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Oral presentations

VLBI with the Square Kilometre Array Observatory

Presenter: Jun Yang (Chalmers, Onsala Space Observatory), Jack Radcliffe (University of Manchester)

Very Long Baseline Interferometry (VLBI), coupled with the transformational ability of SKA-Low and SKA-Mid, is poised to deliver groundbreaking observations with milliarcsecond resolution, surpassing the capabilities of the standard SKAO array.

VLBI, alongside the SKAO, offers the potential to unlock deep insights across a range of astrophysical topics. It is set to transform our understanding of galaxy evolution and the physics of jet accretion by examining Active Galactic Nuclei (AGN) at low luminosities. Furthermore, it is prepared to make significant advances in cosmology by constraining dark energy and dark matter through gravitational lensing and water maser studies. The investigation of stellar lifecycle processes, including the temporal development of supernova remnants, and the rapid follow-up of transients (such as localising FRBs and tidal disruption events), adds another layer to the diverse scientific applications of VLBI with the SKAO.

In this presentation, I will highlight a select range of scientific achievements possible through VLBI with the SKA, explain the operational aspects of SKA VLBI, and outline the necessary steps to realise VLBI with SKAO.

VLBI observations with the SKA-Mid at 12/15 GHz

Presenter: Jun Yang (Chalmers, Onsala Space Observatory)

The SKA-Mid plans to support VLBI observations at frequencies up to 15 GHz. The Qitai 110 m and Jingdong 120-m telescopes in China are also going to become operational over the next five years. Moreover, there are more stations available at Ku band in Oceania, Europe, and China. With 32 Gbps VLBI observations at Ku band, one could easily reach an image sensitivity of $\sim 1 \mu\text{Jy}/\text{beam}$. This would allow astronomers to carry out some unprecedented research, such as detecting a $\sim 10 \mu\text{Jy}$ compact transient and gaining an astrometric precision of $\sim 1 \mu\text{as}$. Here, we present some initial exploration results of the VLBI network, show its scientific advantages, and propose a possible roadmap for its formation and development.

Improved UV Coverage for Southern-Hemisphere VLBI through the SKAMPI telescope

Presenter: Jompoj Wongphechauxsorn (JMU)

The SKA-MPIfR telescope (SKAMPI) is a 15-meter prototype antenna for the SKA-Mid located at the SKA site in the Karoo Desert, South Africa. Funded by the Max Planck Institute for Radio Astronomy (MPIfR) and operated together with SARAO (South African Radio Astronomy Observatory). For this telescope, the MPIfR backend development team implemented a novel VLBI backend. In the near future, SKAMPI will serve as a science and technology testbed for the SKA era, including SKA-VLBI science. In particular, SKAMPI is a key instrument for

demonstrations of technical and operational VLBI readiness of new and upgraded stations on African soil, including the SKA-Mid. SKAMPI is therefore in the vanguard of new telescopes in Africa that will make the African VLBI Network (AVN) a reality. In this talk, I will present the first fringe detections at S-band tests with the Australian Long Baseline Array as part of the TANAMI program. TANAMI is a multi-wavelength observing program monitoring the relativistic jets of Active Galactic Nuclei in the southern sky. We conclude with a discussion of potential AVN baselines and the new software implemented for SKAMPI's novel backend

LOFAR: VLBI at the lowest frequencies

Presenter: Ilse van Bemmelen (ASTRON)

Co-authors: Carla Baldovin (ASTRON), Michiel Brentjens (ASTRON), André Gunst (ASTRON), Boudewijn Hut (ASTRON), Tom Kamphuis (ASTRON), Wim van Cappellen (ASTRON)

The LOw Frequency ARray (LOFAR) has been operating at the longest radio wavelengths since 2010. It has opened up a wide range of scientific applications, from ionospheric studies to mapping the largest coherent radio structures in our Universe. This was enabled by new technologies such as aperture array antenna systems, and one of the world's fastest supercomputers.

LOFAR consists of two types of antennas: Low-Band Antennas (LBA, 30 to 90 MHz), and High-Band Antennas (HBA, 110 to 240MHz). Each station has fields of both, with different HBA layout depending on the station type. Due to budget limitations LOFAR could not use all LBA at the same time, nor could LBA and HBA be used simultaneously. In just 15 years the technologies have matured, and network capabilities and compute power per euro have increased significantly. This allows for the ongoing transition to LOFAR2.0, which will increase sensitivity and bandwidth by using all LBA and HBA at once.

In addition, LOFAR had individual station clocks for all stations outside the central core (superterp). This is a key characteristic of a VLBI telescope array. With baselines of thousands of kilometres, LOFAR is in its essence a VLBI array. Though this will change in LOFAR2.0 by installing White Rabbit time keeping for all Dutch stations, the data processing challenges remain similar, especially for VLBI applications.

The future of LOFAR aims for real-time data processing in the entire observatory post-processing chain and exploiting the long baseline science, which is one of the most compute intensive use cases. LOFAR VLBI requires high resolution in both time and frequency, creating datasets of hundreds of Terabytes. An important next step for LOFAR VLBI is to improve the performance of the data flow, which is part of the LENS proposal that was recently granted.

In this talk I will present an overview of LOFAR, the LOFAR2.0 improvements, and future steps towards further improving performance of LOFAR VLBI capabilities with LENS."

Orchestrating low-frequency VLBI at the scale of LOFAR

Presenter: Frits Sweijen (Durham University)

With baselines up to 2000 kilometres, the International LOFAR Telescope has a unique high-resolution view on the low-frequency radio sky. Unlike more typical VLBI arrays, however, with its 76 operational stations it forms a sizable network with dense uv coverage across angular scales from approximately a degree down to a few tenths of an arcsecond. Due to its low frequency nature, the ILT's field of view is a substantial 6.25 square degrees on the sky. Unfortunately, successful science exploitation of the longest baselines across such an area requires data to be stored at high time and frequency resolution, making typical ILT observation around 5 TB in size. Needing around double the observations to cover the entire northern sky compared to the LOFAR Two-Metre Sky Survey done with only the Dutch stations, a data processing strategy that does processing at scale is needed.

In this talk I will present an overview of the LOFAR HBA VLBI pipeline for data between 120 and 168 MHz from two sides. First, I will discuss how we tackle ILT calibration in general. Its main challenges such as the ionosphere will be discussed, as well as the differences with more traditional VLBI. Secondly, I will cover how we orchestrate the data reduction at scale by using the Common Workflow Language to interface with managed clusters like Slurm. Current efforts are focussing on delivering a first end-to-end pipeline to go from raw data to a widefield sub-arcsecond resolution image without human intervention, to be prepared for when LOFAR2.0 comes online.

The deepest radio image with the full European LOFAR

Presenter: Jurgen de Jong (Leiden Observatory & ASTRON)

Over the past decade, significant efforts have gone into developing calibration and imaging pipelines to automatically process data from the Dutch high-band antennas of the Low Frequency Array (LOFAR), which observe the Universe at about 150 MHz and reach with the Dutch array a 6'' resolution (e.g. Shimwell et al. 2017; 2019). Recently, we have extended this work by developing a pipeline to calibrate and image data taken with all European LOFAR stations, reaching sub-arcsecond resolutions across a 2.5x2.5 degrees field of view (Morabito et al. 2022; Sweijen et al. 2022; de Jong et al. 2024). Since the computational costs for producing wide-field high-resolution images represent a major bottleneck, we have focused on reducing these costs by up to a factor of 15, through the development of advanced techniques and refined calibration strategies to mitigate ionospheric distortions and improve image fidelity as well (de Jong et al. 2025; de Jong et al., submitted). These advancements have led to the production of the deepest radio image to date with a field of view of 2.5x2.5 degrees and reaching an RMS near the pointing centre of about 6 μ Jy/beam at about 0.3'' resolution, using 200 hours of LOFAR data (de Jong et al. in prep.).

