IVTW IX2024

9th International VLBI Technology Workshop

MIT Haystack Observatory

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MIT HAYSTACK OBSERVATORY

Abstracts

Kazu Akiyama

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Presentation

The Black Hole Explorer Mission: Vision and Motivation

We present the motivation and vision for the Black Hole Explorer (BHEX), a next-generation space very long baseline interferometry (VLBI) mission concept. BHEX, currently under formulation for a NASA Small Explorer mission, will discover and measure the bright and narrow ''photon ring'', comprising rays of light that have orbited the black hole before escaping, hidden in the famous black hole images captured by the ground-based Event Horizon Telescope (EHT). BHEX will reveal the properties of dozens of additional supermassive black holes to address the processes that drive supermassive black hole creation and growth, and will connect supermassive black holes to their relativistic jets. The transformative science with BHEX will be enabled by its extremely high angular resolution, not achievable with the earth-bound telescopes alone, with an extension of the existing ground-based Global Millimeter VLBI Array (GMVA) and EHT to space at the observing frequencies of 80-320 GHz. The mission is enabled by recent technological breakthroughs, including the demonstration of ultra-high-speed downlink using laser communications and the establishment of high-sensitivity ground arrays such as EHT and GMVA. In the talk, we will introduce the motivation for BHEX, its science goals and associated requirements, and the pathway to launch within the next decade.

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John Barrett

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Presentation

Pushing the Mark6 to 60Gbps and beyond with DPDK

The data plane software of the Mark6 recorder has up until now relied on the packet capture library PF_RING to perform kernel-bypass of network data. However, this technique still requires the use of typical network card drivers resulting in a heavy CPU interrupt load when handling high packets rates. This is detrimental to performance. We have made an effort to redesign the data plane software around the Intel Data Plane Development Kit (DPDK) library to handle the kernel-bypass functionality, which has allowed us to make use of poll-mode network card drivers that eliminate the need for CPU interrupt handling. This new library, in conjunction with additional architectural changes to the data plane software has allowed us to demonstrate recording rates onto hard disk drives (HDDs) in excess of 60Gbps from a single network interface using simulated network data. We expect recording rates to improve with faster media.

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Walter Brisken

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Presentation

The VLBA New Digital Achitecture

The Very Long Baseline Array (VLBA) has been employing the ROACH Digital Back End (RDBE) ver 1 for well over a decade. This equipment has served the VLBA well, however it has become difficult to maintain and is limiting the growth path of the VLBA. The VLBA New Digital Architecture (VNDA) project will replace the RDBEs on the VLBA with an Ethernet-based back-end. The project exclusively uses Commercial Off-The-Shelf hardware and makes extensive use of standard interfaces and data formats. VNDA will initially consist of three module types: (1) the Producer, which generates digital Intermediate Frequencies (IFs) and multicasts these into (2) a fast Ethernet switch from which various other equipment can connect, including (3) the Consumer, which will channelize and requantize the data for recording or real-time data distribution. The modular nature of this architecture will make it practical to install additional hardware in the future.

In addition to discussing VNDA, I will describe some other ongoing VLBA technical developments, including new GNSS receivers, new frequency synthesizers, and the VLBA's path toward real-time data transfer.

Niclas Esser

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Presentation

The VLBI Mode of the Universal Effelsberg Direct Digitization (EDD) System

The Effelsberg Direct Digitization (EDD) system is a versatile and modular radio astronomy platform that integrates receivers, time distribution, digitization, and a universal backend. Supporting diverse scientific modes such as pulsar timing, high-resolution spectroscopy, and recently, standard Very Long Baseline Interferometry (VLBI) recording, the EDD system utilizes commercial off-the-shelf (COTS) hardware, including GPUs, FPGAs, NICs, and CPUs.

We have successfully deployed the EDD system at telescope stations in Thailand, Germany, South Africa, and potentially Botswana, demonstrating the system's adaptability. Initial fringe detection experiments have yielded promising results, validating our VLBI mode.

My talk will cover the technical implementation of the EDD system's VLBI mode, focusing on key subcomponents like GPU-based Digital Down Converters (DDC), VDIF packetization, and recording mechanisms. Our GPU DDC pipelines have shown robust performance, effectively downsampling data for VLBI applications. The presentation also provides an overview of the EDD system's architecture, deployment experiences, technical specifics of the VLBI subcomponents, and performance metrics, showcasing the EDD system as a cutting-edge solution for modern radio astronomy.

