EVGA 2019

Las Palmas de Gran Canaria

March 9, 2019

EVGA 2019 Information

Scientific Organising Committee (SOC)

- Sabine Bachmann (BKG, Germany)
- Johannes Böhm (Vienna University of Technology, Austria)
- Susana Garcia-Espada (Instituto Geográfico Nacional, Spain)
- Rüdiger Haas (Chair) (Chalmers University of Technology, Sweden)
- Laura La Porta (Max Planck Institute for Radioastronomy, Germany)
- Evgeny Nosov (Institute of Applied Astronomy of the Russian Academy of Sciences, Russia)
- Nataliya Zubko (Finnish Geospatial Research Institute, Finland)

Local Organising Committee (LOC)

- Víctor Araña Pulido
- Esther Azcue Infanzón
- Rubén Bolaño González
- David Cordobés Gallo
- Itahiza Domínguez Cerdeña
- Pablo Dorta Naranjo
- Abel García Castellano
- Susana García-Espada (Chair)
- Yaiza Gómez Espada
- Víctor Puente García

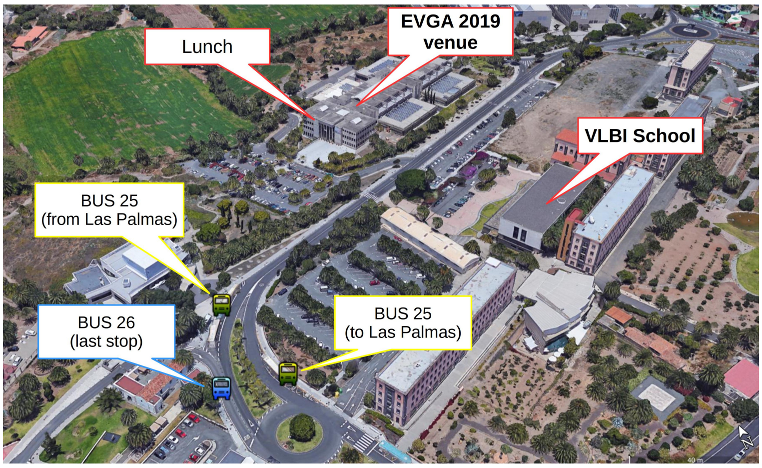
Schedule of events

Date	Time	Event	Location
14 Mar	08:45–19:00	VLBI School day 1	Telecom. Eng. School
15 Mar	09:00–20:00	VLBI School day 2	Telecom. Eng. School
16 Mar	09:00–18:00	VLBI School day 3	Telecom. Eng. School
16 Mar	20:00–23:00	VLBI School dinner	Los Chorros restaurant
17 Mar	19:00–21:00	Icebreaker, cocktail and registration	AC Gran Canaria Hotel
18 Mar	09:00–19:30	EVGA day 1	Architecture Faculty
19 Mar	09:00–19:30	EVGA day 2	Architecture Faculty
19 Mar	20:00–23:00	EVGA dinner	La Marinera Restaurant
20 Mar	08:30–09:30	VTC face-to-face Meeting	Architecture Faculty
20 Mar	09:30–12:00	18th IVS Analysis Workshop	Architecture Faculty
20 Mar	12:00–17:00	Lunch and Excursion	Puerto de las Nieves - Agaete
20 Mar	18:00–20:30	Southern VLBI Astrometry Group Meeting	Architecture Faculty
21 Mar	09:00–18:00	IVS Directing Board Meeting	AC Gran Canaria Hotel

Registration will be open during the icebreaker reception on March 17 from 19:00 to 21:00 in AC Gran Canaria Hotel. It will be possible to register on March 18 from 08:30 at the Architecture Faculty.

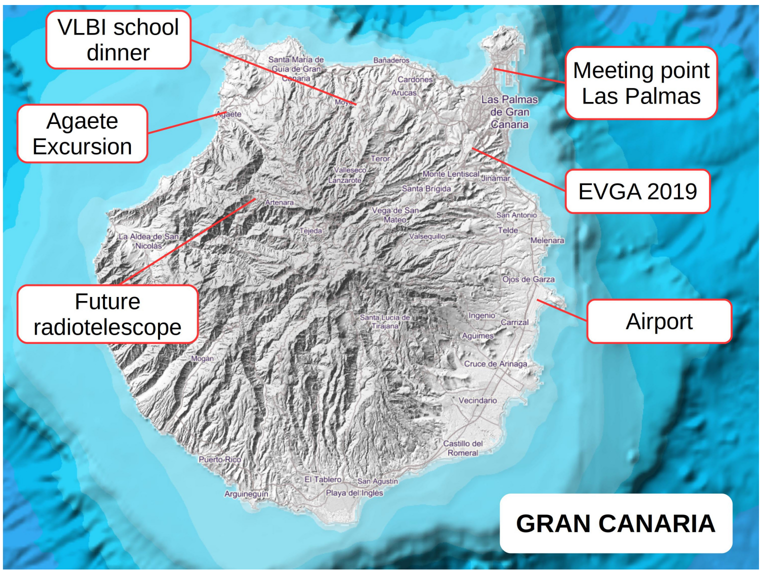
Useful information

- The VLBI school will be held at the basement of the lecture building of the Telecommunications Engineering School.
- The EVGA icebreaker will take place at AC Gran Canaria Hotel (3 Eduardo Benot street)
- The EVGA 2019 meeting will be at the Architecture Faculty.
- A bus will pick up participants from VLBI school and EVGA meeting at two meeting points at 91 Albareda street (in front of El Puerto Market) and at 3 Eduardo Benot street (in front of AC Gran Canaria Hotel). There will be a person from the LOC with a identified banner at both points. Buses will leave 45 minutes before the beginning of the program. In case you miss the bus or go from another part of the city we recommend you to take bus number 25 or 26 (https://www.guaguas.com).
- Lunch breaks in both events will take place at the Architecture Faculty



EVGA 2019 meeting and VLBI School venue

EVGA 2019 icebreaker and organised bus transfer meeting points



Points of interest

Contributions requirements

The requirements for contributions are:

- **Oral contributions**: maximum 12 minutes presentation. Plus 3 minutes for questions from the audience.

  A PC with Windows 10 Operating System will be available for the meeting. All presenters must upload their presentations in this PC in advance to their session. Personal laptops cannot be connected.
  Recommended presentations formats are PDF or PPT.
  Available software:

  - Adobe Reader Pro 2015
  - Microsoft PowerPoint Plus 2016

  Beamer resolution is 1024x768 (4:3) The format for oral presentations should be 4:3

- **Poster contributions**: maximum size A0. Portrait.

  Poster session will take place just in front of the meeting room. Each poster has a code assigned (please check the book of abstracts to check your code). Each frame will be identified with the correspondent code.
  Poster should be mounted on Monday March 18 before 17:00. Each presenter is responsible to mount his/her poster.
  Material to fix the posters will be available.
  Posters shall be dismounted on Tuesday March 19 before 18:00. Please note that posters which are not dismounted in time will be removed permanently when the meeting ends.
  Each presenter is responsible to mount and dismount his/her poster withing the indicated time frames.