In this talk, I will present the latest developments in the LOFAR VLBI pipeline for wide-field imaging and highlight the recent enhancements that enabled this record-breaking image. I will also briefly highlight future directions, including the work on improved automated decision-making, opportunities for the use of AI, and data volume management. These developments will make the pipeline more robust and pave the way for high-resolution (and

ultra-deep) LOFAR surveys at 150 MHz, enabling us to study the low-frequency universe across the northern sky at the smallest angular scales."

Demonstrating Low-Frequency VLBI in the Southern Hemisphere for SKA-Low

Presenter: Chris Phillips (CSIRO)

Currently, SKA-Low baselines extend only ~ 70 km, and there are few low-frequency stations in the Southern Hemisphere to enable joint VLBI observations with SKA-Low. On its own, SKA-Low will not deliver the sub-arcsecond angular resolution required to maximise synergy with frontline optical/IR telescopes such as JWST. The planned tied-array mode will add the capability to participate in VLBI, but new stations or facilities are needed to take advantage of this mode.

CSIRO is taking the first steps toward establishing low-frequency VLBI capability in the Southern Hemisphere. A modest-scale project can demonstrate feasibility, establish a pathway for long-term technology development, and help build momentum toward the original vision of SKA-Low as a continent-scale telescope. Our initiative is LAMBDA: the Low-frequency Australian Megametre-Baseline Demonstrator Array.

A full array could comprise several (4–6) low-frequency aperture arrays co-located with existing LBA telescopes across Australia. In this talk, we will present an overview of the project, its current status and future plans, and the science opportunities that such an array will enable."

A new VLBI Station at Bosscha Observatory

Presenter: Taufiq Hidayat (Department of Astronomy and Bosscha Observatory, Institut Teknologi Bandung, Indonesia)

A new VLBI Global Observing System (VGOS) radio telescope is currently being constructed at Bosscha Observatory, Indonesia, in partnership with the Shanghai Astronomical Observatory (SHAO) of the Chinese Academy of Sciences (CAS). The telescope tower structure, comprising a three-story building that includes the reinforced concrete foundation and the anchor ring assembly for the antenna's steel pedestal, has been successfully completed. The Big Lift operation for the main reflector disk was successfully executed in early July of this year, marking a critical milestone in the structural assembly phase of the VGOS antenna system. The integration and installation of the signal chain components are scheduled to commence shortly, initiating the next phase of the VGOS system's RF and backend instrumentation deployment. It is expected to have first observational tests by the end of 2025. The telescope is anticipated to participate in international VLBI observing campaigns in the near future, including sessions coordinated by the International VLBI Service for Geodesy and Astrometry (IVS) and the Asia-Oceania VLBI Group (AOV), thereby contributing to global geodetic and astrometric reference frame maintenance. Situated at geodetic coordinates $6^{\circ} 49' 29.85316''$ S and $107^{\circ} 37' 03.09318''$ E, with an ellipsoidal altitude of 1324.1265 m, the newly established VGOS telescope is optimally located to strengthen VLBI baseline coverage in the equatorial

zone and to support the densification of the International Celestial Reference Frame (ICRF) in the Southern Hemisphere.

The Ghana Radio Astronomy Observatory: Technical Progress and VLBI Participation

Presenter: Emmanuel Proven-Adzri (Ghana Space Science and Technology Institute)

Co-authors: Theophilus Ansah-Narh (Ghana Space Science and Technology Institute), Evaristus Iyida (Ghana Space Science and Technology Institute), Pieter Pretorius (South African Radio Astronomy Observatory)

The Ghana Radio Astronomy Observatory (GRAO), located at Kutunse near Accra, houses a 32-metre converted telecommunications antenna that is now Africa's largest fully steerable radio telescope. Since its commissioning, the observatory has advanced steadily towards routine scientific operations, supporting observations of pulsars, methanol masers, and continuum sources. A core focus has been enabling Very Long Baseline Interferometry (VLBI), with GRAO contributing uniquely to global baselines due to its strategic equatorial location.

This presentation outlines recent technical upgrades to the telescope's receiver and backend systems, including the C-band dual-polarization frontend, ROACH2-based single-dish backend, and VLBI-ready digital baseband converter with Mark5b recording. We highlight lessons learned from fringe tests, calibration strategies, and early participation in global VLBI sessions. Beyond instrumentation, capacity building and operator training have been central in sustaining operations and ensuring data quality.

By demonstrating its capability to reliably join international VLBI campaigns, GRAO not only strengthens global networks but also positions Ghana as a key partner in radio astronomy development. The talk will also share ongoing efforts to improve system sensitivity, and expand the range of science cases, while fostering collaborations that integrate African facilities more fully into the global VLBI ecosystem.

Using techniques of radio astronomy for a sustainable development and Science

Presenter: Nectaria Gizani (Hellenic Open University)

Co-authors: Antonios Polatidis (Hellenic Open University), Giannis Prokopiou (University of Thessaly), Giorgos Veldes (University of Thessaly)

We present the usage of radio telescopes for space and environment applications as well as for the science of radio astronomy. In Greece two science projects are taking place involving the conversion of a 2 m (called Hellios) and 30m (called THERMOpYlae) dishes into radio telescopes.

The small dish will monitor the solar flux at 10.7cm to study climate change. It is actually a flux monitor. The 30m dish will be used for radio astronomy, both in single dish and VLBI modes. THERMOpYlae will also work on deep space applications. We also plan to include the radio telescope for geodetic studies.

We report on the work done so far, on the difficulties we have confronted, other than scientific, and on the hardware we have.

The Wetterstein Millimeter Telescope

Presenter: Jompoj Wongphechauxsorn (JMU)

The Wetterstein Millimeter Telescope (WMT) is a planned radio telescope associated with the Environmental Research Station (UFS) Schneefernerhaus at the Zugspitze in the Bavarian Wetterstein mountains.

The WMT is planned to operate at radio frequencies between 1.2GHz and 120GHz with the goal to extend further towards shorter millimeter wavelengths. It is envisioned as an interdisciplinary research platform for astronomy, geo- and environmental research as well as for data and technology development. The WMT shall be integrated into international networks such as the European VLBI Network, the Global mm-VLBI Array, and provide long baselines to the upcoming next-generation Very Large Array (ngVLA) and Square Kilometre Array (SKA VLBI). It can further provide key contributions to satellite technology and operation, to worldwide geodetic-VLBI services, to space-situational awareness and to solar-system research. In this talk, we will present the current status of the WMT project and discuss options for the WMT to contribute to the scientific goals of various VLBI networks.

RADIOBLOCKS

Presenter: Arpad Szomoru (Joint Institute for VLBI ERIC)

In this presentation I will talk about the 4-year RADIOBLOCKS project, funded by the EC under the Horizon Europe programme. I will describe its structure, ambition, current status and accomplishments. I will also touch upon its potential for the future of the EVN and European radio astronomy in general.

Radio Blocks for a VLBI GPU correlator

Presenter: Mark Kettenis (Joint Institute for VLBI ERIC)

Co-author: Aard Keimpema (Joint Institute for VLBI ERIC)

Within the RADIOBLOCKS EU project, JIVE, in collaboration with partners, is investigating state-of-the-art accelerator technologies for implementing a (VLBI) correlator. In particular we are developing GPU kernels that implement the same algorithm as the SFXC CPU correlator. This development will provide re-usable VLBI delay and Windowed Overlap (WOLA) filter modules (which we call Radio Blocks) that can be combined with the Tensor Core Correlator Radio Block developed by our project partner ASTRON to implement a VLBI correlator as well as additional modules to implement coherent de-dispersion and multiple field center correlation. We also developed a wrapper library for UCX that allows efficient transfer of sampled baseband data directly into GPU memory. The result is a correlator that uses almost no CPU cycles. Initial power consumption estimates indicate that with these technologies we can build a correlator that is significantly more efficient than the existing EVN data processor at JIVE (SFXC). In this talk I will present the technologies that make this possible, discuss the

current power consumption estimates and the scalability. I'll conclude with an outlook on what a future EVN correlator might look like.

