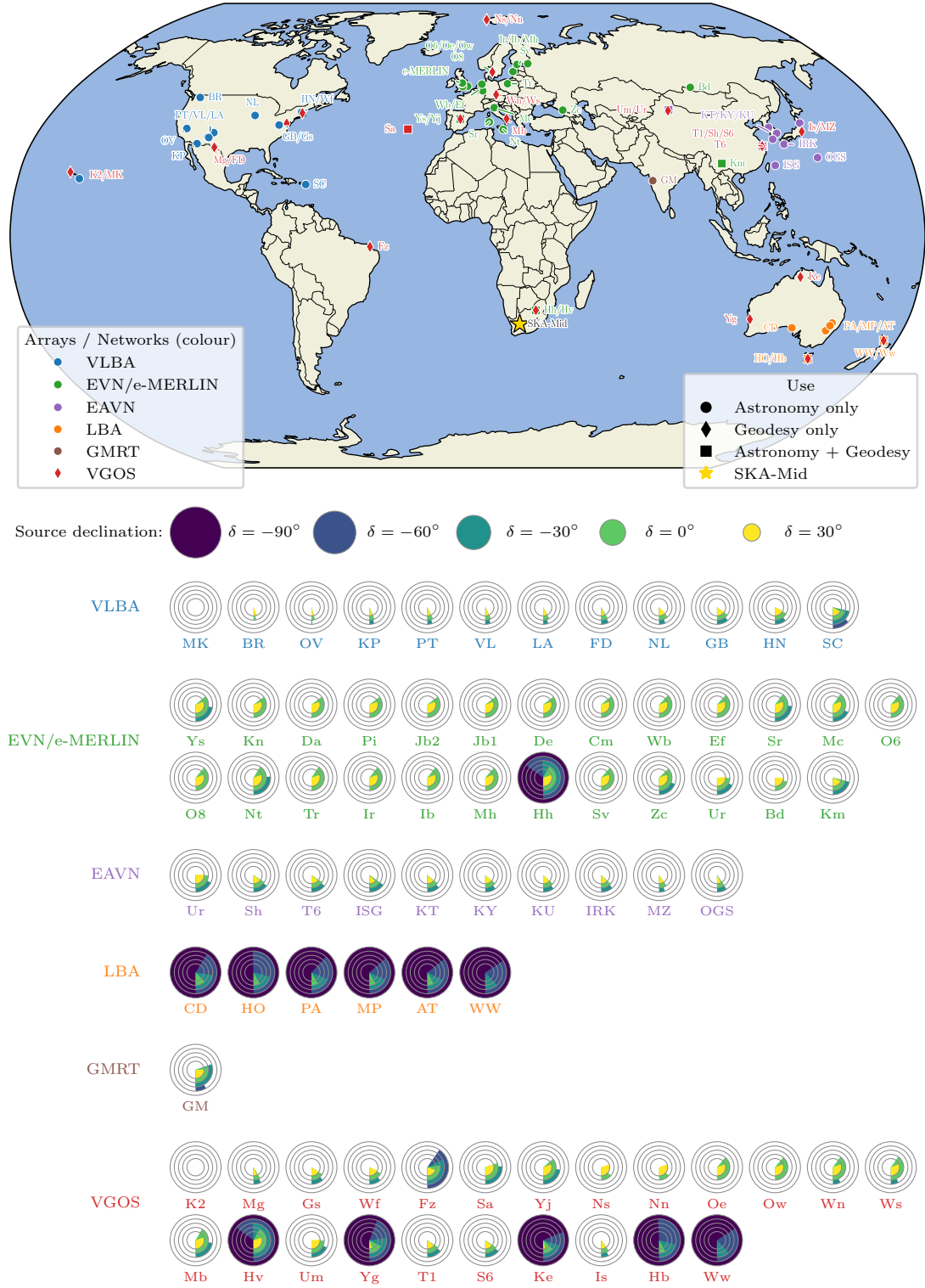


Figure 3: Locations of a selection of radio telescopes with frequency-band overlaps with the SKA-Mid telescope (station acronyms are defined in Appendix A). In the bottom panel, each small circular diagram shows the mutual sky coverage between one telescope (labelled by its acronym) and SKA-Mid. Each diagram contains a set of concentric arcs, one per source declination δ (the outermost arc is $\delta = -90^\circ$, the innermost $\delta = +30^\circ$), and the colour of an arc indicates that declination (colour scale from $\delta = -90^\circ$ to $+30^\circ$, shown in the key above the grid). The length of each arc is the fraction of a sidereal day during which the two telescopes can simultaneously see a source at that declination, so a full circle means the source is always mutually visible.