Program

Sunday, March 17

	Icebreaker reception	Register, get your badge, meet your friends, have fun!	19:00-21:00

Monday, March 18

	Rafael Robaina Romero (Rector of Las Palmas University); José Antonio López-Fernández (Astronomy, Geophysics and Space Application Subdirector in IGN); Rüdiger Haas (EVGA Chair)	Opening ceremony of the EVGA 2019	09:00-09:30

	Session 1.1	09:30-10:30, chair: Gino Tuccari	
O101	José Antonio López-Fernández	The current status of RAEGE	09:30-09:45
O102	Rüdiger Haas	Status of the Onsala twin telescopes	09:45-10:00
O103	Leif Morten Tangen	Status for the establishment of a new fundamental site in Ny-Ålesund	10:00-10:15
O104	Jinling Li	The Sheshan 13-m radio telescope	10:15-10:30

	coffee break	10:30-11:00

	Session 1.2	11:00-12:00 chair: Evgeny Nosov	
O105	Michael Lösler	Measuring focal-length variations of VGOS-telescopes using unmanned aerial systems	11:00-11:15

O106	Pablo de Vicente	Instrumentation developed for VGOS at IGN Yebes Observatory	11:15-11:30
O107	Gino Tuccari	DBBC3 towards the BRAND EVN receiver	11:30-11:45
O108	Walter Alef	BRAND - A wideband receiver for astronomy and geodesy	11:45-12:00

"stretch your legs" break	12:00-12:15

	Session 1.3	12:15-13:15 chair: Pablo de Vicente	
O109	Evgeny Nosov	The stability of delay in VLBI digital backends	12:15-12:30
O110	Jakob Gruber	A simulator to generate VLBI baseband data in Matlab	12:30-12:45
O111	Roberto Ricci	Optical fiber links used in VLBI networks and remote clock comparisons: the LIFT/MetGesp project	12:45-13:00
O112	Mamoru Sekido	Italy-Japan broadband VLBI experiment for optical clock comparison	13:00-13:15

lunch break	13:15-14:15

	Session 1.4	14:15-15:15 chair: Walter Alef	
O113	Xin Zheng	Researching and application of VLBI differential phase delay in lunar exploration	14:15-14:30
O114	Walter Brisken	Status and development plans of the VLBA	14:30-14:45
O115	Aard Keimpema	Recent technical developments at JIVE	14:45-15:00
O116	Tetsuro Kondo	Comparison of results between CVN and K5 software correlators	15:00-15:15

"stretch your legs" break	15:15-15:30

	Session 2.1	15:30-16:30 chair: Aletha de Witt	
O201	Laura La Porta	The Bonn Correlation Center and VGOS	15:30-15:45

O202	Walter Alef	The EU-VGOS project	15:45-16:00
O203	Maria Eugenia Gomez	Implementation of a geodetic path at the JIVE correlator	16:00-16:15
O204	Takahiro Wakasugi	Activity report on the Asia-Oceania VLBI Group (AOV)	16:15-16:30

		coffee break	16:30-17:00

	Session 2.2	17:00-18:00 chair: Laura La Porta	
O205	Aletha de Witt	The Southern VLBI Operations Centre	17:00-17:15
O206	Matthias Schartner	Results with the scheduling software VieSched++	17:15-17:30
O207	Christian Plötz	INT9 - dUT1 determination between the geodetic observatories AGGO and Wettzell	17:30-17:45
O208	Torben Schüler	LCONT18 - The local continuous measurement campaign at Wettzell of 2018	17:45-18:00

	Poster session	**Look at all the nice posters!**	18:00-19:30

Tuesday March 19

	Session 2.3	09:00-9:45 chair: Torben Schüler	
O209	Jing Sun	Preliminary work on promoting radar astronomical study	09:00-09:15
O210	Oleg Titov	Observations of radio sources near the Sun	09:15-09:30
O211	Alexander Neidhardt	Autonomous observations of VLBI radio telescopes	09:30-09:45

		"stretch your legs" break	09:45-10:00

	Session 3.1	10:00-10:45 chair: Arthur Niell	
O301	Dan MacMillan	Analysis of EOP and scale from the simultaneous CONT17 networks	10:00-10:15

O302	Johannes Böhm	CONT17 from a VieVS perspective	10:15-10:30
O303	Maria Davis	The IERS Rapid Service / Prediction Center UT1-UTC combined solution: Present and future Contributions	10:30-10:45

		coffee break	10:45-11:15

	Session 3.2	11:15-12:00 chair: Dan MacMillan	
O304	Anastasiia Girdiuk	Analysis of regular and specific intensive sessions	11:15-11:30
O305	Armin Corbin	Scheduling of twin telescopes and the impact on troposphere and UT1 estimation	11:30-11:45
O306	Arthur Niell	VLBI tie between the KOKEE12M and KOKEE20M antennas	11:45-12:00

		"stretch your legs" break	12:00-12:15

	Session 3.3	12:15-13:15 chair: Johannes Böhm	
O307	Axel Nothnagel	Gravitational deformation investigations and their impact on global telescope coordinates: The Onsala 20 m radio telescope case	12:15-12:30
O308	John Gipson	Gravitational deformation of VLBI antennas and the impact on the TRF	12:30-12:45
O309	Matthias Glomsda	Impact of non-tidal loading in VLBI analysis	12:45-13:00
O310	Kyriakos Balidakis	How does geophysical loading affect Earth rotation? Simulations and reality	13:00-13:15

		lunch break	13:15-14:15

	Session 3.4	14:15-15:15 chair: Axel Nothnagel	
O311	Víctor Puente	Comparison of troposphere delays from GNSS and VLBI in R1 and R4 sessions	14:15-14:30

O312	Periklis-Konstantinos Diamantidis	Comparison of tropospheric delay estimation using VLBI CONT14 data and WVR for the Onsala station	14:30-14:45
O313	Tobias Nilsson	An assessment of the tropospheric parameters estimated from the CONT17 campaign	14:45-15:00
O314	Frédéric Jaron	An analytical VLBI delay formula for Earth satellites	15:00-15:15
		"stretch your legs" break	15:15-15:30
	Session 3.5	15:30-16:15 chair: John Gipson	
O315	Grzegorz Klopotek	Geodetic VLBI observations of lunar radio sources – Current status and recommendations for future research	15:30-15:45
O316	Benedikt Soja	Ionospheric calibration for K-band celestial reference frames	15:45-16:00
O317	Karine Le Bail	Time stability of the K-band catalog sources	16:00-16:15
		coffe break	16:15-16:45
	Session 3.6	16:45-17:45 chair: Karine Le Bail	
O318	Patrick Charlot	ICRF3, the new realization of the International Celestial Reference Frame	16:45-17:00
O319	James M. Anderson	Toward imaging 3000+ ICRF sources from closure quantities from 1979–present	17:00-17:15
O320	Lucas Hunt	VLBA Imaging of ICRF 3 sources	17:15-17:30
O321	Arnaud Collioud	The Bordeaux VLBI Image Database (BVID)	17:30-17:45
		"stretch your legs" break	17:45-18:00
	Session 3.7	18:00-19:00 chair: Patrick Charlot	
O322	Ming Hui Xu	Structure effects in broadband VGOS data	18:00-18:15

O323	Sergei Bolotin	The source structure effect in broadband observations	18:15-18:30
O324	Simin Salarpour	Source structure effects in the next-generation of VLBI observations	18:30-18:45
O325	Leonid Petrov	Remaining problems in geodesy / astrometry VLBI and approaches to their solutions	18:45-19:00