Deep dive into the ATCA "BIGCAT" GPU correlator

Presenter: Chris Phillips (CSIRO)

The Australia Telescope Compact Array (ATCA) is a six-element interferometer operated by CSIRO. We are in the process of installing a new digital backend that employs a small cluster of GPU accelerators to process 8 GHz of bandwidth in real time from all six telescopes. In this talk, I will provide a brief overview of the system and discuss some of the technical challenges encountered, along with the solutions developed to achieve maximum performance. These issues are common to any "small-N" GPU correlator and are directly relevant to the use of GPUs for VLBI correlation.

The correlation terminal for the Antarctic submillimeter interferometer

Presenter: Yajun Wu (Shanghai Astronomical Observatory, CAS)

Co-authors: Wu Jiang (Shanghai Astronomical Observatory), Lei Liu (Shanghai Astronomical Observatory), Fengxian Tong (Shanghai Astronomical Observatory), Zhang Zhao (Shanghai Astronomical Observatory)

In order to construct a submillimeter interferometer in Antarctica, the correlator is a core component that converts the signals received by two antennas into digital signals and performs correlation operations to obtain the visibility function. This talk will introduce a design scheme for the correlator of this project. Firstly, in order to ensure the coherence between the antennas, we will use fiber optic transmission to provide a common frequency reference to each antenna for signal acquisition and processing. Install a data acquisition device on each antenna and transmit the collected data to the central processor through optical fiber. At the same time, time synchronization between the two antennas is also a key factor. On the central processor, the high-speed data from two antennas will be received first, and the data from the two antennas will be aligned based on the geometric delay and instrument delay, and relevant processing will be performed using acceleration techniques. This article provides preliminary design and simulation of these, and presents some test results in Lab.

Developments at Wettzell Observatory

Presenter: Alexander Neidhardt (FESG - Technical University of Munich)

Co-author: Simon Seidl (FESG - Technical University of Munich)

The talk gives an overview about current (software) developments for VLBI, which might also be interesting for other VLBI stations.

VCAT: A python module for VLBI data analysis

Presenter: Anne-Kathrin Baczko (Chalmers, Astronomy & Plasma physics, Onsala Space Observatory)

I will present our newly developed Python module VCAT (VLBI Comprehensive Analysis Tool), which aims at easing data analysis of VLBI data, specifically aimed for studying AGN jets. It allows a comprehensive analysis of the radio signature of AGN jets as obtained from multi-frequency continuum VLBI observations to obtain information about the morphology and polarization of the extended emission.

VIPCALs: A fully-automated calibration pipeline for VLBI data

Presenter: Diego Alvarez-Ortega (Institute of Astrophysics - FORTH)

Co-authors: Carolina Casadio (Institute of Astrophysics - FORTH), Felix Pötzl (Institute of Astrophysics - FORTH), Avinash Kumar (Institute of Astrophysics - FORTH), Michael Janssen (Radboud University)

Very long baseline interferometry (VLBI) requires complex and often manual post-correlation calibration to correct for instrumental, geometric, and propagation-related errors. Unlike connected-element interferometers, VLBI arrays typically provide raw visibilities rather than science-ready data, and existing pipelines are largely semi-automated and reliant on user supervision. This manual oversight becomes a critical bottleneck for large-scale VLBI projects involving thousands of radio sources.

We present VIPCALs, a fully automated, end-to-end calibration pipeline for continuum VLBI data that operates without human intervention or prior knowledge of the dataset. Designed for scalability to thousands of sources and heterogeneous archival observations, VIPCALs addresses the needs of initiatives such as the Search for Milli-Lenses (SMILE) project. Implemented in AIPS using ParselTongue, VIPCALs reproduces the standard calibration workflow in a fully unsupervised mode. Besides the usual calibration tasks, the pipeline also performs data preprocessing, automatic reference antenna selection, calibrator identification, and generates diagnostic outputs for inspection. The pipeline has been validated on a representative sample of Very Long Baseline Array (VLBA) data covering 1000 sources from the SMILE project. The results demonstrate that fully automated VLBI calibration is feasible, paving the way for incoming large-scale VLBI projects.

Ambient L-band receiver development at ASTRON

Presenter: Paulus Kruger (ASTRON)

Co-authors: Mark Ruiter (ASTRON)

ASTRON is developing technology for 'large-N, small-D' radio telescopes, i.e. systems having many, small, low-cost antennas. To reduce the receiver cost, we are investigating various technologies, such as non-cryogenic ultra-low noise frontends, simple RF chains with direct sampling receivers and white-rabbit timing.

An L-band technology demonstrator, using one of the Westerbork Synthesis Radio Telescope (WSRT) dishes, is currently being developed to test these new technologies. The demonstrator aims to achieve a system noise temperature of 30 K over a 1 GHz bandwidth in the L-band, which is a crowded RFI environment.

The frontend builds upon advances in low-noise transistors operating at ambient temperatures. A new design technique makes it possible to integrate the low-noise amplifier into the feed and optimise them together for minimum noise. The first such active feed will be presented, with a measured receiver noise temperature of around 15 K at room temperature.

Following amplification and filtering, an ethernet receiver is used to directly sample the RF signals (at 14 bits per sample) and transport them via optical fiber ethernet. Timing is distributed over the optical fiber using white-rabbit technology. A first 100MHz bandwidth ethernet receiver with integrated white-rabbit timing has been produced and a new 1 GHz bandwidth receiver is currently under development.

Modernizing the VLBI data-reduction software stack

Presenter: Mark Kettenis (Joint Institute for VLBI ERIC)

Over the last decade JIVE, in collaboration with NRAO, has been working on adding VLBI functionality to CASA. As a result CASA is now a feasible alternative to AIPS. A significant number of EVN and VLBA users use CASA to reduce their VLBI data and the CASA-based rPICARD pipeline is used as one of the two calibration pipelines for the EHT.

However the technology behind CASA is already three decades old. As a result it has proven difficult to do data processing with CASA at the scale that is necessary for the next generation of radio interferometers such as the SKA, ALMA after the wide-band sensitivity upgrade and ngVLA. To address these difficulties the CASA teams at NRAO, ESO and JIVE have started designing a new scalable framework to do data processing, and in collaboration with the SKA a new MSv4 data model/format to support this framework. VLBI is one of the main use cases for this new framework (as ngVLA will include VLBI-scale baselines).

In this presentation I will discuss the technologies behind this new framework: the MSv4 schema and associated Zarr-based data format, the xradio reference implementation based on xarray and the GraphVIPER package that use Dask to parallelise computation. And present the effort at JIVE to implement fringe-fitting in this new framework.

Multi-dimensional image reconstruction using adaptive correlated noise model

Presenter: Venkatesh Ramakrishnan (Tampere University)

The measurable quantities in radio interferometric observations are visibilities of the target signal at given spatial frequencies. The limiting factor of the visibilities to spatial frequencies and the sampling pattern introduces both spectral and spatial correlated noise in the image. The widespread radio-interferometric image reconstruction algorithms that have been used over the past few decades ignore these aspects and have several limitations, thereby introducing artefacts in the reconstructed image. The rigorous treatment of correlated noise thus remains unaddressed in the development of state-of-the-art imaging algorithms for radio interferometry.

We address the problem of detection and image reconstruction of different kinds of sources within a radio-interferometric image from severely underdetermined and noisy linear measurements using a sparsity promoting algorithm. The mutual and complementary information found within or across different epochs can be used in synergy, to enable exploration, insight and analysis, which would not be possible from individual epochs neither for the characterisation of features like transients nor the underlying noise.