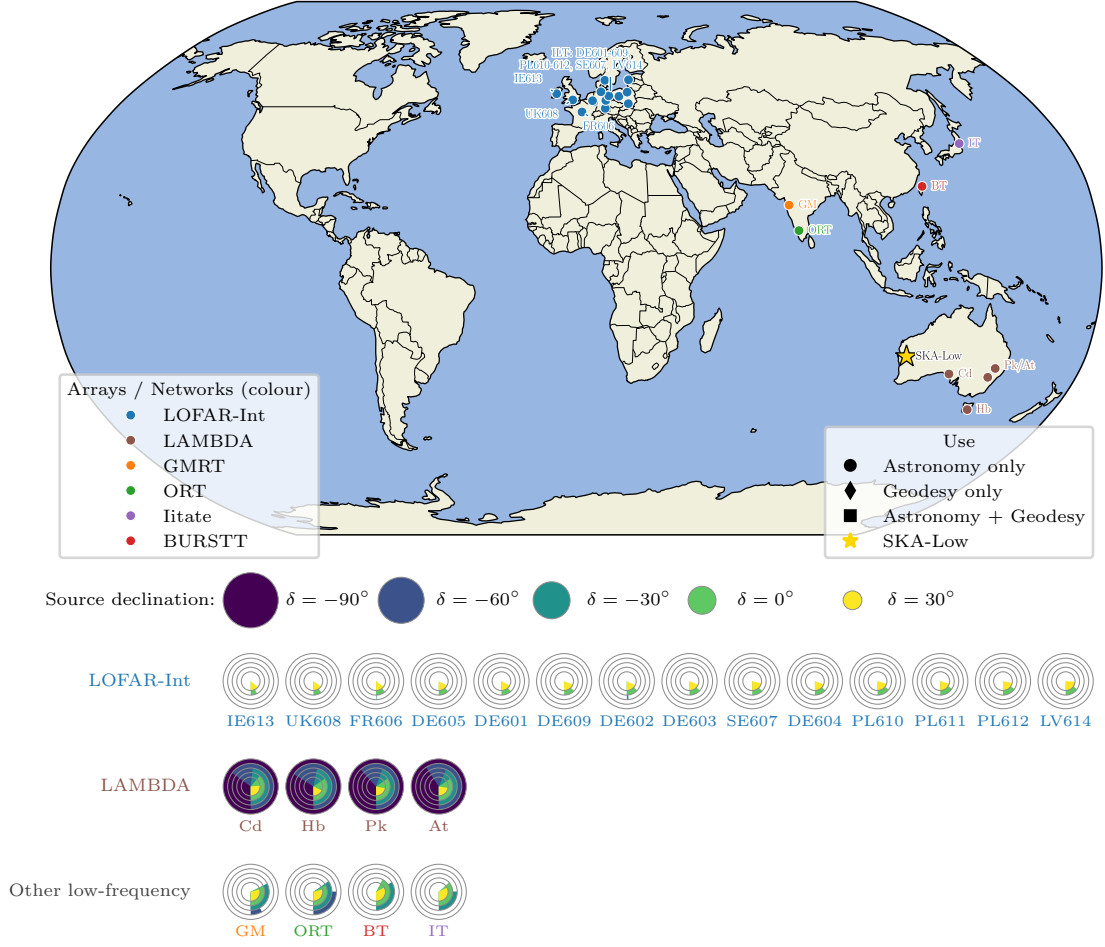


Figure 4: Locations of a selection of radio telescopes with frequency-band overlaps with the SKA-Low telescope (station acronyms are defined in Appendix A). In the bottom panel, each small circular diagram shows the mutual sky coverage between one telescope (labelled by its acronym) and SKA-Low. Each diagram contains a set of concentric arcs, one per source declination δ (the outermost arc is $\delta = -90^\circ$, the innermost $\delta = +30^\circ$), and the colour of an arc indicates that declination (colour scale from $\delta = -90^\circ$ to $+30^\circ$, shown in the key above the grid). The length of each arc is the fraction of a sidereal day during which the two telescopes can simultaneously see a source at that declination, so a full circle means the source is always mutually visible. Given the smaller number of stations, we have included prospective stations of the LAMBDA telescope (see Timmerman et al., 2026)