	Rüdiger Haas	Closing remarks	19:00-19:15

EVGA dinner	19:15-23:59

Posters

	Session 1	
P101	David Cordobés	Status of the future RAEGE radiotelescope at Gran Canaria
P102	Andrea Prudencio	First steps in gravitational deformation modeling of the VLBI Yebes radio telescopes
P103	Gunnar Elgered	The Onsala Tide Gauge Station: Experiences from the first three years of operation
P104	Hiroshi Munekane	VLBI-GNSS collocation survey at the Ishioka VLBI station
P105	Nataliya Zubko	Progress and current status on VGOS project at the Metsähovi Geodetic Research Station
P106	Alexander Neidhardt	Centralized monitoring of VLBI antennas for seamless auxiliary data
P107	Alexander Neidhardt	Remote access to the NASA Field System via Web browser
P108	Weimin Zheng	Space low-frequency radio observatory and the Earth-moon VLBI experiment
P109	Ahmad Jaradat	An artificial radio signal for VLBI satellite tracking

	Session 2	
P201	Xuan He	Mixed-mode VLBI observations with Chinese stations in APSG40
P202	Christopher Dieck	Intensive sessions with the Mauna Kea VLBA Station
P203	Dirk Behrend	Roll-out status of the VGOS network
P204	Hayo Hase	Argentinean-German Geodetic Observatory (AGGO)
P205	Karen Baver	The effect of source flux catalog latency on IVS-INT01 scheduling
P206	Marisa Nickola	HartRAO local tie measurements: VLBI and ground survey
P207	Matthias Schartner	Impact of different observing rates on geodetic results
P208	Matthias Schartner	In-depth analysis of schedules optimized for certain VLBI experiments using VieSched++
P209	Michael Lösler	A modified approach for process-integrated reference point determination
P210	Fengchun Shu	High sensitivity astrometry with the AOV
P211	Jakob Gruber	Vienna correlation activities
P212	Ed Himwich	2018 IVS Network Performance
P213	Dhanya G. Nair	GMVA image database at 86 GHz now online
P214	Juan Zhang	The progress of CVN Software correlator and its applications

	Session 3	
P301	Andreas Hellerschmied	Vienna VLBI Analysis Center (VIE)
P302	Christopher S. Jacobs	The X/Ka-band 2019a celestial frame:
P303	Esther Azcue	VLBI analyses at the National Geographic Institute of Spain

P304	Hana Krásná	Earth orientation parameters estimated from K-band VLBA measurements
P305	Helene Wolf	AUA047: Students at TU Wien organize their own VLBI session
P306	Aletha de Witt	The K-band (24 GHz) Celestial Reference Frame
P307	Markus Mikschi	Comparison of integrated LOD values from GNSS and AAM to dUT1 from VLBI
P308	Niko Kareinen	Simulated combined effect of extended source structure and baseline geometry to geodetic parameters estimated with VLBI
P309	Sabine Bachmann	Combination of IVS intensive sessions ' approach, benefit, and operability
P310	Susanne Lunz	Radio source position offsets among various radio frames and Gaia
P311	Suxia Gong	Comparison of ionospheric delays between VLBI and GNSS
P312	Tuomas Savolainen	NT-VGOS - Mitigating the source structure errors in the VGOS era
P313	Simona Di Tomaso	Inter-comparison of GNSS and VLBI tropospheric parameters at co-located sites in Italy
P314	Víctor Puente	Comparison of VLBI-based series of celestial pole offsets
P315	Ming Hui Xu	Comparison between time series of closure analysis and source positions since 1980
P316	Svetlana Mironova	Diurnal and sub-diurnal EOP variations from VLBI global solution

Contents

Abstracts

Session 1: Technology

Oral presentations

The current status of RAEGE

18 Mar
09:30
O101

José Antonio López-Fernández, Pablo de Vicente

Observatorio de Yebes, IGN

We present the current status of RAEGE, introducing the recent activity at the different stations that compose the RAEGE network. Further detailed information will be addressed by other detailed presentations from IGN staff.

Status of the Onsala twin telescopes

18 Mar
09:45
O102

Rüdiger Haas, Simon Casey, John Conway, Gunnar Elgered, Roger Hammargren, Leif Helldner, Karl-Åke Johansson, Ulf Kylenfall, Mikael Lerner, Lars Pettersson, Lars Wennerbäck

Chalmers University of Technology

We present the status of the Onsala twin telescopes (OTT), two identical VGOS-type telescopes, named ONSA13NE and ONSA13SW in IVS terminology. They are equipped with 13.2 m diameter main reflectors and ring-focus subreflectors. They are located at a distance of 70 m. The telescopes were built during 2015-2017 and inaugurated in connection to the EVGA working meeting in May 2017. There are two slightly different receiver systems on the telescopes. ONSA13NE has a receiver with a QRFH-feed covering $3-18$ GHz, while ONSA13SW is equipped with an Eleven-feed covering $2.2-14$ GHz. Both feeds receive dual-linear polarisation. The two receiver front-ends are cryogenically cooled and are connected to one phase and cable delay measurement system (CDMS) each. The two CDMS were purchased from the MIT/Haystack observatory. The H-maser for the time and frequency distribution is located in the maser room at about 1 km cable distance from the telescopes. Each system has a digital backend of type DBBC3 with 8 Core3H boards, which are located in the backend room within about 15 m distance from the maser room. The signal chain for both the CDMS systems and the received signals from the telescopes to the backend room uses optical fibres that are insulated against short-term temperature variations. The two DBBC3s are connected to a FlexBuff recorder that currently has a capacity of 360 TB and a 10 Gbps connection to the Swedish fibre backbone SUNET. Both telescope towers, as well as the elevation and azimuth cabins, are equipped with numerous temperature and humidity sensors to monitor the environment. We started to participate in VGOS test experiments with the two telescopes in the autumn of 2017. These were primarily performed with the current

'Haystack VGOS setup', i.e. 8 frequency bands of 32 MHz bandwidth each and both polarisations in four RF-bands, e.g. 64 frequency bands in total per system. First fringes in some of the frequency bands were found with ONSA13NE for session VT7268 on 25-26 September 2017. A couple of days later, first fringes in some RF-bands for ONSA13SW were found in session MC7278 on 5-6 October 2017. Based on the experience gained the systems were improved and for VT7317 on 13-14 November 2017, fringes in all bands and all polarisations were found for ONSA13NE. A comparable performance was achieved for ONSA13SW in VT8039 observed 8-9 February 2018. Since then several further VGOS test experiments have been observed, primarily with ONSA13NE, but recently also involving ONSA13SW. Since the DBBC3 backends can be configured flexibly in various modes, we also started to carry out test observations together with the Kashima 34 m telescope using the 'Japanese VGOS setup', i.e. observing and recording 1 GHz windows. The first session, OK8051, was performed on 20 February 2018 using one 1 GHz wide band in two polarisations and fringes were found.

During the coming months we will continue the fine-tuning of the VGOS systems to improve the performance. We want to participate in all possible VGOS sessions using all possible VGOS configurations. Our goal for 2019 is to gradually improve the system performance as well as reliability in order to become fully operational with both systems.

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18 Mar
10:00
O103

Status for the establishment of a new fundamental site in Ny-Ålesund

Leif Morten Tangen, Laila Løvhøiden, Per Erik Opseth

Norwegian Mapping Authority (NMA)

In June 2018 the new twin VGOS telescopes at the Ny-Ålesund geodetic observatory was officially inaugurated. But due to some hardware challenges the telescopes are still not in operation. Building the core site is slowly progressing, but still the ability to utilise VGOS data is restricted. In this presentation we give a thorough status on the development of the Ny-Ålesund core site, and elaborate on the challenges connected with getting VGOS into regular operation.

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18 Mar
10:15
O104

The Sheshan 13-m radio telescope

Jinling Li

Shanghai Astronomical Observatory

The Sheshan 13-m radio telescope is designed for astrometry and geodesy VLBI studies. The technical specifications are introduced and the newly experimental results are displayed.