A common feature of existing algorithms is that the degradation to be filtered at each iteration is modelled as additive white Gaussian noise (AWGN). The common assumption of AWGN holds only under special conditions that are hardly met in practice, particularly in radio-interferometric imaging. We instead propose to model the degradations as stationary spatiotemporally correlated noise and adopt the corresponding denoiser for the recovery. This correlation can be a result of multiple contributors: the structure of the interferometric beam, the statistics of the noise in the observations (e.g. thermal noise), as well as their interaction with the structure of the underlying signal and the effect of denoiser during the previous iteration. In contrast to AWGN, correlated noise can lead to disproportionate errors across the data spectrum, to the extent that AWGN denoisers may not effectively discern between the true signal and noise in regularisation via shrinkage. Hence, ignoring such correlation in the denoising step can lead to ineffective filtering and distortion to the underlying signal, thus impairing the accurate, high-quality recovery of the underlying signal.

The Synoptic Wide-field EVN–eMERLIN Public Survey (SWEEPS) - Overview and Results

Presenter: Célestin Herbé-George (Kapteyn Astronomical Institute/University of Pretoria)

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. 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 EVN–eMERLIN Public Survey) is a commensal survey mode for the EVN+e-MERLIN, where single-target PI-led observations are re-correlated at the position of all known radio sources within 12 arcmin. Initially, the phase centres are selected using the LoTSS survey program of LOFAR. In the future, however, additional phase centres will be provided by a wide-field image using the short baselines of e-MERLIN that will be generated on-the-fly for the initial correlation. From archival data, full implementation of this program would observe on average ~10,500 radio sources per year without any additional observing time. Here, we present an overview of the upcoming survey programme as well as results and methods from the pilot program, where we detected 21 new VLBI objects in the data of a PI-led single target observation.

Preparing for VLBI with signals of ESA's Genesis satellite

Presenter: Rüdiger Haas (Chalmers, Onsala Space Observatory)

The European Space Agency (ESA) currently works on the Genesis mission. Genesis is a so-called co-location satellite that should contribute to the improvement of the International Terrestrial Reference Frame (ITRF). The idea is to combine the four space geodetic techniques Very Long Baseline Interferometry (VLBI), Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR) and Doppler Orbitography and Radio Positioning Integrated by Satellite (DORIS) on one single spacecraft that is orbiting Earth. The Genesis satellite is planned to be launched in 2028 and have a life time of at least 2 years.

In order to work on the goals of the Genesis mission, ESA has set up a Genesis Science Exploitation Team (GSET). GSET involves four technique-specific working groups (WGs), one each for VLBI, GNSS, SLR and DORIS, as well as one working group for the ITRF and combinations. The technique-specific WGs have the task to advise and support ESA for all aspects of the Genesis mission, including assistance in calibration, processing and validation of Genesis data, and the exchange information with the international science community.

Working Group 3 (WG-3) focused on the VLBI aspects of Genesis. Currently discussed topics are the VLBI transmitter and transmitting antenna, compatibility with normal operations of the International VLBI Service for Geodesy and Astrometry (IVS), and the IVS product generation. Other important aspects for WG-3 are optimal scheduling, end-to-end simulations, and eventually also test observations of Genesis.

This presentation is on behalf of ESA GSET WG-3 (VLBI) and gives an overview on the current status of the work performed in the working group.

Signal-to-Noise and Link Budget Analysis for the GENESIS VLBI Transmitter

Presenter: Ozgur Karatekin (Royal Observatory of Belgium)

The GENESIS mission will integrate four geodetic techniques onboard a dedicated satellite, including a novel Very Long Baseline Interferometry (VLBI) transmitter. A key requirement for this payload is that the transmitted power flux density (PFD) remains within the operational range of global VLBI radio telescopes. Unlike traditional VLBI observations of distant quasars, where the received flux is essentially uniform across stations, a satellite-based transmitter yields variable received power at different antennas due to orbital geometry, antenna gains, and station sensitivities.

We simulate the received signal-to-noise ratio (SNR) at VLBI Global Observing System (VGOS) stations over a one-day period. The analysis accounts for antenna gain patterns, station system equivalent flux densities (SEFD) at different bandwidths, and the influence of atmospheric and meteorological conditions. We present link budget estimates that combine transmitter power, antenna characteristics, and ground station parameters, underscoring the critical role of PFD in achieving reliable correlation and delay determination for GENESIS VLBI observations.

Removing source structure in DiFX visibility data

Presenter: Frederic Jaron (TU Wien)

Source structure introduces a systematic error in VLBI observations on a per-source basis. We have developed a software tool that takes models of the brightness distribution to correct the interferometric phases of the DiFX correlator output. We have tested our method by applying it to observational VGOS data. Here we present our results concerning the effect on imaging the corrected data, the impact on closure delays, and a full geodetic analysis of group delay databases.

Progress of Full Automated Correlation Process for VGOS-INT-B/C at Tsukuba Correlator/Analysis Center

Presenter: Kaho Hashimoto (Geospatial Information Authority of Japan)

Co-authors: Haruna Furui (Geospatial Information Authority of Japan), Tetsuya Hara (Advanced Engineering Service Co. Ltd.), Masafumi Ishigaki (Geospatial Information Authority of Japan), Takahiro Wakasugi (Geospatial Information Authority of Japan)

Tsukuba Correlator/Analysis Center in GSI are involved in correlation and analysis of intensive sessions INT-2 and VGOS-INT-B/C every weekend. We report on the status and changes in VGOS-INT-B/C sessions' correlation process which has been updated from last year.

One of the large barriers to full automated correlation is the process of short baseline between ONSA13NE and ONSA13SW. In VGOS-INT-B/C, data quality of the short baseline is significantly affected by P-cal signals and noises which both stations have in common. Most of the scans have fringe qualities below 3 or G code when all the 32 channels are applied to the process, and thus, we should manually choose which channels to be removed in each observation. Therefore, we investigated the influences of short baseline in the analysis using nuSolve and

concluded that the accuracy of UT1-UTC is equal within 1 sigma level between the results with and without short baseline. Thus, GSI decided to omit the short baseline process after bandwidth synthesis from B25164 (June 14, 2025) after discussing it with other IVS correlators, analysts, and Onsala operators. Currently we proceed to make correlation reports and vgosDBs and submit them to the IVS automatically if the HOPS program can estimate all the ""pc_phases_x,y"", ""pc_delay_x,y"", and ""pc_phase_offset_x,y"". We succeeded in a full automated correlation for the first time in B25185 (July 5, 2025), and the latency was 14 hours 9 minutes, where the data transfer consumed almost 12 hours of them. There still remain some bugs in our automation program, and we are on the way to fixing them. In this presentation, details of some updates in our automation program will be reported.

In the near future, we would like to establish a versatile full automated program which is capable of processing various kinds of intensive sessions as a correlation phase through collecting the data format of each telescope. As an analysis phase, GSI is planning to analyze VGOS-INT-B/C sessions using c5++ provided by Hitotsubashi University, NICT and JAXA in the same way as conducted in INT-2 sessions to perform quality inspection of the vgosDB before submission.

Multi-twin flux density monitoring at VGOS frequencies

Presenter: Alva Kinman (Chalmers, Onsala Space Observatory)

Co-authors: Rüdiger Haas (Chalmers, Onsala Space Observatory), Karine le Bail (Chalmers, Onsala Space Observatory), Jun Yang (Chalmers, Onsala Space Observatory) Eskil Varenius, Susana Garcia Espada (Norwegian Mapping Authority), Rubén Bolaño González (Norwegian Mapping Authority), Alexander Neidhardt (FESG - Technical University of Munich)

The VLBI Global Observing System (VGOS) has been operational since 2020. To optimize VGOS schedules and derive more accurate geodetic parameters, a SNR-based scheduling approach has recently been introduced. However, many geodetic sources still have poorly known radio flux densities in the operationally used VGOS frequency bands. We have carried out flux monitoring observations at Onsala Space Observatory (OSO) since 2023 in order to create a VGOS flux density catalog. However, not all VGOS sources are observable from Onsala. A complete and frequently updated catalog is only possible with the involvement of other stations. We here present early results of flux monitoring observations carried out with three pairs of twin telescopes simultaneously: Onsala, Ny-Ålesund and Wettzell. The data was correlated at OSO using DiFX, and calibrated using Common Astronomy Software Applications (CASA). We compare the flux density values obtained by the different twin pairs, evaluating the feasibility of a future flux monitoring program involving multiple VGOS telescopes.