consider aspects such as how to transport the data – given it will not go through SRCNet, where to correlate, how to propose for SKAO VLBI time, and how to provision VLBI data recorders for the SKAO. It would also need to coordinate responsive observing across arrays to support time-domain science cases.

Utilising the wide SKAO bandwidths and frequency coverage. The SKAO will provide extremely wide bandwidths ranging from 300 MHz on SKA-Low to 5 GHz on SKA-Mid Band 5b, improving sensitivity, image fidelity, and the ability to characterise the spectral profile of sources.

In contrast, current VLBI stations (especially those operating at SKA-Mid frequencies) have limited data rates (e.g., 4 Gbps for the VLBA, EVN, and LBA; corresponding to a 512 MHz bandwidth – assuming 2-bit sampling). While this should be sufficient for the lower-frequency bands, SKA-VLBI will be limited to the bandwidth available from the VLBI arrays. This would be exacerbated if higher bit rates are adopted, for example, to provide greater resilience to radio frequency interference (RFI).

A related limitation applies to the frequency coverage itself. Band 5b extends up to 15.4 GHz, and observing at the top of this band would deliver the finest angular resolution accessible to SKA-VLBI. However, Ku-band (roughly 12–15 GHz) receivers are not widely deployed across the stations that SKA-Mid would be correlated against, and Ku-band is not currently a standard observing band for the EVN or the LBA. Without this, the upper part of Band 5b cannot be exploited for VLBI.

Recommendations: VLBI arrays continue to plan for expansion to 16/32 Gbps operational data rates and to develop their data transport, correlation, post-processing and archiving capabilities to handle larger data volumes and increased computational loads. In parallel, stations should consider installing Ku-band receivers, and the EVN and LBA should work towards supporting Ku-band VLBI observations in the future, given that MeerKAT will soon be equipped with these receivers, so that the full frequency range of SKA-Mid Band 5b, and with it the highest possible resolution, becomes available to users. In contrast, the SKAO should consider expanding to cover K-band/Band 6, given the large number of science cases (e.g., [SKAO memo 20-01](#)) it would enable, the higher resolutions that are possible, and that many telescopes in VLBI arrays are already equipped with K-band receivers.

Image fidelity. The SKA telescopes will provide extremely sensitive single elements to global VLBI arrays (SEFD: ~ 3.3 Jy for SKA-Mid AA* at 18 cm, reducing to ~ 1.55 Jy for AA4), which will dominate the image weighting when generating images at the best sensitivities. This will result in point spread functions with strong sidelobes and sharp, stripe-like structure, set by the small number of highly weighted baselines to the SKA telescopes, which will make deconvolution and recovery of the true sky brightness distribution difficult (see Figure 5). This is a similar problem to the one the Event Horizon Telescope has experienced, in which baselines to phased-up ALMA dominate the images.

Recommendations: Investigate the application of next-generation imaging algorithms (e.g., [Junklewitz et al., 2016](#); [Müller and Lobanov, 2022](#)), for use in SKA-VLBI. This could be conducted as a new SKA Data Challenge, in which a simulated SKA-Low and SKA-Mid observation is provided to the community, and the goal is to recover the input model as accurately as possible. Adding additional sensitive elements to the participating networks would also help, since a more uniform distribution of baseline orientations across the array reduces sidelobe levels to some degree. Examples include the GMRT at 1.4 GHz¹ and the upcoming Jingdong 120-m ([Chen et al., 2026](#)) and Qitai 110-m telescopes.