Measuring focal-length variations of VGOS-telescopes using unmanned aerial systems

18 Mar
11:00
O105

Michael Lösler[1], Cornelia Eschelbach[1], Rüdiger Haas[2], Ansgar Greiwe[3]

[1]Frankfurt University of Applied Sciences; [2]Chalmers University of Technology; [3]University of Applied Sciences Bochum

VLBI radio telescopes are large technical facilities whose structures are affected by several deformation patterns. In particular, temperature- and gravity-dependent deformations bias the estimated global telescope position and, therefore, if uncorrected, deteriorate the geodetic results that can be derived from the geodetic VLBI analysis. The rigidity of a telescope structure under varying acting forces is restricted by its structural properties. Large conventional radio telescopes are more affected by deformation effects than the new compact-designed VGOS antennas. The design document for the next generation VLBI system (today called VGOS) states $< 300\,\mu$m as requirement for the path length stability. A traceable metrological system that can be used to check this stability level must be at least three times better than the requirements. Close range photogrammetric methods fulfil these accuracy requirements but usually need a crane during the survey of a telescope. To avoid the latter, an unmanned aerial system was used for the first time to evaluate the possible deformation of the main reflector surface of the north-eastern of the Onsala twin telescopes (ONSA13NE). The focal-length of the ring-focus paraboloid was derived in several elevation angles to study the gravitational deformation effects on the main reflector of this VGOS antenna.

Instrumentation developed for VGOS at IGN Yebes Observatory

18 Mar
11:15
O106

José Antonio López-Pérez, Félix Tercero-Martínez, José Manuel Serna-Puente, Beatriz Vaquero-Jiménez, María Patino-Esteban, Pablo García-Carreño, Juan Daniel Gallego-Puyol, Inmaculada Malo-Gómez, Isaac López-Fernández, Carmen Díez-González, Ricardo Amils-Samalot, Javier González-García, Abel García-Castellano, Carlos Albo-Castaño, Javier López-Ramasco, Laura Barbas-Calvo, Marta Bautista-Durán, Oscar García-Pérez, Francisco J. Beltrán-Martínez, Alejandro Baldominos-Delgado, Gabriel Gómez-Molina, Pablo de Vicente, José Antonio López-Fernández

Yebes Observatory (IGN)

IGN Yebes Observatory keeps on developing the required instrumentation for its RAEGE network of VGOS radio telescopes, together with broadband receivers for other institutes like NMA and FGI which are finishing their VGOS antennas. These developments include new VGOS receivers, low noise amplifiers and hybrid circuits, feed optimization, phasecal and noisecal units, cryogenic cooling control units, RFI monitorization and telescope control.

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18 Mar
11:30
O107

DBBC3 towards the BRAND EVN receiver

Gino Tuccari[1], Walter Alef[1], Sven Dornbusch[1], Rüdiger Haas[2], Karl-Åke Johansson[2], Laura La Porta[1], Helge Rottmann[1], Alan Roy[1], Jan Wagner[1], Michael Wunderlich[1]

[1]INAF - Istituto di Radioastronomia and Max-Planck-Institut für Radioastronomie; [2]Onsala Space Observatory, Chalmers University of Technology

The DBBC3 is a flexible VLBI backend and environment which can be adapted to the observational needs with an appropriate firmware implementing the required fast hardware functions, as well as a software capable to drive and harmonize these functionalities to the requirements of the observation and the very fundamental part of testing the complete system in the laboratory and the field for corrections and improvements. Any additional observing mode requires coordination in all the development phases from the definition of its architecture up to the final validation with real observations. The team working on the DBBC3 development has formed a de facto structure, operating with a constructive synergy in order to enhance existing modes and to introduce any new desired mode. Three different firmware types for observing have been implemented which will be briefly summarized: Direct Sampling Conversion (DSC), arbitrary selection of bands (OCT), Digital Down Conversion (DDC). These modes cover all the requirements of astronomical, VGOS and legacy geodetic VLBI of the present, but also of the near future. At the same time the DBBC3 is an important platform for additional new modes to be implemented for the BRAND receiver. The talk will explain the use of the DBBC3 for the receiver development, pointing out which element in the current DBBC3 structure will be part of the BRAND receiver in order to simplify its introduction into the existing VLBI environment at telescopes with a DBBC3 backend.

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18 Mar
11:45
O108

BRAND - A wideband receiver for astronomy and geodesy

Walter Alef[1], Gino Tuccari[1,2], Sven Dornbusch[1], Michael Wunderlich[1], Jonas Flygare[3], Juan D. Gallego[4], Jose A. López-Pérez[4], Felix Tercero[4], Gijs Schoonderbeek[5], Jonathan Hargreaves[5], Ronald de Wild[5], Vladislavs Bezrukovs[6]

[1]Max-Planck-Institut für Radioastronomie, Bonn, Germany; [2]INAF - Istituto di Radioastronomia, Noto, Italy ; [3]Onsala Space Observatory, Chalmers University of Technology, Sweden; [4]Instituto Geográfico Nacional, Madrid, Spain; [5]ASTRON, Netherlands Institute for Radio Astronomy, Dwingeloo, The Netherlands; [6]International Radio Astronomy Centre, University of Applied Sciences, Ventspils, Latvia

The BRAND wideband receiver is being developed with support from the European Unionś Horizon 2020 research and innovation programme as a part of RadioNet. Its continuous frequency range from 1.5 GHz to 15 GHz makes it a scientifically extremely interesting development for radio astronomy. But it also covers the VGOS frequencies and even extends them to lower and higher frequencies. Used for geodesy, this could yield results superior to the ones which will be achieved with the traditional four VGOS bands. It will also allow to retrofit traditional prime focus antennas to become compatible with VGOS antennas. If we succeed in modeling an adequate feed for secondary focus, BRAND receivers could become the next generation VGOS receiver. The first half of the 3 1/2-year-term of the project is over. We will give an overview of the achievements so far and of what has been planned for the near future.

The stability of delay in VLBI digital backends

18 Mar
12:30
O109

Evgeny Nosov

IAA RAS

To achieve picoseconds level of delay precision in VGOS observations one has to control the variations of instrumental delay from scan to scan with about 1 picosecond level or better. As the instability in electronic devices is strongly related to temperature variations, meeting this requirement implies minimizing both temperature variations and temperature sensitivity of equipment in signal chain and the reference clock distribution system. The unavoidable variations of instrumental delay should be measured to correct their influence on the correlation results. My talk focuses on the stability of VLBI digital backends using as example the Multifunctional Digital BackEnd (MDBE) developed in IAA RAS. I shall discuss the main sources of its delay instability and provide an estimation of the respective temperature coefficients. Also the talk includes a review of the engineering solutions made for precision measurement of delay variations in different parts of MDBE.

A simulator to generate VLBI baseband data in Matlab

18 Mar
12:45
O110

Jakob Gruber[1], Johannes Böhm[1], Axel Nothnagel[2], Matthias Schartner[1]

[1]TU Wien; [2]Universität Bonn

VLBI radio telescopes represent a sophisticated interconnection of electronic devices. The final product of each observation by a radio telescope is the baseband dataset. In this presentation, we show a software tool as part of VieVS which generates simulated VLBI baseband data. The simulator is implemented in Matlab and contains a telescope model which is based on the parametrization of real antenna key characteristics. Moreover, source characteristics such as the signal structure of satellites and spatial velocities of source and receiver are taken into account in the model creation. Advanced digital signal processing (DSP) algorithms of Matlab are applied to model the antenna system. We will present the various model components of the simulator and discuss the potential of applications of such a tool. Furthermore, we will show first results of simulation experiments, such as the simulation of VLBI observations to artificial satellites and mixed mode observations.