Pablo García-Carreño

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Presentation

Development of HTS Filters at Yebes Observatory

One of the primary challenges faced by geodetic Very Long Baseline Interferometry (VLBI) stations is the issue of Radio Frequency Interference (RFI). The growing demand for radio spectrum due to various wireless technologies has led to a reduction in the availability of RFI-free frequencies.

Various methods exist to mitigate this issue; however, if the interfering signal is sufficiently powerful, it can saturate or even damage the low-noise amplifiers. This problem is particularly pronounced in ultra-wideband receivers, such as those used in the VLBI Global Observing System (VGOS), where the whole operating frequency band may be impacted.

To address this challenge, the Yebes Observatory has proposed the use of notch filters fabricated from high-temperature superconductors (HTS). These filters offer several advantages:

- Extremely low losses, resulting in minimal degradation of receiver sensitivity.

- High selectivity, designed to eliminate only the specific band affected by interference.

- The use of HTS ensures that, at the cryostat's operating temperature, the conductor is in its superconducting state.

The Yebes Observatory has conducted several developments in this area in recent years. One significant achievement is the creation of a notch filter for the RAEGE Santa Maria station. This station's receiver was completely saturated by a space debris radar located 1.75 kilometers away. A notch filter was designed and installed to eliminate this RFI, introducing only 0.15 dB of insertion loss in the VGOS observation bands, thereby enabling the station to join the VGOS core network. Other developments include filters to mitigate interferences from Satellite Laser Ranging (SLR) stations at 9.4 GHz and a band-pass filter for the International VLBI Service (IVS) S-band legacy receiver, which provides strong rejection of radio-links at 2.18 GHz, thereby enhancing its performance.

Marcel Gouws

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Presentation

Development of VLBI Obs Mode for MeerKAT

A VLBI observation mode is under development for the MeerKAT telescope for operation in L-band and S-band. The design leverages MeerKATâ€™s beamforming functionality to coherently add voltages from its 64 individual antennas. This creates the equivalent of a large, single-dish telescope for participation in global VLBI networks as a sensitive Southern Hemisphere station. The VLBI backend is a software-defined addition to existing correlator functionality, and does not rely on new or dedicated hardware. The system converts beam voltages to the desired VLBI channels in VDIF format for local storage and e-shipping. Station calibration and other metadata are derived from MeerKATâ€™s existing array calibration pipeline and sensors, with signal timestamps referenced to the array phase center. This presentation will provide an overview of MeerKATâ€™s VLBI instrument design and report on recent milestones and progress.

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Rüdiger Haas

Presentation

VGOS Related Work at the Onsala Space Observatory

Lim Chin Chuan, Rüdiger Haas, Mugundhan Vijayaraghavan, Gary Hovey

The Onsala Space Observatory operates two VGOS stations, the Onsala Twin Telescopes (OTT). The OTT participate in the VGOS sessions of the International VLBI Service for Geodesy and Astrometry (IVS), both in 24 h and Intensive sessions. The OTT use one DBBC3 backend each and record on one FlexBuff each. Usually, for VGOS observations four frequency bands, each slightly less than 512 MHz wide, are observed with 8 channels of 32 MHz bandwidth each. Since VGOS uses two linear polarizations this amounts to a total of 64 channels, with a recording rate of 8 Gbps. In 2024 we experimented with a DBBC3 firmware version that allows observing 128 channels, thus covering 1 GHz per VGOS-band and using a recording rate of 16 Gbps. While observing, recording, and correlating the data with DiFX worked well, there are still limitations in postprocessing with the current version of HOPS/Fourfit. Various attempt were made to circumvent these restrictions and to test the 128 channel VGOS observations and these will be presented.

We also did measurements with the OTT to quantify the impact of Low Earth Orbit (LEO) satellite emissions on radio astronomy observations. Furthermore, we used signals of geostationary communication satellites to perform holography measurements on one of the OTTs. Preliminary results will be presented that appear to indicate a less than expected efficiency of the particular radio telescope. However, further studies at different frequencies and elevations on both OTT and in both linear polarizations are necessary.

Finally, we installed an invar-based measurements system on both OTT to monitor the thermal variation of the VLBI reference point. This system has been in operation since December 2023 and the first results on the system performance as well as the potential seasonal variation of the OTT reference points will be presented.