A new method to derive a VGOS flux density source catalogue based on real observations and theoretical derivations

Presenter: Shilpi Chakraborty (Indian Institute of Technology Kanpur (IITK), India)

Co-authors: Nagarajan Balasubramanian (Indian Institute of Technology Kanpur, India), Onkar Dikshit (Indian Institute of Technology Kanpur (IITK), India), Lucia McCallum (University of Tasmania, Australia), Tieghe McCarthy (University of Tasmania, Australia)

Efficient scheduling in the VLBI Global Observing System (VGOS) requires accurate knowledge of source flux densities at 3–11 GHz. However, the lack of such data leads to fixed 30-second scan durations, often resulting in sub-optimal use of observing time and limited scan counts per session. To address this, we present a method to estimate flux density per projected baseline length bin (in 1000 Km interval) using real VGOS observations, accounting for intrinsic source structure while minimizing system noise effects.

From these baseline bin flux estimates, we compute the integration time needed to achieve a target signal-to-noise ratio (SNR) of 15 per bin. A dedicated pipeline has been developed to dynamically determine observation duration using either individual SEFDs, enabling flexible and accurate flux-based scheduling.

Comparative analysis with SKED's power-law flux model reveals its limitations in capturing detailed source structure, especially at higher frequencies. Applied to one of 19 VGOS sessions, our approach increased the total number of observations by 24%, highlighting its potential to enhance scan efficiency, improve geodetic precision, and support better classification of compact versus extended sources."

Synchronized microwave radiometer and VGOS observations

Presenter: Peng Feng (Chalmers, Onsala Space Observatory)

Co-authors: Gunnar Elgered (Chalmers, Onsala Space Observatory)

Since mid-2023, the Onsala Space Observatory has been operating a new modern microwave water vapor radiometer (WVR), ****Greta****, which is a commercial product of type HATPRO-G5. It is co-located with the other microwave radiometer, Konrad, which has been developed and built at Onsala. Konrad has been in operation since 2000 and is usually operated in so-called sky-mapping mode. Usually, the data of complete sky-scanning sequences are then analyzed together, providing zenith wet delay and wet horizontal gradient results with a temporal resolution of 2–5 minutes. In addition to operating in a similar sky-mapping mode, the new WVR Greta has been operated in synchronization with VGOS observations during several VGOS 24-h and VGOS-INT sessions in 2023 to 2024. This means that Greta was performing measurements of the local atmosphere in the same direction as the VGOS telescopes at Onsala, thus providing slant wet delay measurements for each VGOS observation. Together with the slant hydrostatic delays calculated from ground pressure measurements, the possibility of avoiding estimating the delays due to the neutral atmosphere exists and will be evaluated. We also investigate the agreement between the tropospheric parameters estimated from VGOS and those retrieved by the synchronized WVR observations.

Investigating the Impact of GNSS Orbit and Clock Product Types in Integrated VGOS and GNSS Solutions for VLBI Intensive Sessions

Presenter: Rimsky Wolfs (Chalmers, Onsala Space Observatory)

The International VLBI Service for Geodesy and Astrometry (IVS) conducts both 24-hour and 1-hour geodetic VLBI sessions. The 24-hour sessions utilize global VLBI networks to estimate all five Earth Orientation Parameters (EOP), but they generate large volumes of data, resulting in product delays of several weeks. In contrast, the 1-hour intensive sessions are designed to provide more timely estimates of the Earth rotation angle (UT1-UTC), which is known to vary more over shorter time scales. These sessions use only 2–3 telescopes and offer faster results, but are more sensitive to short-term variations and suffer from limited troposphere modeling due to sparse observations and reduced mutual sky coverage. For instance, tropospheric gradients—routinely estimated in 24-hour sessions—cannot be reliably determined in intensives.

Previous studies have explored enhancing both session types by incorporating GNSS data from co-located stations, using either co-located combination on the observation level (CCOL) or combination at the normal equation (NEQ) level. Some of these approaches showed improvements in UT1-UTC and/or UT1-UTC derived Length of Day (LOD) estimates. However, they primarily relied on Legacy VLBI data combined with final and rapid GNSS products using NEQ-level methods, or on VGOS data combined with final GNSS products using CCOL.

In this study, we investigate the impact of using different GNSS orbit and clock product types—ultra-rapid (same-day), rapid (within 2 days), and final (12–19 days)—in CCOL solutions with VGOS for VLBI intensive sessions. We compare the integrated solutions across GNSS product types and against standalone VGOS processing to evaluate the trade-offs between timeliness and accuracy."

AAC Omnisys to deliver the Band 1 feeds for the SKA-mid telescope for the Square Kilometre Array Observatory (SKAO)

Presenter: Olivier Auriacombe (AAC Omnisys), invited

Co-authors: Josefina Adebahr (AAC Omnisys), Alhassan Aljarosha (AAC Omnisys), Rasmus Augustsson (AAC Omnisys), Mattias Ericson (AAC Omnisys), Marie Holmberg (AAC Omnisys), David Håkansson (AAC Omnisys), Kalle Kempe (AAC Omnisys), Jean Kotze (SKA Organization), Mikael Krus (AAC Omnisys), Ulrika Krus (AAC Omnisys), Alice Pellegrini (SKA Organization), Marius Pop (AAC Omnisys), Daniel Reidal (AAC Omnisys), Jordan Rouse (AAC Omnisys), Steve Sahlberg (AAC Omnisys), Ahmed Salek Brzouami (AAC Omnisys), Mats Svenson (AAC Omnisys)

The Square Kilometre Array (SKA) telescope will provide unprecedented sensitivity across a wide frequency range, combined with high resolution and survey speed, offering the astronomical community a state-of-the-art instrument to address ambitious scientific objectives and advance our understanding of the Universe's history.

During the preconstruction phase of the SKAO project, the Dish Consortium, together with Onsala Space Observatory, developed a prototype of the Band 1 Single Pixel Feed. This prototype underwent several years of development and testing in Sweden, Canada and on the

MeerKAT telescope in South Africa, a precursor to SKA-Mid. After successfully passing its design review, it was selected by SKAO for full implementation.

The feed package is mounted on the telescope indexer and directly exposed to the environment. Under the Band 1 Single Pixel Feed Engineering Construction Contract, awarded to AAC Omnisys [AAC Clyde Space], the task is to finalize the design, manufacture, assemble, install, and test 80 complete Band 1 Single Pixel Feed systems, each weighing around 180 kg (with mechanical parts produced by MECHA and HPG AB). An initial delivery of four prototypes will be installed in South Africa.

The Band 1 system is an ambient-temperature feed package covering frequencies from 350 to 1050 MHz. A dual linear polarized quad-ridge feed horn converts electromagnetic signals focused by the SKA dish. Two low-noise amplifiers (LNAs, Low Noise Factory AB) are integrated directly into the ridges, amplifying the signals by approximately 40 dB. The first-stage LNA also incorporates a directional coupler to inject calibration noise before amplification. Signal conditioning continues in the Band 1 Feed Package Controller (ACORDE), which contains amplifiers, noise diode circuitry, temperature stabilization, and control electronics. The horn aperture is shielded by a radome (FORMPLAST), while a sun shield (MOMEK) reduces solar heating and protects against rain.