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18 Mar
14:30
O111

Optical fiber links used in VLBI networks and remote clock comparisons: the LIFT/MetGesp project

Roberto Ricci[1], Monia Negusini[1], Federico Perini[1], Davide Calonico[2], Cecilia Clivati[2], Filippo Levi[2], Claudio Bortolotti[1], Mauro Roma[1], Giuseppe Maccaferri[1], Matteo Stagni[1], Roberto Ambrosini[1], Giuseppe Bianco[3], Mario Siciliani de Cumis[3], Luigi Santamaria[3]

[1]INAF-IRA; [2]INRiM; [3]ASI

The synchronization between atomic clocks plays an important part in both radio astronomical and geodetic Very Long Baseline Interferometry, as the clocks are responsible for providing time and frequency standards at radio stations. The availability of highly stable optical fiber links from a few radio observatories and their national metrological institutes has recently allowed the streaming of frequencies from optical clocks based on the Sr/Yb lattice technology (even two order of magnitudes more stable than H-maser clocks). We will present the current status of the Italian Link for Frequency and Time (LIFT) and the ongoing efforts to realize a geodetic experiment utilizing the radio stations in Medicina and Matera connected in common clock via the optical fiber link. We will then show the results from the latest VLBI clock timing experiments also making use of the LIFT link to compare atomic clocks of the three italian radio VLBI antennas (Mc, Sr and Nt) using the rms noise in the interferometric phase. VLBI clock timing proves more effective than Global Navigation Satellite System and less expensive than Two-Way Satellite Frequency and Time Transfer in synchronizing remote clocks.

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18 Mar
14:45
O112

Italy-Japan broadband VLBI experiment for optical clock comparison

Mamoru Sekido[1], Kazuhiro Takefuji[1], Hideki Ujihara[1], Hidekazu Hachisu[2], Nils Nemitz[2], Marco Pizzocaro[3], Cecilia Clivati[3], Davide Calonico[3], Tetsuya Ido[2], Masanori Tsutsumi[1], Eiji Kawai[1], Kunitaka Namba[2], Yoshihiro Okamoto[2], Rumi Takahashi[2], Junichi Komuro[2], Ryuichi Ichikawa[2], Hiroshi Ishijima[2], Filippo Bregolin[3], Filippo Levi[3], Alberto Mura[3], Elena Cantoni[3], Giancarlo Cerretto[3], Federico Perini[4], Giuseppe Maccaferri[4], Monia Negusini[4], Roberto Ricci[4]

[1]NICT, Kashima, JPN; [2]NICT, Koganei, JPN; [3]INRIM, Torino, ITA; [4]INAF IRA Bologna, ITA

We have conducted VLBI experiments for optical clock comparison on Italy-Japan intercontinental baseline. Reference signal generated by Yb optical lattice clock at INRIM in Torino is provided to Medicina by optical fiber link. Sr lattice clock has been operated at NICT headquarters. These two optical lattice clock signals were compared by a series of VLBI experiments via VLBI network observations with transportable 2.4 m diameter broadband VLBI stations at Medicina radio astronomy observatory of INAF in Italy and NICT headquarters at Koganei Japan, and 34 m radio telescope at Kashima. Hydrogen masers are used for reference signal of VLBI observations, and behavior of these masers as fly-wheel to keeping clocks are monitored with optical clocks at each end, which were operated intermittently.

The VLBI-link of frequency transfer will be compared with GPS-link as alternative technique. VLBI experiments were conducted in the same way with standard geodetic VLBI experiment, where multiple radio sources in different part of the sky are observed alternatively.

Originally developed broadband NINJA feeds, which is capable to observe $3 - 14$ GHz frequency range, are mounted at two 2.4 m diameter VLBI antennas and Kashima 34 m antenna. Single linear receiver is equipped at these small VLBI stations and dual linear polarization at 34 m VLBI station. Observation was made at 6.0 GHz, 8.5 GHz, 10.4 GHz, and 13.3 GHz radio frequency with 1 GHz bandwidth each. High speed RF-direct sampling technique, which digitize the radio signal at 16 GHz sampling, enables stable group delay measurement in broad frequency range. About 60 TB of observation data at Medicina was transferred to Kashima in 2 days for each session via highspeed research networks (GARR, GEANT, INTERNET2, TransPAC, JGN) and by using jive5ab. Correlation processing was made with GICO3 software correlator. Signal over the broad frequency range is synthesized by wideband bandwidth synthesis. We will present results of experiments and current state of clock comparison.

Researching and application of VLBI differential phase delay in lunar exploration

18 Mar
15:00
O113

Xin Zheng, Qinghui Liu, Yajun Wu, Junwu Ma, Tao Deng

Shanghai Astronomical Observatory, Chinese Academy of Sciences

Same-beam VLBI have been successfully used between the lander and rover named 'yutu' in Chang'e-3.
During Earth-Moon transfer orbit of Chang'e-4 relay satellite mission in May, 2018, the Chinese VLBI network also observed Relay satellite and a microsatellite by same-beam VLBI. Here we will report the research and application of the same-beam VLBI differential phase delay in this mission.

Status and development plans of the VLBA

18 Mar
12:15
O114

Walter Brisken

National Radio Astronomy Observatory (NRAO)

After several years of uncertain future the VLBA has rejoined NRAO and is operating with solid near-term prospects thanks to new partnership with the US Naval Observatory. This transition led to a significant increase in the VLBA's contribution to astrometric and geodetic VLBI. In this talk I will focus on the current technical capabilities of the VLBA and ongoing development projects. I will conclude with a brief description of the next generation VLA project, which looks to supercede the VLA and VLBA with a single new, considerably more capable instrument.

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18 Mar
13:00
O115

Recent technical developments at JIVE

Aard Keimpema, Mark Kettenis, Arpad Szomoru

Joint Institute for VLBI ERIC

In this talk I will report on recent technical developments at JIVE, the correlation centre of the European VLBI network (EVN). As part of the EU funded JUMPING JIVE project, JIVE is developing the capability to use the EVN correlator at JIVE to process geodetic and absolute astrometric experiments. As part of this effort we are adapting SFXC, the JIVE software correlator, and related post-correlations tools to produce data products suitable for geodetic use. Recently a significant upgrade of the EVN correlation cluster at JIVE was taken into operations, adding an additional 840 CPU cores to the cluster. At the same time some of the older machines in the cluster were retired, the correlation cluster now contains 1244 CPU cores in total. The upgrade was motivated by the EVN's upcoming increase in maximum data-rate for real-time eVLBI observations from 2 Gbps to 4 Gbps. As well as an increase in the size of the eEVN array. Recently the Sardinia Radio Telescope and a subset of the eMERLIN array started participating in both eVLBI and disk-based EVN observations.

Real-time eVLBI continues to form an integral element of the EVN, accounting for about a quarter of all EVN hours and providing unique rapid-response capabilities to transient events as well as the opportunity for higher-cadence observations compared to the standard EVN sessions that fall three times per year. In addition to correlation there is also the possibility to record the raw voltage data locally at JIVE in parallel with the correlation. This feature is useful for experiments which require multiple correlator passes.