Rüdiger Haas

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Presentation

Towards VLBI with ESA 's Genesis Satellite

Rüdiger Haas, on behalf of ESA GSET WG-3 (VLBI)

The European Space Agency (ESA) plans to launch in 2028 the Genesis satellite. This mission is meant to contribute to the improvement of the International Terrestrial Reference Frame (ITRF) by combining 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 orbiting Earth. ESA has set up a Genesis Science Exploitation Team (GSET) to work on the goals of the mission. 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. They also should assist in calibration, processing and validation of Genesis data, and exchange information with the international community. Currently, WG-3 (VLBI) focusses mainly on the VLBI transmitter that is planned for Genesis. Important aspect are the compatibility with the normal operations of the International VLBI Service for Geodesy and Astrometry (IVS) and the IVS product generation. Other important aspects such as optimal scheduling, end-to-end simulations, and eventually test observations of Genesis, will be addressed at a later stage. This presentation gives an overview on the current status of the work performed in ESA GSET WG-3.

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Presentation

On the Efforts to Prepare VLBI for the Next Decade

VLBI observations to quasars are increasingly affected by additional noise from new telecommunication transmitters on ground and in space. The coordination among different users of electro-magnetic spectrum requires an active spectrum management for VLBI. Due to the adverse situation new observation bands for geodetic VLBI have been proposed and been tested partly. New technical challenges have arosen in order to mitigate undesired interference from broadband receivers. This presentation tries to give an overview of different strategies to prepare VLBI for the next decade.

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Poster

Progress of Process Automation at Tsukuba Correlator / Analysis Center

GSI operates Tsukuba Correlator/Analysis Center, and it is responsible for correlation and analysis of intensive sessions every weekend. Correlation and analysis of INT-2 sessions have already been optimized for automation process, while it is not fully ready for VGOS-INT-B/C sessions conducted by ONSA13NE, ONSA13SW and ISHIOKA. We will report on the status of program modifications for the automation of VGOS-INT-B/C in addition to an overview of our activities.

In VGOS-INT-B/C, data quality of the short baseline between ONSA13NE and ONSA13SW are 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 if all the 32 channels are applied to the process. Up until now, we have manually screened out some of the channels to make at least 80% of the total scans in a session fringe quality 5 or better, but the process was tried to be automated. We will introduce how we select channels for short baseline processing based on fringe qualities, SNRs and fringe rates and compare the results between the new automated programs and manual sorting.

Phase correction is adjusting phases among channels properly to improve fringe qualities and SNRs on accurate fringe fitting. The control file contains the setting values for fringe fitting and phase correction. In the correlation of VGOS-INT-B/C, phase correction is sometimes failed depending on initial values in the control file. We have modified our program to be able to adjust the initial values for phase correction and to improve the speed by distributed processing. We will compare the results between our program and HOPS program in version 3.25 we previously used for phase correction.

We are planning to apply the program not only to VGOS-INT-B/C but also to other sessions such as VGOS-INT-G by making it applicable to various data format and station names.

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Frederic Jaron

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Presentation

Cross-polarization Gain Calibration of VGOS Antennas

Antennas of the VLBI Global Observing System (VGOS) observe dual linear polarization. Calibration of the complex gain differences between the two polarizers of each antenna is necessary in order to form Stokes I and to maximize the signal-to-noise ratio of observables. On this poster we present results from a detailed investigation of VGOS cross-polariazation bandpasses and a search for suitable calibrator sources.

Frederic Jaron

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Presentation

A Source Structure Correction Tool for VLBI Visibility Data

In the conventional geodetic VGOS processing chain all observed objects are treated as if they were point sources. We have developed a software tool to remove the impact of source structure directly from the correlator output. Here we present the functionality of this tool and show first results from its application to observational data.

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Presentation

VGOS Phase-Cal Performance at High Frequencies

Since 2019, VGOS observations have routinely been carried out using the same frequency setup with a range from 3 to 10.7 GHz. Employing a network of European VGOS stations, we carried out experiments testing four alternative frequency setups covering the range between 3 and 14 GHz. The network consisted of antennas Onsala-East, Onsala-West, Santa Maria, Wettzell-South, and Yebes. The four new frequency ranges were 3000.4-13976.4, 4204.4-13964.4, 5004.4-13932.4, and 3000.4-13976.4 MHz. One important issue is the performance of the phase-cal signal, especially at the highest frequencies. We investigated the phase-cal signal by inspecting the raw data and by analyzing the signal extracted by the DiFX software correlator. Here we present our results concerning the quality of the phase-cal signal above 11 GHz. We conclude that phase-cal does not prevent VGOS observations at these high frequencies.