Increase the number of VLBI partner instruments. For SKA-Mid, [Bempong-Manful et al. \(2026\)](#) highlighted the need for more African VLBI stations to improve image fidelity, especially

¹<https://www.jive.eu/gmrt-evn-vlbi-observations.html>

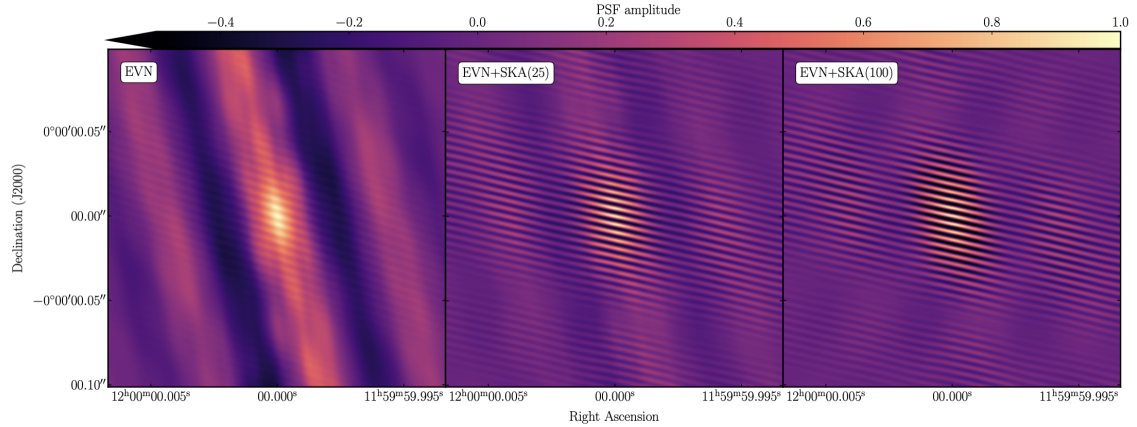


Figure 5: A 12-hour simulated point-spread function of an observation with the European VLBI Network (left panel) plus the inclusion of 25 and 100 phased-up SKA-Mid dishes (central and right panel, respectively) operating at a central frequency of 1.6 GHz. The inclusion of the sensitive SKA-Mid dishes, along with the long North-South baseline orientations of SKA-Mid, degrades the PSF, making accurate deconvolution more challenging.

in equatorial fields, and summarised stations under development, such as the Botswana SKAO telescope and the Africa mm-telescope. As Figure 3 shows, the stations with the longest mutual visibility with SKA-Mid are concentrated in the northern hemisphere, so the north-south baselines that these African stations would provide are precisely the ones the array currently lacks. Further developments in other areas, such as Asia (e.g., the FAST core array, the Thai Radio Telescope, and the Jingdong 120-m and Qitai 110-m telescopes), will further enhance VLBI image quality and sensitivity with the SKAO. Any potential developments in South America could provide key East-West baselines and link the SKAO to the VLBA and ngVLA.

For SKA-Low, [Timmerman et al. \(2026\)](#) have highlighted the wide range of science cases that SKA-Low VLBI can address, including exoplanets, AGN and jet formation, young stellar objects, pulsar astrometry, and more. They also emphasise the unique position of SKA-Low VLBI in the Southern Hemisphere and its ability to target Galactic (e.g., LMC) and extragalactic objects (e.g., Pic A, Cen A) at low frequencies for the first time. However, as shown in Figure 4, there are far fewer stations that can participate in long-baseline SKAO observations than in SKA-Mid. Aside from the ongoing LAMBDA project, very few compatible stations are available or planned before SKA-Low VLBI is operational. This threatens our ability to realise the scientific opportunities offered by SKA-Low.

Recommendations: The community must actively work to increase the number of SKA-Low and Mid long-baseline instruments. Particular attention should be made to SKA-Low, which has far fewer long-baseline stations, and investment in current initiatives, such as LAMBDA, should be considered. Given current trends in funder and government priorities in developing countries (e.g., Africa, SE-Asia), the community should consider dual-use applications (e.g., Space Situational Awareness, geodesy) and public-private partnerships to support their efforts to secure new infrastructure.



Figure 6: The SKAO precursor MeerKAT observing as a phased-array element of the European VLBI Network. A tied-array beam formed from the MeerKAT dishes is correlated with the other stations of the network, using the same operational model that SKA-Mid will follow. Illustration: Benito Marcote, JIVE. Image credits: MeerKAT image ©SARAO; EVN map image ©Paul Boven, JIVE (satellite image: Blue Marble Next Generation, courtesy of NASA Visible Earth).