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18 Mar
14:15
O116

Comparison of results between CVN and K5 software correlators

Tetsuro Kondo[1,2], Weimin Zheng[1], Lei Liu[1], Juan Zhang[1], Fengchun Shu[1], Li Tong[1], Fengxian Tong[1]

[1]Shanghai Astronomical Observatory (SHAO); [2]National Institute of Information and Communications Technology (NICT)

To handle the geodetic VLBI observations data, CVN software correlator developed by SHAO has been upgraded to a general correlator from the lunar mission specified correlator. And we have conducted the comparison between CVN and K5 software correlators. Observed values, such as delay, delay rate, and fringe amplitude, obtained by CVN (China VLBI Network) software correlator and fringe fitting software "fourfit" have been compared with those obtained by K5 software correlator which has been developed by NICT (National Institute of Information and Communications Technology, Japan) VLBI group. Regarding the correction of X-station clock offset in the K5 system, a post correction method and a correction during correlation processing have also been compared. As a result, it has been confirmed that CVN and K5 correlator results show a good coincidence. As for the X-station clock offset correction in the K5 system, correction during a correlation processing shows the same results with the post correction method. Thus it is also confirmed that the correction during a correlation processing works as expected. K5 and CVN comparison results show a good coincidence with each other on fine (multi-band) delay, delay rate, and fringe amplitude. The average of the standard deviation of the differences between X band fine delays is

7.6 psec. As for the delay rate, the average of differences at X band is 0.00±0.09 ps/s. As for the fringe amplitude at X band, the average of ratio (CVN/K5) is 0.98±0.11. We hope CVN will be used in the IVS routine observations.

Poster presentations

Status of the future RAEGE radiotelescope at Gran Canaria

Poster P101

David Cordobés[1], Víctor Araña[2], José Antonio López-Pérez[1], Abel García[1], Itahiza Domínguez-Cerdeña[1], Jaime Ticay[2], Pablo Dorta[2], Iván Pérez[2], José Antonio López-Fernández[1], Jesus Gómez González[1]

[1]Instituto Geográfico Nacional, Spain; [2]Instituto para el Desarrollo Tecnolgico y la Innovacin en Comunicaciones (IDeTIC), Universidad de Las Palmas de Gran Canaria (ULPGC), Spain;

The IGN in cooperation with the Azores Regional Government, is developing since 2012 the RAEGE network, which consists of four VGOS antennas for space geodetic observation. Currently, two of the four antennas are operative at Santa María (Azores) and Yebes (Guadalajara, Spain). The third antenna will be operational by 2021 at Gran Canaria (Spain) with the cooperation of the University of Las Palmas de Gran Canaria (IDETIC-ULPGC). We present here the progress made on the site selection, construction and a snapshot of the future projects for the VLBI antenna of Gran Canaria.
The site was selected after a longterm noise measurement all along the island. The chosen final site is close to Artenara village at an altitude of 1100m and presents the lowest measured electromagnetic noise. At the present time, we have finished the bureaucratic procedures with local administrations and almost finished the architecture projects for the different buildings of the site.
The Artenara station will have a fully compliant VGOS radiotelescope, equipped with a broadband receiver in the 2-14GHz band. In addition to these, the facilities at Artenara will also include an absolute gravimeter, a GNSS receiver and a seismic station, with the goal of turning Artenara RAEGE site into a Geodetic Fundamental Station.

First steps in gravitational deformation modeling of the VLBI Yebes radio telescopes

Poster P102

Andrea Prudencio[1], Esther Azcue[2], Javier López-Ramasco[3], Susana García-Espada[4], Yaiza Gómez-Espada[2], Víctor Puente[2], Marcelino Valdés[2]

[1]Complutense University of Madrid; [2]National Geographic Institute of Spain; [3]Yebes Observatory - National Geographic Institute of Spain; [4]RAEGE Santa Maria - National Geographic Institute of Spain

Geodetic VLBI is one of the most accurate geodetic techniques for the study of the size and shape of the earth, the rotation and time variations. This accuracy is achieved taking into account all the error sources involved in the process. The effect of gravity in VLBI antennas is one of these errors that should be taken into account in the analysis of VLBI data. This effect can reach several millimeters and it has to be determined specifically for each radio telescope. In this poster, the first steps in the gravitational deformation modeling of the VLBI antennas of Yebes are presented. A preliminary simulation of the measurements and its processing in Matlab and the future works and campaigns are shown.

Poster P103

The Onsala Tide Gauge Station: Experiences from the first three years of operation

Gunnar Elgered, Jonas Wahlbom, Lars Wennerbäck, Lars Pettersson, Rüdiger Haas

Chalmers University of Technology

The location of the Onsala geodetic VLBI telescopes close to the coast line motivates continuous and accurate sea level observations. A tide gauge station was developed and constructed in house, with advise from the Swedish Meteorological and Hydrological Institute (SMHI). The station was inaugurated on the 17th of September 2015 and has since then been an official site in SMHI's national monitoring network of the sea level. The official tide gauge station includes several independent senors: one radar and three pneumatic sensors (also referred to as bubblers). The radar and two bubblers are mounted in a well and one bubbler outside the well. Additional sensors such as one laser sensor and three radar sensors have been used during different time periods in order to further assess the quality of the acquired sea level data. In this presentation we compare the four official sensors and the laser sensor. The latter was installed in April 2016. In fact the expected accuracy (one standard deviation) for all of these sensors is approximately 3 mm, estimated from the data-sheet specifications. Results from the first three years of operations are used to assess and estimate the actual accuracies by means of comparisons between the sensors. We observe typical biases over time scales of months of up to 10 mm. Biases are caused by uncertainties of the reference level of the sensor, the salinity of the water for the bubblers, multipath effects for the radar, and nonlinearities with temperature for the laser. The observed monthly standard deviation between the sensors vary between 2 mm and 6 mm, which is roughly consistent with the data sheet specifications.

Poster P104

VLBI-GNSS collocation survey at the Ishioka VLBI station

Hiroshi Munekane

Geospatial Information Authority of Japan

We conducted a two-week collocation survey campaign in November 2018 to determine a local tie vector between the Ishioka VLBI station and the IGS station ISHI. First, we determined the position of ISHI w. r. t. four surrounding reference pillars by angle/distance measurements. Next, we determined the position of the VLBI antenna reference point w. r. t. reference pillars by two different methods. The first is the "outside method" where the position of VLBI antenna reference point is determined by angle/distance observations of mirrors on the antenna from the reference pillars. The other is the "inside method" where the position of the VLBI antenna reference point is determined by directly observing mirrors installed inside the AZ cabin from the fixed point inside the cabin, whose position is determined by angle/distance measurements from the reference pillars. In this talk, we will report a local tie vector determined by these two different methods and discuss pros and cons of each method.

Progress and current status on VGOS project at the Metsähovi Geodetic Research Station

Poster P105

Nataliya Zubko, Jyri Näränen, Guifre Molera, Niko Kareinen, Joona Eskelinen, Markku Poutanen

Finnish Geospatial Research Institute

The new VGOS radio telescope has been installed during summer 2018 at Metsähovi Geodetic Research Station, Finland. The telescope is functioning, although the work on telescope finalization and its testing by the manufacturer is in progress and expected to be completed by summer. The work on control of telescope and communicating with Field system is underway. This involves an interface software communicating between the antenna control unit and the Field System. Integration of the signal chain components is moving forward. The broadband receiver with a quad-ridge feed horn (QRFH) operating at frequency range of $2.4 - 14.1$ GHz and filtering and pre-amplifier modules have been manufactured by IGN-Yebes technology development center. They are expected to be delivered to Metsähovi during the spring 2019. The DBBC3 and Flexbuff recording system has been installed and partly tested. The integration of the signal chain components has been planned for 2019. The testing observations of the complete VGOS telescope system are expected by the end of 2019.