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Presentation

A Cascading Beam Pattern Simulation for Multi-level Aperture Arrays

We present a novel beam pattern simulation scheme for aperture array. In this scheme, an aperture array is consist of a set of element, with each element correpsonds to an aperture array of the underlying level. The beam pattern of given level is calculated based on the relatively distribution and beam pattern of every individual element. Since the arrays and elements are described using the same set of properties and data structures, this scheme is able to support arbitrary levels of antennas and calculate the beam pattern in a cascading way. We can demonstrate that, for a given array configuration and sky direction, our scheme can produce exactly the same beam pattern as that in OSKAR. This scheme will be further integrated into OmniUV, so as to facilitate the widefield simulation of aperture array.

Jose A. Lopez-Perez

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Presentation

Future RAEGE Station in Gran Canaria

The Red Atlántica de Estaciones Geodinámicas y Espaciales (RAEGE) project is a key infrastructure under the National Geographic Institute of Spain (IGN) and the Regional Government of Azores (GRA) aimed at enhancing geodetic observations on a global scale. This presentation will focus on the ongoing development of the RAEGE station in Gran Canaria, which is one of the four key installations strategically located across different tectonic plates.

Located in the area of Temisas, the Gran Canaria station is designed to host a suite of advanced geodetic and astronomical instruments, including a VGOS radiotelescope with a 2-14 GHz receiver, an active hydrogen maser, GNSS receivers, SLR telescope, gravimeters, sismographs and a local-tie network to link all the techniques. It will also host an optical telescope for tracking of Near-Earth Objects (NEO).

These instruments will significantly contribute to the Global Geodetic Observing System (GGOS), providing crucial data for monitoring Earthâ€™s dynamics, including tectonic plate movements, EOPâ€™s, sea level changes, and global warming indicators.

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Presentation

Recent and Planned VLBI Developments at ALMA

The ALMA Phasing Project (APP) developed, deployed, and commissioned the hardware and software necessary to bring phased array and VLBI capabilities to the Atacama Large Millimeter/submillimeter Array, the world's most sensitive millimeter telescope, starting in 2017. The addition of phased ALMA to global VLBI arrays operating at millimeter wavelengths has enabled groundbreaking new science, including the first event horizon scale imaging of supermassive black holes. Since then, two additional ALMA North America Development projects (APP2 and APP3; both recently completed) have further advanced ALMA's VLBI capabilities, including the extension of VLBI to the submillimeter and the introduction of a fully flexible spectral line VLBI mode. I will give a brief overview of these recent upgrades. I will also provide an update on plans for VLBI at ALMA in the next decade as part of the ALMA2030 vision and the ongoing Wideband Sensitivity Upgrade (WSU) project.

Lucia McCallum

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Presentation

News from Down Under Auscope VLBI Project

This contribution covers results and current statuses of the Australian IVS stations, Hb, Ke, Yg and Hobart26.

New high-speed data connections across the Australian continent have gone live, enabling major changes in operation and data transport.

A lot of work has been done regarding testing the phasecal of the VGOS stations although the performance is still less than ideal. We carry out test sessions both in VO and VAU mode, experimenting with different frequency sequences. Here the new firmware of the DBBC3 has been helpful.

We review the Australian mixed-mode technique, that is now routinely applied to many IVS legacy sessions, including non-AuScope stations.

At the start of 2024, a thorough measurement campaign was undertaken to determine gravitational deformation of the Hobart26m dish.

New local tie surveys have been performed in Hobart and Yarragadee, with results being discussed here.