Assembly and testing will be carried out at Omnisys in Gothenburg, RISE in Borås, and on-site in South Africa. Site acceptance of the feeds is planned for late 2025, after which AAC Omnisys will begin serial production of 80 units for SKAO.

Compact Downconverters for VGOS and BRAND receivers

Presenter: Andrea Martínez Parra (Observatorio de Yebes, IGN)

Co-authors: Marta Bautista Durán (Observatorio de Yebes, IGN), María Patino Esteban (Observatorio de Yebes, IGN), Pablo García Carreño (Observatorio de Yebes, IGN), José Antonio López Pérez (Observatorio de Yebes, IGN)

The transition of VLBI systems towards ultra-wideband receivers represents a decisive step for both radio astronomy and space geodesy, where achieving millimeter-level accuracy critically depends on highly reliable signal conversion and processing chains. Within this context, we present the design, development, and validation of a 4–8 GHz downconverter conceived for cryogenic receivers compatible with VGOS and BRAND. Its purpose is to translate broadband RF signals into a DC–4 GHz intermediate frequency, ensuring full compatibility with the DBBC3 backend and enabling next-generation observations within the RAEGE network.

The proposed design integrates commercially available surface mount devices (SMD) with custom components specifically developed at Yebes Observatory. All elements are mounted in a precision-machined aluminum housing that guarantees mechanical stability, optimal impedance matching, and high electromagnetic isolation between polarizations. The signal chain incorporates isolators, mixers, low-pass filters, amplifiers, and programmable digital attenuators, carefully configured to achieve stable conversion gain, controllable output levels, and minimal additional noise.

Extensive measurements demonstrate that the prototype satisfies the requirements of VGOS and BRAND. Experimental results confirm stable and adjustable gain in both polarizations, adequate linearity with input compression points (Pi1dB) up to +13.4 dBm, noise figure consistently below 25 dB across the band, and excellent cross-polarization rejection exceeding 44 dB. In addition, the phase stability was characterized through dedicated measurements at several frequency points across the 4–8 GHz RF band, with integration times of 5, 10, and 30 minutes. The results show an average peak-to-peak phase variation of approximately 4.3°, 6.5°, and 6.9°, respectively, consistently observed at all tested frequencies. Since VGOS scans last 30 s, stability was verified over extended integration times to ensure phase coherence well beyond the operational requirements. These results validate the downconverter as a reliable and efficient building block for ultra-wideband VLBI receivers.

Beyond technical validation, this development represents a significant milestone towards the implementation of a new generation of downconverters for ultra-wideband receivers in the RAEGE network.

OSO 20m Tri-Band Receiver Project

Presenters: Leif Helldner (Chalmers, Onsala Space Observatory), Magnus Dahlgren (Chalmers, Onsala Space Observatory)

Co-authors: Denis Meledin (Chalmers, Onsala Space Observatory), Mugundhan Vijayaraghavan (Chalmers, Onsala Space Observatory)

A new Tri-band receiver would advantageously replace Onsala's 20m telescope existing millimeter wave single-pixel receivers within the K,Q and W frequency bands, having next-generation performance, IF bandwidth, and sampling capabilities. The receiver system will support both Astro VLBI observations and single-dish functionality. Moreover, the new receiver aims to enable simultaneous observations over those frequency bands, compatible with current and coming Tri-band receivers within the EVN (following on from Korean VLBI Network (KVN) developments)

At the workshop, we present the main specifications, the conceptual design and overview of the project plan for a future Tri-band receiver for Onsala's 20 m telescope.

Redundant National Fiber Distribution of Time and Frequency

Presenter: Sven-Christian Ebenhag (NETNOD AB), invited

Recent geopolitical developments have led to severe disruption for crucial systems that society relies on, even for countries that are not part of any ongoing conflict. This includes intentional sabotage of infrastructure or denial of access to critical support systems. Global Navigation Satellite System is one of those systems that society depends on, both in terms of positioning but also for time and frequency . Time and frequency from a GNSS receiver are widely utilized, as receivers are inexpensive and easy to install. A number of the systems that are crucial for society are GNSS dependent in terms of correct and traceable time and frequency. These systems include those critical for the function of energy, communication, security systems as well as health systems for entire countries.

National time is based on the national time scale of each country and can be distributed via various different routes to end users. The main issue with time and frequency is that while it is a key part of critical infrastructure, with society dependent on its correct functioning, the market is not willing to cover the current costs for delivering correct traceable time. Another issue is that the publicly funded National Metrology Institutes (NMIs) that realize the national timescales have limited resources, which results in end users not having access to correct traceable time and frequency, and instead relying on GNSS without redundancy.

To meet current and future needs, research and development must be carried out regarding TF distribution in existing fibre infrastructure, as well as coexistence with communication methods.

Here we present the latest work on traceable national distribution of time and frequency from the Swedish national time scale. The distribution takes place from a number of different locations in Sweden, each location having redundant time scales based on atomic clocks.

State of the art of optical communications

Presenter: Magnus Karlsson (Chalmers, Microtechnology and Nanoscience), invited

Optical communications have had a remarkable development over the last 50 years thanks to developments in, e.g., fiber optics, laser technology, optical amplifiers and signal processing. Fiber communications form the backbone of there internet, and one can now readily transmit 10-100 Tb/s over transoceanic distances. The presentation will briefly describe these developments, and then discuss the emerging challenges when we want to take optical communications into space, where distances can be even longer and where we will not benefit from fiber waveguiding, but the diffraction losses instead poses a significant challenge to the available data rates.

SHARP and Space Array initiatives

Presenter: Eric Villard (European Southern Observatory)

Over the past decades, ground-based astronomy has advanced through the search for drier sites and the construction of ever-larger telescopes, resulting in facilities such as VLT, ALMA, and soon the SKA and ELT. These observatories deliver unprecedented angular resolution and sensitivity, yet their cost and complexity continue to rise. At the same time, even prime observing sites such as the Atacama desert are experiencing worsening atmospheric conditions, underscoring the need to move the frontier of high-resolution astronomy into space.

Interferometry offers the only path to angular resolutions far beyond the capabilities of single-dish telescopes. Past space VLBI missions such as VSOP and RadioAstron demonstrated the feasibility of placing a radio antenna in orbit, but with only one spacecraft, their imaging capabilities and sensitivity were limited. Truly transformative progress requires an array in space: a constellation of antennas forming a flexible interferometer that can probe compact sources with unprecedented fidelity.

We present two complementary initiatives toward this goal. SHARP (Space-based High-resolution Array for Radio astronomy and Physics) is a concept submitted to the recent ESA call for M-class mission proposals. It will consist of three satellites operating at sub-mm wavelengths to demonstrate key technologies for space interferometry, including high-frequency receivers, precise baseline knowledge through GNSS and laser ranging, high-bandwidth inter-satellite links, and real-time correlation. SHARP will enable pioneering science such as resolving the event-horizon-scale structure of black holes at frequencies beyond the EHT.

Looking further ahead, Space Array is a study for a large orbital interferometric array of (sub)-millimetre and far-infrared antennas. Building on SHARP's pathfinding work, Space Array envisions tens of satellites in medium Earth orbit, providing dense uv-coverage and order-of-magnitude improvements in angular resolution and imaging capability. Enabled by recent advances in small satellite platforms, re-usable launch vehicles, and precision metrology, such a facility would open a new era of ultra-high-resolution astronomy.

We will present the status on both initiatives and argue that the convergence of science drivers and technological maturity makes now the right moment to take decisive steps toward interferometric arrays in space."