Centralized monitoring of VLBI antennas for seamless auxiliary data

Poster P106

Alexander Neidhardt, Arpad Szomoru

[1]Technische Universität München, Forschungseinrichtung Satellitengeodäsie

Twelve institutes from 8 different countries have teamed up in the JUMPING JIVE project, currently financed by the Horizon 2020 Framework Program of the EU for the next 4 years. The project is led by JIVE, the Joint Institute for VLBI ERIC, located in Dwingeloo (the Netherlands). The Technical University of Munich at the Geodetic Observatory Wettzell participates to this project integrating monitoring systems for global VLBI interfaces. Existing techniques were analyzed and compared. A test setup was implemented and installed at the Wettzell observatory. The poster describes the current status of the monitoring task with a focus on seamless auxiliary data.

Remote access to the NASA Field System via web browser

Poster P107

Alexander Neidhardt

Technische Universität München, Forschungseinrichtung Satellitengeodäsie

Remote control offers advantages for operation of VLBI radio telescopes. Night shifts and weekend shifts can be operated from remote. Engineers can support student operators or can fix failure situations from home. Operation centers can monitor important health states. Using the remote control software 'e-RemoteCtrl' for the NASA Field System, remote control and attendance have been possible for years. During the past years, 'e-RemoteCtrl' was extended with a rudimentary, integrated web server. Therefore, operators can access the Field System parameters via web browser. 110 parameters are accessible and can be extended with individual station-specific values.

Poster P108

Space low-frequency radio observatory and the Earth-moon VLBI experiment

Weimin Zheng[1,2], Tao An[1,2], Juan Zhang[1,2]

[1]Shanghai Astronomical Observatory, Chinese Academy of Sciences; [2]Key Laboratory of Radio Astronomy, Chinese Academy of Sciences

The earth-based Chinese VLBI NetworkCVNwill plan to extend to the space in the future and there are several proposals. One proposal is the Space Low-Frequency Radio Observatory, which is proposed to image the fine structure of compact celestial objects such as black hole, pulsar and so on. It offers astronomers unique opportunities to make revolutionary discoveries in exoplanets, pulsars, gravitational wave electromagnetic counterparts, and to probe the evolutionary history of the Universe. The unprecedented high resolution enables the accurate astrometry, allowing for supplying precise localization of pulsars, FRBs, GRBs at mas level. The mission plans to launch two 30 meter-diameter radio telescopes into an earth elliptical orbit, and works together with the earth-based VLBI network, Square Kilometre Array (SKA) and Five-hundred-meter Aperture Spherical radio Telescope (FAST) to get very high resolution and very high sensitivity. ROSE is operated at decimeter and long centimeter.

In the subsequent Chinas Lunar Exploration Project, there will be an Earth-moon VLBI experiment, using the antenna of the lunar orbit Tracking and Data Relay Satellite (TDRS) to construct the first Earth moon space VLBI experimental system. We hope using the earth-moon VLBI system to verify the key space VLBI technology. Because the Earth-moon VLBI baseline is over 300 km, the experiments of astrometry, astrophysics and the deep-space tracking will be carried. After this, a 10 m level radio telescope is planned to be constructed on the moon surface in the future by the astronaut.

Poster P109

An artificial radio signal for VLBI satellite tracking

Ahmad Jaradat, Frédéric Jaron, Axel Nothnagel

University of Bonn

VLBI observations of satellites orbiting the Earth bear the potential of improving the frame-ties between terrestrial and celestial reference frames. A dedicated satellite mission, however, is currently not in orbit yet nor is there any satellite emitting a radio signal which is optimal for the observation with VLBI. Here we review the technical feasibility of the generation of a broad-band noise signal, its amplification, and emission. We find that a satellite could be equipped with the necessary instrumentation with relatively low power consumption. This could make it an interesting option, e.g., for GNSS satellites, thus enabling co-location in space.

Session 2: Observations

Oral presentations

The Bonn Correlation Center and VGOS

18 Mar
15:30
O201

Laura La Porta[1], Walter Alef[2], Simons Bernhart[1], Arno Müskens[3], Helge Rottmann[2], Torben Schüler[4], Jan Wagner[2]

[1]Reichert GmbH/BKG; [2]MPIfR; [3]IGG-Uni Bonn [4]BKG

The MPIfR/BKG correlator in Bonn has a long experience in processing IVS sessions, and it has been preparing for handling broad band experiments for years. We would like to give an estimate of our current capabilities for a sustainable VGOS duty cycle.

The EU-VGOS project

18 Mar
15:45
O202

Walter Alef[1], James M. Anderson[2], Simone Bernhart[3], Pablo de Vicente[4], Javi González[4], Rüdiger Haas[5], Laura La Porta[3], Ivan Marti-Vidal[4], Arno Müskens[6], Axel Nothnagel[6], Apurva Phogat[7], Christian Plötz[7], Helge Rottmann[1], Torben Schüler[7], Des Small[8], Jan Wagner[1]

[1]MPIfR; [2]TU-Berlin; [3]Reichert GmbH/BKG; [4]Observatorio de Yebes; [5]Chalmers University of Technology; [6]IGG-Uni Bonn; [7]BKG; [8]JIVE

In Spring 2018, upon initiative of Walter Alef, the Bonn correlation center started a collaboration with the three European stations of Wettzell, Onsala and Yebes, equipped with both S/X- and broad band systems, to perform VGOS-like test sessions. The aim is to verify and develop further the processing chain for VGOS experiments end-to-end, from the scheduling to the analysis of the derived observables. We will present the current status of the project.

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18 Mar
16:00
O203

Implementation of a geodetic path at the JIVE correlator

Maria Eugenia Gomez[1], Mark Kettenis[2], Patrick Charlot[3], Robert Campbell[2], Aard Keimpema[2]

[1]Laboratoire d'Astrophysique de Bordeaux; [2]Joint Institute for VLBI-ERIC; [3]Laboratoire d'Astrophysique de Bordeaux

This presentation reports on the progress towards the implementation of a complete geodetic path for the JIVE correlator. It is conducted as part of the JUMPING JIVE project funded by the Horizon 2020 Framework Programme of the EU. JUMPING JIVE is dedicated to enhance the JIVE infrastructure in various ways for the benefit of the European VLBI Network (EVN). This includes implementation of new capabilities, among which is the possibility to correlate geodetic-type experiments and export them in a standard fashion so that they can be further processed by the usual geodetic software packages. The implementation of this new capability requires (i) to make the EVN software correlator at JIVE (SFXC) able to handle complex geodetic-like schedules with sub-netting, and (ii) to incorporate total quantities and measured phase-cal values in the data provided to the users. To facilitate post-processing, it was also decided to convert the correlator output to the standard geodetic Mark4 format. All such developments are now complete. To test the implementation, we are reprocessing IVS session R1872 and will compare the output from the JIVE correlator with that obtained at the DIFX correlator in Bonn, where the session was originally processed. The result of this comparison will be reported in the presentation. After validation, future work will focus on the processing of a K band EVN experiment dedicated to measure the positions of non-geodetic EVN telescopes.

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18 Mar
16:15
O204

Activity report on the Asia-Oceania VLBI Group (AOV)

Takahiro Wakasugi

Geospatial Information Authority of Japan

The Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) was established in 2014 as a subgroup of the International VLBI Service for Geodesy and Astrometry (IVS) in order to foster regional collaboration of VLBI. The AOV has been coordinating regular VLBI observing sessions since 2015. The total number of sessions amounts to 30 at the end of 2018 and 19 stations in five countries have participated in these sessions. The Geospatial Information Authority of Japan (GSI) has actively involved in the AOV as not only an observing station but also a scheduler and correlator. This talk will summarize activities of the AOV since its launch. Observing status and results will also be included.