Marco Midon

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Marco Midon, Stephen M. Merkowitz, Christopher Beaudoin, Munther Hassouneh, Wei-Chung Huang, Heather C. Livingston

Geodetic Reference Instrument Transponder for Small Satellites (GRITSS)

The accuracy of the Terrestrial Reference Frame is limited by systematic errors in tying the contributions from the different geodetic techniques. Local survey uncertainties are limited due to the inaccessibility of the instrument reference points. NASA is implementing a technology demonstration mission called Geodetic Reference Instrument Transponder for Small Satellites (GRITSS) that uses a small satellite as a space-based reference point for tying together collocated geodetic stations. The technology being demonstrated uses a novel idea of upconverting the Global Positioning System (GPS) signals received at the satellite and transponding them to a VLBI Global Observing System (VGOS) antenna ground station. This approach does not require the satellite to be in view of more than one VLBI station at a time, allowing the use of Low Earth Orbits and an inexpensive CubeSat. The demonstration will initially involve only the NASA VGOS stations in Maryland, Hawaii, and Texas, but may be expanded later in the mission to include other international VGOS stations. This presentation will provide an overview of the GRITSS mission and the measurement concept.

Alexander Neidhardt

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Presentation

Monitoring of RFI with Onboard Techniques from DIFx

RFI monitoring is an essential task. Besides professional hardware, like direction finder and spectrum

analyzer, every station and every correlator can use methods which come onboard with the DiFX software package. We developed a toolbox of Python, Perl, and Shell scripts using the â€mark5accessâ€ library of the DiFX software. Spectra data are extracted from real VLBI recordings of each scan. The developed Python scripts convert these data to spectrograms (waterfall plots) and skyplots even with directional information of the strongest sources on map projections.

Alexander Neidhardt

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Presentation

System monitoring of a complete VLBI site with ZABBIX 7.0

Monitoring of health states and workflows becomes increasingly important when we consider the complex, combined systems of a telescope. Fast error detection and locality identification leads to better quality of observations. Therefore, ZABBIX is a very suitable and simple way to monitor VLBI telescopes and complete observatories. The latest version of ZABBIX offers many new features and continues a long history of a very good monitoring tool.

Chris Phillips

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Presentation

GPU Upgrade for the ATCA

The ATCA is a 6-element interferometer operating between 1-105 GHz. The existing 4 GHz bandwidth digital system is currently being replaced with a hybrid FPGA/GPU digital system which will double the process bandwidth to 8 GHz and allow a much more flexible digital backend. Installation is planned for late 2024.

The core GPU processing will be released under a GPLv3 license and are â€œVLBI suitableâ€, using the same underlying algorithms as the DIFX software correlator. As the system optimised for â€œSmall-Nâ€ arrays, the code base would suit VLBI processing with minimal changes.

Chris Phillips

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Presentation

LBA Update

The Long Baseline Array (LBA) is the only Southern Hemisphere VLBI network, operated as a collaboration between CSIRO, the University of Tasmania, HartRAO, and SpaceOps New Zealand. Most experiments are conducted at frequencies between 1.4 and 22 GHz, although ATCA and Mopra can observe at 43 and 86 GHz. Experiments are correlated by CSIRO staff using the DiFX software correlator running on a supercomputer at the Pawsey Supercomputing Centre in Perth.

In this talk, I will discuss the current capabilities of the LBA, as well as current and planned developments for the individual antennas, such as "Ultra-wideband" receivers and a cryogenically cooled phased array feed for the Parkes Murriyang telescopes, and a new GPU-based digital backend for the ATCA. In the era of the SKA, the LBA will be positioned to play a major role in VLBI follow-up of discoveries and will continue to play a significant role in global VLBI science.

Helge Rottmann

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Presentation

Advances in Wide-band VLBI Technology

very wide band sampler chips are beginning to become available on the market for general, non-restricted use. Managing this technology allows to greatly extend the instantaneous bandwidth to be processed by radio-astronomical equipment. I will present in my talk recent advances at the MPIfR in the development of very wide band systems, mainly the BRAND receiver that serves the frequency range of 1.5-15.5 GHz and the DBBC4 backend that can process up to 8x28GHz of bandwidth.