Time-Resolving Sgr A* at 86 GHz via Low-Earth Orbit VLBI

Presenter: Amelia Frickey (Brown University)

Co-authors: Ref Bari (Brown University), Graham Neely (Brown University)

T-REX (Time-Resolving Explorer) is a proposed SmallSat which seeks to time-resolve the accretion disk of Sgr A* through direct radio interferometric imaging utilizing VLBI -- enabling the first constraints on black hole spin. T-REX will operate in Low-Earth Orbit (LEO) at 86 GHz ($\lambda \sim 3.5\text{mm}$) with a $d \sim 2.5\text{m}$ antenna. It will co-observe with BHEX (Black Hole Explorer) in MEO and the EHT (Event Horizon Telescope) in a unique MEO-LEO-Ground "sandwich" configuration. If successful, T-REX would be the first demonstration of Space-Space VLBI (between BHEX and T-REX. Additionally, unlike BHEX which has only long baselines ($> 20G\lambda$) which can reveal horizon- scale structure of Sgr A/M87 (but which is not as adept at observing larger-scale structure like jets), T-REX will benefit from both a long Space-Space Baseline (BHEX to T-REX) and a shorter, Space-Ground Baseline (T-REX to EHT). T-REX is thus uniquely positioned to access both horizon-scale and extended jet-structure morphology of low-accretion state black hole targets. T-REX's primary science objective is to leverage this orbital structure to time-resolve Sgr A*, effectively creating the first ever video of a black hole. In addition to this ambitious goal, T-REX plans to conduct an all-sky survey of ~ 25 targets, potentially enabling multi-messenger astronomy on binary black hole systems, quasars, and black hole accretion disks.

Progress of the Chinese VLBI Network from Earth to Space

Presenter: Weimin Zheng (Shanghai Astronomical Observatory)

The Chinese Very Long Baseline Interferometry Network (CVN) currently consists of six ground-based radio telescopes, one space-borne experimental telescope, and a data

processing center affiliated with the Shanghai Astronomical Observatory. Two newly commissioned 40-meter telescopes are located in Shigatse, Tibet Autonomous Region, and Changbai Mountain, Jilin Province. Shigatse and Changbai stations have joined China's first asteroid sample-return mission, Tianwen-2 (TW-2), in May 2025. New receivers are under development, with the goal of operating from the L to K/Q/W bands .

The "6-station + 1-center" configuration has extended the longest baseline of the CVN from 3200 km to 3800 km. This six-telescope setup enables the construction of two 3-station subnetworks for simultaneous observations, thereby supporting space VLBI observations and high-precision deep-space probe orbit determination. Besides, the Lunar Orbital VLBI Experiment (LOVEX) – which utilizes a 4.2-meter space VLBI telescope onboard the Queqiao-2 lunar relay satellite – has expanded the CVN from an Earth-based network to an Earth-space integrated network.

The baseline length of LOVEX can extend up to approximately 400,000 kilometers, making it the longest VLBI baseline to date. Recently, LOVEX has obtained VLBI fringes of the blazar AO 0235+164 and captured the telemetry signal of Chang'e-6 along the Earth-Moon baseline. In the future, with the addition of more ground-based and space-borne VLBI telescopes, the sensitivity and angular resolution of the CVN will be further improved, providing powerful tools for studying black hole physics, and the formation mechanisms of transient celestial sources.

VLBI Transmitter preliminary performance and link budget estimates for NovaMoon

Presenter: Ozgur Karatekin (Royal Observatory of Belgium)

The ESA NovaMoon proposal includes a Very Long Baseline Interferometry (VLBI) transmitter as part of its longline geodetic payload suit on the surface of the Moon. A stable and consistent lunar reference frame is essential for geodesy, geophysics, and the success of future lunar missions, enabling precise positioning and long-term monitoring of lunar orientation and interior dynamics. To date, the fundamental selenodesy network relies primarily on passive Apollo-era retroreflectors, which, while valuable, cannot alone provide the accuracy and stability required for next-generation lunar science and exploration.

VLBI offers a unique capability: it is the only space geodesy technique able to simultaneously determine terrestrial and celestial reference frames. Installing a dedicated VLBI transmitter on the Moon would transform the Moon into a continuously observable VLBI target, in analogy to the GENESIS geodetic satellite mission. This capability, particularly when co-located with Lunar Laser Ranging (LLR), would significantly enhance the lunar reference frame and support investigations into lunar orientation, interior structure, and fundamental physics. We present preliminary link budget analyses and expected performance of a lunar VLBI transmitter, together with its scientific objectives, functional design, and operational concepts.

Industrial return from large-scale research facilities

Presenters: Paul Häyhänen (Big Science Sweden), Oscar Isoz (Big Science Sweden), invited

Big Science Sweden (BiSS) has a government assignment to strengthen the opportunities of Swedish companies, universities and institutes to deliver components and services to thirteen large-scale international research facilities. The focus of our support is high-tech deliveries that, in addition to the business opportunity, contribute to strengthened research environments in Sweden, that drive innovation and that expand international collaborations. Currently, hundreds of companies are active members of the BiSS network. BiSS also works to ensure that more people from Sweden discover career opportunities at the Big Science facilities through outreach activities aimed mainly at students.

In this talk, we will describe how BiSS works to support Swedish universities, institutes and companies to contribute to large-scale research facilities in general, with some focus on Square Kilometre Array and ALMA.

RFI Measurements for SKAO Equipment – Challenges and Practice

Presenter: Kristian Karlsson (RISE), invited

The Square Kilometre Array Observatory (SKAO) sets stringent requirements for electromagnetic compatibility (EMC) to ensure minimal radio frequency interference (RFI) from its equipment. This presentation outlines the comprehensive EMC emission testing methodology developed and implemented at RISE using Reverberation Chambers (RCs). Covering a frequency range from 300 MHz to 25.5 GHz, the tests utilize advanced instrumentation, real-time spectrum analysis (RTSA), and I/Q data sampling to identify and characterize emission culprits. The methodology includes chamber calibration, noise reduction, spectrum integration, and traceability mechanisms. Practical challenges such as auxiliary equipment leakage, Doppler effects, and data storage are addressed.

Monitoring of Unwanted Electromagnetic Radiation at Onsala Space Observatory

Presenter: Lim Chin Chuan (Chalmers, Onsala Space Observatory)

Co-authors: Rüdiger Haas (Chalmers, Onsala Space Observatory)

The next-generation very-long-baseline interferometry (VLBI), also known as the VLBI global observing system (VGOS), was designed to observe the frequency band that spans from 2 to 14 GHz. This range overlaps with numerous licensed radio services, as coordinated by the International Telecommunication Union (ITU).

Essentially, all VGOS frequency bands overlap with other radio services that have ground stations which emit much stronger artificial radio signals compared to those from quasars. Additionally, there is an increasing number of space-borne emitters, e.g. from satellite communication systems.

It is becoming more crucial to avoid or mitigate signal interference from unwanted sources as more ground stations and satellites are built for telecommunication services locally and globally.

To address this issue, as a first step, we conducted Tsys monitoring sessions using the Onsala Twin Telescopes (OTT) to study the changes in the Tsys when pointing the antennas in different directions. We also ran dedicated Tsys sessions to study the radio environment behaviour in a selected direction for an extended period.

MIT Haystack Digital Backend Updates

Presenter: Chester Ruszczyk (MIT Haystack Observatory)

The 5th generation digital backend (DBEv5) is backward compatible for Geodesy work, and adds new features in support of upcoming satellite mission support. Also described are the FPGA personalities in support of legacy S/X systems and some new interesting developments.