5 Summary and conclusions

In summary, Very Long Baseline Interferometry (VLBI) will be a vital mode for the SKAO, enabling high-resolution and high-sensitivity observations that the SKAO alone cannot perform (see Figure 1). As discussed in Section 2, SKAO’s VLBI capability is key to many scientific applications, including the study of jets in AGN and X-ray binaries, microsecond astrometry for defining the celestial reference frame and galactic structure, pulsar parallax measurements for timing, and tests of general relativity.

Furthermore, integrating SKAO into VLBI arrays is now quite well understood. According to Section 3, both telescopes will generate tied-array beams from sub-arrays via the PST system within the SKAO. This will happen in stages, offering up to 16 tied-array beams for SKA-Mid and 8 for SKA-Low. These beams will be saved in a VLBI-compatible format and sent to an external facility for correlation with data from other VLBI telescopes. This approach has been demonstrated with SKAO precursors, such as MeerKAT, which has been phased-up and correlated successfully with telescopes from the European VLBI Network (see Figure 6) and the Southern Hemisphere Long Baseline Array. These experiments serve as proof of concept for SKAO’s potential operation with VLBI arrays.

Since VLBI involves collaboration among multiple telescopes worldwide, the scientific benefits of

SKA-VLBI depend on the arrays it partners with. Accordingly, recommendations from Section 4 are based on this. VLBI arrays should continue upgrading to 16/32 Gbps data rates to utilise SKAO bandwidths and work toward Ku-band support to access higher parts of Band 5b. Developing and testing imaging and deconvolution techniques that can handle the non-uniform weighting introduced by SKA telescopes is essential, and a dedicated SKA Data Challenge would be suitable for this. The number of long-baseline partner stations, especially for SKA-Low, needs to increase, as currently few compatible stations are available or planned. Lastly, a coordinating organisation is necessary to represent the VLBI community to SKAO collectively, addressing issues like data transport, correlation, proposals, recording facilities, and organising quick-response observing, which are beyond the SKAO's direct scope. While not insurmountable, each step requires community effort rather than just the SKAO alone.

A VLBI and geodetic station acronyms

Tables 1 and 2 give the full names and locations of the stations and networks identified by acronym in Figures 3 and 4, respectively. Coordinates, diameters and other technical details for these stations are also maintained by their respective networks and consortia (e.g., the IVS network station list², the EVN³, the VLBA⁴, and the LBA⁵).

Table 1: Stations shown in Figure 3, grouped by network.

Acronym	Station
<i>VLBA (and associated High Sensitivity Array antennas)</i>	
BR	Brewster, WA, USA
FD	Fort Davis, TX, USA
HN	Hancock, NH, USA
KP	Kitt Peak, AZ, USA
LA	Los Alamos, NM, USA
NL	North Liberty, IA, USA
OV	Owens Valley, CA, USA
PT	Pie Town, NM, USA
SC	Saint Croix, US Virgin Islands
MK	Mauna Kea, HI, USA
GB	Green Bank Telescope (100 m), WV, USA
VL	Karl G. Jansky Very Large Array (phased), Socorro, NM, USA
<i>EVN / e-MERLIN</i>	
Ef	Effelsberg (100 m), Germany
Sr	Sardinia Radio Telescope (64 m), Italy
Ys	Yebes (40 m), Spain
Mc	Medicina (32 m), Italy
Nt	Noto (32 m), Italy
Tr	Toruń (32 m), Poland
O6	Onsala (20 m), Sweden
O8	Onsala (25 m), Sweden
Ir	Irbene (32 m), Latvia
Ib	Irbene (16 m), Latvia
Wb	Westerbork (25 m, single dish), the Netherlands
Jb2	Jodrell Bank Mk II (32 m), UK
Jb1	Lovell Telescope (76 m), Jodrell Bank, UK
Cm	Cambridge (32 m), UK
Ur	Urumqi (25 m), China
Km	Kunming (40 m), China
Bd	Badary (32 m), Russia
Zc	Zelenchukskaya (32 m), Russia
Sv	Svetloe (32 m), Russia
Mh	Metsähovi (14 m), Finland