Chester Ruszczyk

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Presentation

Broadbanding Broadband VLBI to Also Observe GNSS Signals

The research and development results to be presented are the fusing of the (microwave) space techniques, particularly VLBI and GNSS, at the observation level by developing a single instrument capable to simultaneously observe both VLBI and GNSS signals. To achieve this, we explore approaches that would broaden the frequency range of the next-generation VLBI Geodetic Observing Station (VGOS), which nominally spans from 2 to 14 GHz. The goal is to further extend the low-end of that frequency range from 2 GHz down to 1 GHz. The extension enables the possibility of observing GNSS (i.e., GPS, Glonass, Galileo, and other constellations) signals with the same VGOS antenna that is used to observe extragalactic radio sources. This could be accomplished with the addition of a fifth observing band to the existing four-band VGOS configuration along with subsystems downstream capable of supporting the frequency range specific to GNSS satellite observing. By adding a fifth band dedicated to GNSS signals, we can effectively integrate two geodetic techniques into a single instrument eliminating the need of local ties, the differential vectors between station reference points at co-located sites necessary to effectively tie the otherwise disconnected reference frames of the individual space geodetic techniques, such as VLBI and GNSS, into a unified TRF. We will present preliminary results from this ongoing study. We will also outline a roadmap for the advancement of the proposed VLBI-GNSS concept into an enhanced geodetic observing system that includes a VGOS network operating interferometrically as well as correlation and data post-processing strategies. This study could have a significant impact on the accuracy goals of the Global Geodetic Observing System (GGOS) community and the TRF realization on which science, military, and society critically depend.

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Chester Ruszczyk

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Presentation

Haystack Technology Roadmap

This presentation will cover three main areas of research and development at MIT Haystack Observatory. The first is the science DMZ that connects the new 100Gbps network to a set of storage nodes with NAS and Mark6 systems. Data can be transferred to the storage nodes, and then pulled safely to the correlator for correlation. The second area is the fifth generation Digital Back End (DBEv5) that will be a drop in replacement for the R2DBE and beyond. The last area will introduce the Haystack Edge Router Buffer that will act as an aggregator of high-speed data streams and pace the output streams to legacy or new storage nodes.

Frank Schinzel

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Presentation

Radio Spectrum Access Challenges and Possible Solutions

Driven by technological advances and economics, the utilization of the radio spectrum is seeing a major revolution, with increased bandwidth needs for mobile communication, the Internet of Things, and especially moving into an era of large satellite constellations providing direct communication to handheld devices. This creates challenges for radio astronomy to conduct observations in especially the mostly unprotected parts of the cm-wavelength radio spectrum, which is something we have grown accustomed to in past decades. If not addressed, this will have significant consequences for e.g. traditional S/X as well as wider bandwidth VGOS geodetic observations. I will highlight current and future challenges that will likely have a significant impact on how we conduct radio astronomical observations in the future. I will then provide an overview of possible technical and regulatory solutions that would allow us to tackle these challenges in order to be able to continue to conduct radio astronomical observations for decades to come, despite an ever more crowded radio spectrum. These include regulatory steps like establishing coordination zones around radio telescopes or coordination agreements with operators, as well as technical frameworks such as the recent implementation of an operational data sharing system and direct engagement with the U.S. National Spectrum Strategy, as well as contributing to work at the International Telecommunication Union.

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Marcelo Segura

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Presentation

CART Current Status Update and Future Collaborations

The "Félix Aguilar " Astronomical Observatory (OAFA) from the National University of San Juan (UNSJ), Argentina and the National Astronomical Observatories (NAOC) of the Chinese Academy of Sciences (CAS) have maintained a close collaboration for more than 30 years in the field of "Astrometry." Based on the strong relationship between China and Argentina, both UNSJ and CAS have extended their agreement to other areas of astronomy and related sciences. In 2015, an agreement was signed to install a 40-meter radio telescope in San Juan called CART, China Argentina Radio Telescope, which will be the largest single dish in South America.

The working frequency will range from 1 GHz to 45 GHz. While it will primarily focus on establishing and maintaining the Celestial Reference Frames (ICRF) and Terrestrial Reference Frames (ITRF), it will also support research in cosmology, astrophysics, geodesy, geophysics, and space navigation.

This work details the tasks already completed, including site search, RFI monitoring, and seismological and geological studies, given that CART is located in a high seismic area. It also updates the current status of the main reflector assembly and supporting structure, expected to be completed by the end of this year.

CART is intended to start operating in the S/X bands for geodetic studies, with the goal of becoming part of the VLBI network once fully operational. Plans include installing Ka band receivers to enhance measurement accuracy from centimeter to millimeter levels. Additionally, we are developing a new digital backend. The goal is to create a software defined radio Spectrometer using AMD Xilinx RFSoC4x2 boards and open-source CASPER software, facilitating global collaboration and helping the CASPER community.

This work will present the latest updates on CART's status and outline the future activities planned for this year.