The Effelsberg Direct Digitization Triband Receiver

Presenter: Niclas Esser (Max Planck Institute for Radio Astronomy)

The Effelsberg Direct Digitisation (EDD) system is a flexible platform for broadband radio astronomy, supporting observation modes ranging from single-dish spectroscopy to Very Long Baseline Interferometry (VLBI). Building on the existing EDD capabilities, we are developing a new Triband receiver system to simultaneously cover the K, Q, and W bands, providing an instantaneous digitized bandwidth of up to 12 GHz and an overall RF coverage of approximately 50 GHz. This design will enable coordinated observations across widely separated frequency bands, with particular emphasis on implementing multi-band phase transfer techniques directly within the EDD backend. Such integration aims to improve high-frequency VLBI coherence and sensitivity by transferring phase stability from lower to higher frequency bands in real time. We will present the receiver and backend architecture, the planned digitization and data transport chain, and the anticipated performance for VLBI and other high-frequency observing modes. This development represents a key step toward fully exploiting Effelsberg's high-frequency capabilities for global VLBI and broadband science.

Poster presentations

New VGOS Frequency Sequences Test Observations

Presenter: Simone Bernhart (Max Planck Institute for Radio Astronomy)

Co-author: Frederic Jaron (TU Wien)

The IVS VGOS Technical Committee (IVS VTC) discussed several times on how to maximize the benefits of VGOS for geodesy and astrometry. Unused potential for improvement was identified in (a) increasing the synthesized bandwidth per VGOS observing band from 480 MHz to 1024 MHz, and (b) distributing the four VGOS frequency bands between 3 and 14 GHz instead of only up to 10.6 GHz as is currently the case. In order to demonstrate the feasibility and possible benefits by using that potential, a series of fringe tests and test sessions were carried out in 2024 and early 2025. The results of these tests are expected to provide important input to the efforts of the IVS to anchor the observed frequency channels in the ITU Radio Regulations, so that in the future more consideration could be given to VGOS radio telescopes with regard to unwanted radio radiation. To this end, the optimum VGOS frequency configurations are being sought, as they are to be used in the long term. The poster depicts the four frequency sequences and their performance during these sessions and draws conclusions for potential further tests.

Single station analyses of GPS data from the AuScope VLBI array in preparation to GENESIS mission

Presenter: Yuting Cheng (Royal Observatory of Belgium)

Co-authors: Alime Ozyildirim (Royal Observatory of Belgium), Ozgur Karatekin (Royal Observatory of Belgium)

The Australian VGOS telescopes offer the capability of observing GNSS satellites in L-band, which is not common for traditional VLBI telescopes. Dual-band observations from several GPS satellites were recorded from the three telescopes and graciously shared by the University of Tasmania. Based on the correlation between the recorded samples and locally generated replicas, the signal traveling time can be estimated and compared with either GNSS products or geometric calculations based on the knowledge of the station and satellite positions. Characterizations can be done for ionospheric delay related parameters (e.g. Total Electron Content) and eventually for station clocks and compared to corresponding results from GNSS and VLBI data.

The interest in this study is two-fold. Firstly, it allows to process the same signal with different hardware belonging to two of the major geodetic techniques, opening the door to a fair comparison between them. Secondly, it demonstrates the concept of single operations in view of the GENESIS mission (see dedicated poster).

Waveform comparison for single station operation with the GENESIS VLBI transmitter

Presenter: Thibault Deleu (Royal Observatory of Belgium)

Co-authors: Yuting Cheng (Royal Observatory of Belgium), Ozgur Karatekin (Royal Observatory of Belgium), Alime Ozyildirim (Royal Observatory of Belgium), Birgit Ritter (Royal Observatory of Belgium)

The GENESIS satellite, scheduled for launch in 2028, will contribute to the improvement of the International Terrestrial Reference Frame (ITRF), by combining the four major space geodetic techniques, namely GNSS, DORIS, SLR and VLBI, onboard a single platform at an altitude of 6000 km. The VLBI transmitter (VT) is one of the key instruments, designed to operate in two distinct transmission modes. In the primary mode, the VT will mimic quasar sources with a Gaussian signal, enabling conventional geodetic operations through cross-correlation of signals between two ground stations. In the secondary mode, a periodic signal is transmitted, allowing for single-station operation by correlating the received signal with a locally generated digital replica. In this case, the measured delay relates directly to the propagation time between the satellite and the station. The selected waveform for the second mode is a binary offset carrier (BOC) modulation applied to a pseudo-random noise (PRN) spreading code, similar to Galileo satellites. BOC parameters, however, have not been fixed yet.

Single-station measurements are expected to benefit from a higher signal-to-noise ratio (SNR), since the local replica is noiseless. While the primary mode will require the use of four different frequency bands (S, C, low X and high X bands) compatible with VLBI Global Observing System (VGOS), the secondary mode is expected to rely on only one or two of those four allocated bands.

In this poster, we compare the performance between the two modes in terms of delay resolution and secondary peak levels under realistic assumptions. Different BOC parameters are being evaluated to identify the most suitable configuration for the GENESIS mission.

Local-tie Experiments of Chinese VLBI Stations

Presenter: Xuan He (Shanghai Astronomical Observatory, Chinese Academy of Sciences)

Co-authors: Yidan Huang (Shanghai Astronomical Observatory, Chinese Academy of Sciences), Minghui Xu (GFZ), Bo Xia (Shanghai Astronomical Observatory, Chinese Academy of Sciences), Fengchun Shu (Shanghai Astronomical Observatory, Chinese Academy of Sciences), Cong Liu (Shanghai Astronomical Observatory, Chinese Academy of Sciences)

This report presents local-tie experiments using three co-located VLBI stations in China: Tianma and Sheshan in Shanghai, and Urumqi. The VGOS antennas were utilized in mixed-mode observations across the conventional S/X bands, followed by correlation of X-band-only data and subsequent post-correlation analysis. Phase delay analysis was performed to determine the relative coordinates of these co-located VLBI antennas. Moreover, Tianma13 and Sheshan13, forming a baseline of 6km long, joined a few VGOS 24-h sessions together. We attempted to determine the baseline vector using phase delay approach.

Implementation of VLBI simulations for Earth orbiting satellites in C5++

Presenter: Hakan Sert (Royal Observatory of Belgium)

Co-author: Özgür Karatekin (Royal Observatory of Belgium)

VLBI tracking and analysis of Earth-orbiting satellites is becoming increasingly important in geodesy and fundamental astronomy, as demonstrated by recent initiatives such as GENESIS. A central requirement for these applications is the accurate modelling of near-field effects, along with realistic treatment of station clocks and atmospheric delays.

To support these scientific goals, we have implemented in C5++ new capabilities for simulating and processing joint sessions of Earth-orbiting satellites and quasars. While some other distributions of C5++ already provide related functionality, our work offers a complementary implementation and serves as an independent check. The developments include four near-field VLBI models as well as error simulations for zenith wet delays and clock behaviour. We assess their performance by comparing the generated simulations with those from an alternative C5++ distribution, demonstrating consistent results and enabling future multi-technique geodetic applications.

LOFAR-VLBI: Insights into High-Energy Emissions from Low-Frequency Radio Observations

Presenter: Hrishikesh Shetgaonkar (University of Wuerzburg)

The X-ray emission from resolved knots in the jets of many blazars cannot be explained as a simple extension of the radio synchrotron spectrum. So far no general consensus has been reached on the relative dominant contribution of the different broadband-emission mechanisms at play. In particular, observing the low radio frequencies provides valuable constraints to test different emission models like IC/CMB, Synchrotron Self Compton(SSC) or second synchrotron peak. The long international baselines of LOFAR allow us to spatially resolve the individual X-ray emitting jet knots at 140MHz and to probe the previously inaccessible part of the low-energy electron population. In combination with shorter-wavelength radio in uGMRT (600 MHz), the VLA GHz regime and Chandra X-ray data, the LOFAR-VLBI data will help test and constrain the above-mentioned different emission models. Here, we present results from this project with a focus on connecting the low frequency radio to X-ray emissions in the kiloparsec scale knots in the jet. Furthermore, we present broadband SED modeling analysis for these knots, thereby understanding the physical properties of the underlying electron population. Our analysis highlights the potential of low-frequency, high-resolution radio observations to bridge the gap between radio and X-ray regimes in blazar jets.