²<https://ivsc.gsfc.nasa.gov/stations/>

³<https://www.evlbi.org/stations>

⁴<https://public.nrao.edu/telescopes/vlba/>

⁵<https://www.atnf.csiro.au/vlbi/overview/>

Table 1 – continued

Acronym	Station
Hh	Hartebeesthoek (26 m), South Africa
Kn	e-MERLIN Knockin (25 m), UK
De	e-MERLIN Defford (25 m), UK
Da	e-MERLIN Darnhall (25 m), UK
Pi	e-MERLIN Pickmere (25 m), UK
(T6: Tianma and Sh: Sheshan, listed below under EAVN, are also EVN stations)	
<i>EAVN (East Asian VLBI Network)</i>	
KY	KVN Yonsei (21 m), South Korea
KU	KVN Ulsan (21 m), South Korea
KT	KVN Tamna, Jeju (21 m), South Korea
MZ	VERA Mizusawa (20 m), Japan
IRK	VERA Iriki (20 m), Japan
ISG	VERA Ishigakijima (20 m), Japan
OGS	VERA Ogasawara (20 m), Japan
T6	Tianma (65 m), China
Sh	Sheshan (25 m), China
(Ur: Urumqi, listed above under EVN, also participates in EAVN)	
<i>LBA (Australian Long Baseline Array)</i>	
AT	ATCA (phased array), Narrabri, Australia
PA	Parkes (64 m), Australia
MP	Mopra (22 m), Australia
HO	Hobart (26 m), Australia
CD	Ceduna (30 m), Australia
WW	Warkworth (12 m), New Zealand
<i>GMRT</i>	
GM	Giant Metrewave Radio Telescope (phased array), Khodad, India
<i>VGOS (VLBI Global Observing System, geodetic)</i>	
Wn	Wettzell twin telescope 1, Germany
Ws	Wettzell twin telescope 2, Germany
Wf	Westford (18.3 m), MA, USA
K2	Kokee Park (12 m), HI, USA
Gs	GGAO12, Greenbelt, MD, USA
Oe	Onsala twin telescope 1, Sweden
Ow	Onsala twin telescope 2, Sweden
Hb	Hobart (12 m), Australia
Ke	Katherine (12 m), Australia
Yg	Yarragadee (12 m), Australia
Is	Ishioka (13 m), Japan
Nn	Ny-Ålesund twin telescope 1, Norway
Ns	Ny-Ålesund twin telescope 2, Norway
Hv	Hartebeesthoek VGOS (13.2 m), South Africa
Um	Urumqi VGOS (13 m), China
Mb	Matera VGOS (13.2 m), Italy
Yj	Yebes VGOS (13.2 m), Spain
Sa	Santa Maria (13.2 m), Azores, Portugal
S6	Sheshan VGOS (13 m), China

Table 1 – continued

Acronym	Station
T1	Tianma VGOS (13.2 m), China
Mg	McDonald (12 m), TX, USA
Fz	Fortaleza VGOS (12 m), Brazil
(Ww: Warkworth 12 m, listed above under LBA as WW, is also a VGOS station)	

Table 2: Stations shown in Figure 4, grouped by network.

Acronym	Station
<i>LOFAR international stations</i>	
IE613	Birr, Ireland
UK608	Chilbolton, UK
FR606	Nançay, France
DE601	Effelsberg, Germany
DE602	Unterweilenbach, Germany
DE603	Tautenburg, Germany
DE604	Bornim (Potsdam), Germany
DE605	Jülich, Germany
DE609	Norderstedt (Hamburg), Germany
SE607	Onsala, Sweden
PL610	Borówiec (Poznań), Poland
PL611	Baldy, Poland
PL612	Łazy, Poland
LV614	Irbene, Latvia
<i>LAMBDA (prospective low-frequency stations at existing LBA sites)</i>	
At	Narrabri (ATCA site), Australia
Pk	Parkes, Australia
Cd	Ceduna, Australia
Hb	Hobart, Australia
<i>Other low-frequency telescopes</i>	
GM	GMRT, Khodad, India
ORT	Ooty Radio Telescope, India
IT	Iitate Observatory (Tohoku University), Japan
BT	BURSTT, Fushan, Taiwan

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