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Samuel Thé

Presentation

Observations and Modeling of RFI from Mega-constellations of Satellites on Radio Telescopes

The growing number of satellites in emerging mega-constellations marks a major step forward in global connectivity, aiming to close communication gaps even in the most isolated regions. Many private companies are now competing to deploy their own satellite networks in Low-Earth Orbit (LEO), enabling customers to connect via antennas and even directly through their cellphones. However, while these systems enhance connectivity, they also pose significant challenges for astronomy, geospace and geodesy.

Telescopes, which observe faint astronomical objects, require extremely sensitive instruments that can easily be affected by radio frequency interference. Both intentional and unintentional satellite emissions can disrupt the quality of the data collected. Coordinating satellite orbits with telescope observations can help reduce interference by avoiding satellite transits through the main observation beam. However, interactions between the telescope's sidelobes and the increasing number of satellites remain inevitable.

Using the 18.3-meter Westford telescope at MIT's Haystack Observatory, we conduct in-band and out-of-band observations of the Starlink constellation. From this survey, we can refine our model of the aggregated power received by the antenna and assess the potential impact that thousands of future LEO satellites may have on radio astronomy.

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Presentation

Estimation of the instantaneous Earth rotation with geodetic Very Long Baseline Interferometry

The Very Long Baseline Interferometry (VLBI) measures two standard observables: group delay and fringe frequency (delay rate). While the group delay is widely used for estimation of a large set of geodetic and astrometric parameters, the fringe frequency is almost ignored due to some technical limitations. However, the fringe frequency could be used as a direct measure of the instantaneous Earth rotation vector which is not accessible with the group delay. Here we show that nowadays all three components of the instantaneous Earth rotation vector are estimated on daily basis with a formal error of 1 prad/s or 10âˆ’8 in relative units, or even better if a large international VLBI network is at work. Implementation of the fringe frequency to the routine analysis of the geodetic VLBI results will result in additional improvement of the Earth rotation velocity. A direct comparison of the angular rotation velocity with the length of day (LOD) parameter is now possible to develop more precise transformation between the two observable values. Additionally, the delay rate may be used for monitoring of the variability of the Earth flattening.

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The Global VLBI Alliance and the IVTW

1. Brief history of the GVWG and its accomplishments
2. Introduce the motivation for the GVA and the proposed structure http://gvlbi.evlbi.org/
3. Capture input from the crowd on GVA process and topics that the GVA should consider addressing Discuss the proposal that the GVA Technical forum will be formed a dedicated session at IVTW, where discussion and approval of technical standards and reference documents can be initiated and/or proposed.

There is already a tentative list of topics where the GVAT could (should?!) coordinate and be the "standardizing body" of:

- Data format specifications: VDIF/CoDIF and the upcoming "timebomb", RDEF support?
- Maintainer of VEX format (and possibly others, such as IDI-FITS, Mark4/HOPS4, ...)
- Maintainer of station codes
- Requirements capture and interaction with the CASA / RADPS group
- Requirements capture for correlators (e.g., to provide standards against which compliance testing can be done)
- Baseband voltage distribution policy guidelines (both physical media and e-transfer)
- E-transfer protocols and best practice
- Interaction w/ next-gen arrays (SKA, ngVLA)

IVTW IX2024

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Presentation

The RADIOBLOCKS project contribution to the VLBI of the future

RADIOPBLOCKS is a JIVE-coordinated 10 Mâ‚¬ EC-funded project to work on imrpoving all elements of the (VLBI) signal chain, from developing improved cryogenic LNAs and SiS mixers, cryoPAFs, a new generation of Digital Backends w/ RFI mitigation built-in, (extremely) high bandwidth connections between the frontend(s) and novel processing blocks (correlation, beamforming) powered by accelerators such as FPGAs and TensorCore GPUs, and, at the end of the chain, a scalable post processing framework build on e.g. Python Dask, to handle the voluminous data as well as e.g. Bayesian-based calibration algorithms built on improved simulations. In this talk I would like to illustrate how this project implements an integrated approach producing compsosable building blocks with the aim of increasing the observed bandwidth and the number of simultaneously observed bands, and accessible field-of-view throughout the whole signal chain.

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Presentation

Results of the 4 year EC Funded ESCAPE Project at JIVE for the EVN and VLBI Communities

At the previous IVTW (Sydney, November 2019), almost five years ago to the day, I presented the plans and goals of the 15 Mâ‚¬/31 partner European Commission (EC) funded ESCAPE project which had just started; the European Science Cluster for Astronomy and Particle physics ESFRI research infrastructures, of which JIVE, the Joint Institute for VLBI as a European Research Infrastructure Consortium (ERIC) was a part of. JIV ERIC was awarded 12 FTE of manpower to be spent over the four-year duration of the project, which ended 31 January 2023 (more than a year and a half ago). The ESCAPE project revolved around creating the building blocks of the European Open Science Cloud - an EC-promoted infrastructure framework implementing FAIR and open science, designed to support large- to extreme scale science data processing for research infrastructures in the domain of Astronomy and Particle physics.

In this presentation I would like to highlight important progress made towards user-facing improvements of VLBI data handling, catalogueing, calibration and, finally, providing a mechanism for reproducible science: JIVE staff worked on improvements in the CASA software for VLBI-specific tools and calibration (the fringe fit task, for example!), Jupyter kernels, radio-astronomical data support in the Virtual Observatory and a "science platform for VLBI data reduction".

In the technical workshops so far these topics are rarely considered - thanks to EC funding these could be started to be addressed in anger.

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Presentation

Four years of accumulated very practical improvements in jive5ab

The absence of a new release of the jive5ab software over the last four years does not imply nothing has happened. In fact, nothing could be further from the truth. Several different improvements in quite diverse areas were implemented, tested, and included in a pre-release. In this presentation I would like to introduce and highlight those, in the hope they may be useful in dealing with (very) large data rates- and volumes. It is now simpler to configure and build the package, or build different configurations, specifically on any POSIX operating system, including Ubuntu, Debian, RedHat, MacOS (Intel, M1/AMD64), OpenBSD and FreeBSD. The optional inclusion of an e-transfer client should make parallel data transfers from station(s) into a central facility easier and more reliable to set up and operate.

There are now different ways to configure the software to (dynamically) sort the recorded VLBI data into multiple recordings. The ability to let the recorder split the data before writing it to disk can have a dramatic impact on operations: e.g. eliminating the need for vmux'ing saves a lot of time and disk space and the correlator software will run more efficient.

Finally, one of the largest bottlenecks for high(er) speed recording was lifted: it is now trivial to enable multiple CPU cores to capture data from the network. Previously, jive5ab was severely limited by only using a single core for that task - by old design.

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Presentation

An Efficient Serial Multiview Approach to Mitigation

Atmospheric Spatial-Structure Errors for VLBI Astrometry

Weimin Zheng

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Presentation

Chineses VLBI Network - New 40m Dish

Weimin Zheng and Zhong Chen

The Chinese VLBI network (CVN) currently includes five major telescope stations: Shanghai Tianma, Shanghai Sheshan, Beijing Miyun, Urumqi Nanshan, and Yunnan Kunming, along with the VLBI Data Center at the Shanghai Astronomical Observatory. Starting in 2023, two new 40-meter radio telescopes have begun construction in Shigatse, Tibet, and the Changbai Mountains in Jilin Province.

Located on the outskirts of Shigatse City and within the Changbai Mountain Nature Reserve, these telescopes benefit from excellent radio observation conditions and low atmospheric water vapor. They are designed with multiple highly sensitive cryogenic receivers covering a spectrum from 700 MHz to 50 GHz and support simultaneous S/X dual-frequency observations, with potential upgrades to 86 GHz.

Both telescopes are fully steerable, high-precision alt-azimuth radio telescopes. The antenna system features high-precision full-aperture panels, with individual panel accuracy better than 80 microns and overall main reflector accuracy within 0.3 mm. The pointing accuracy reaches 5 arcseconds, facilitating detailed astronomical research.

The Shigatse telescope is located at an altitude of over 4,000 meters, while winter temperatures at the Changbai Mountain site can drop to -41Â°C. To withstand these extreme conditions, the telescopes are equipped with advanced thermal insulation, ensuring stable operation.

These telescopes are expected to begin S/X band observations after March next year and the networkâ€™s longest baseline will extend from 3,200 to 3,800 kilometers.

The addition of these telescopes will enhance CVNâ€™s regional observation capabilities, advancing research in supermassive black holes, rapid transient phenomena in compact objects, the dynamics of the Milky Way, and high-precision Earth-space reference frameworks. They will also support space VLBI and deep space exploration missions.