The Southern VLBI Operations Centre

18 Mar
17:00
O205

Aletha de Witt[1], Karine Le Bail[2], Christopher S. Jacobs[3], David Gordon[2], Matthias Schartner[4], Jakob Gruber[4], Fengchun Shu[5], Marisa Nickola[1], Jamie McCallum[6], Stuart Weston[7], Shinji Horiuchi[8]

[1]SARAO/HartRAO Krugersdorp, South Africa; [2]NVI, NASA GSFC, Greenbelt MD; [3]Jet Propulsion Laboratory, California Institute of Technology/NASA, Pasadena CA; [4]Technische Universität Wien, Austria; [5]SHAO, Chinese Academy of Science, China; [6]University of Tasmania, Hobart, Tasmania; [7]IRASR, AUT University New Zealand; [8]C.S.I.R.O/CDSCC, Australia

Astrometric catalogs of compact extra-galactic radio sources are generally weaker in the south in both density and precision. The current S/X band Celestial Reference Frame (CRF) has deficiencies by factors of 2-3 in the south. In order to improve the S/X CRF in the south we discuss the progress towards a Southern VLBI Operations Centre (SVOC). We introduce the contributing institutions and present the goals of the SVOC, programmes to be supported, describe functions to be performed and discuss planned upgrades. We also provide details of our efforts, to date, to improve both the density and precision of the southern CRF.

Results with the scheduling software VieSched++

18 Mar
17:15
O206

Matthias Schartner, Johannes Böhm

TU Wien, Advanced Geodesy, Department of Geodesy and Geoinformation, Wien, Austria

The Department of Geodesy and Geoinformation at Technische Universität Wien has recently developed a new scheduling tool in C++ called VieSched++ as part of the Vienna VLBI and Satellite Software (VieVS). VieSched++ features an elaborate backward fill-in mode for optimizing the number of observations and runs multiple versions of the same schedule in a fast batch mode using different optimization criteria and parameters. Large scale Monte-Carlo simulations with VieVS are then used for selecting the best schedule for the purpose of the session within this sample. In particular, the schedules can be optimized for the given network, source list, observing mode and scientific goal. VieSched++ already successfully used for scheduling T2, INT3, EUR&D, AUA and AUM sessions. We present those schedules and show how they were optimized by simulating millions of VLBI experiments. Scheduling multiple versions of a single experiment and selecting one of these schedules by analyzing simulations lead to a significant improvement in the quality of the result.

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18 Mar
17:30
O207

INT9 - dUT1 determination between the geodetic observatories AGGO and Wettzell

Christian Plötz[1], Torben Schüler[1], Hayo Hase[2], Claudio Brunini[2], Federico Salguero[3], José Vera[3], Gerhard Kronschnabl[2], Walter Schwarz[1], Alexander Neidhardt[4], Martin Brandl[4], Apurva Phogat[1], Johannes Böhm[5], Matthias Schartner[5], Laura La Porta[6], Simone Bernhart[6]

[1]Geodetic Observatory Wettzell (BKG); [2]Argentinian German Geodetic Observatory (BKG); [3]Argentinian German Geodetic Observatory (Conicet); [4]Geodetic Observatory Wettzell (TU Munich); [5]Technical University Vienna (TU Vienna); [6]Bonn Correlator (Reichert GmbH/BKG)

The AGGO radio telescope, located at La Plata in Argentina, comprises together with the radio telescopes in Wettzell, Germany a baseline configuration spanning a longitude difference of 71^o. Therefore, mid of 2018, tests were initiated to prove the usability for dUT1 determination between the legacy S/X VLBI systems at AGGO and Wettzell. The 6 m AGGO radio telescope was either with the 20 m radio telescope Wettzell (Wz) or with the 13.2 m Wettzell North ' TWIN1 (Wn) in almost weekly VLBI tests for UT1 determination, named INT9, scheduled.
The scheduling of INT9 was done with sked and the time duration was set to be 2 hours each. The sessions were conducted mostly on Thursday just before the INT1 Intensive session takes place. The recording mode needed to be evaluated step by step to increase gradually from a standard 256 MBit/s recording mode to 1 Gbit/s. The latter mode yields a higher amount of scans in a given time period. The goal is to exploit the highest dUT1 determination accuracy between AGGO and Wettzell as possible.
We will report our experiences with the VLBI operation at both observatories and compare first results between official UT1 measurements and the INT9 derived values as well as a potential future outlook of this INT9 VLBI application.

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18 Mar
17:45
O208

LCONT18 - The local continuous measurement campaign at Wettzell of 2018

Torben Schüler[1], Christian Plötz[1], Gerhard Kronschnabl[1], Alexander Neidhardt[2], Martin Brandl[2], Apurva Phogat[1], Laura La Porta[3], Simone Bernhart[3]

[1]Geodetic Observatory Wettzell (BKG); [2]Geodetic Observatory Wettzell (TU Munich); [3]Bonn Correlator (Reichert GmbH/BKG)

The Wettzell radiotelescope triple is a local network of VLBI telescopes comprising two VGOS-capable systems with an antenna aperture of 13.2 m and one traditional system with a diameter of 20 m. Each of these telescopes has its individual receiving system at the moment: Whilst Wz (Wettzell - the 20 m telescope) features a legacy S/X-receiver, Wn ("Wettzell North" - TWIN1) can be equipped with either a tri-band receiver (S/X/Ka) or a broadband feed (not used in this campaign), and Ws ("Wettzell South" - TWIN2) is equipped with a broadband receiver ("Elevenfeed").
LCONT18 was a local intensive measurement campaign between Dec, 3rd and Dec, 14th 2018. For the first time, the complete network observed both synchronously and continuously for a duration of two weeks (twice 5 working days in sequence). It is named in analogy to the well-known international CONT-campaigns organized by the IVS. Data were collected in a standard 256 MBit/s recording mode with a duration of up to 24 hours from Monday till Friday. The individual baselines WzWn as well as WnWs had

been tested before minimizing the risk of failure. LCONT18 is the most exhaustive local campaign planned so far at Wettzell. This is important, because the individual baselines observed up to now are not sufficient to assess all essential/substantial questions related to the relative radiotelescope positioning over local baselines. In summary, the purpose of this measurement campaign is as follows:

1. We want to investigate the day-to-day repeatability of the local telescope coordinates (local baselines) in detail. The period at the beginning of December 2018 is a suitable time slot for this, because the local terrestrial survey was conducted right in advance. Local GPS positioning at Wettzell is running since 2014 in fully automatic mode yielding sub-millimeter repeatability between (weekly) solutions. The accuracy potential of VLBI will be compared to that of GNSS.

2. The best compromise between observation duration and baseline accuracy will be investigated having full data sets of up to 24 hours each day.

3. Observing with three telescopes allows us assessing possible loop closure errors. Such errors can stem from residual source structure uncertainties, but more likely from remaining clock and other system-related errors. Hence, LCONT18 will provide a better insight into the systems compared to all local activities carried out so far. We will report about our operational experiences gained during this campaign, and will portray first results for the network adjustment.

Preliminary work on promoting radar astronomical study

19 Mar
09:00
O209

Jing Sun[1], Jinsong Ping[1], Songtao Han[2]

[1]National Astronomical Observatory; [2]Beijing Aerospace Control Center

Radar astronomy observations provide information on surface characteristics, orbits, rotations, and polar ices for a wide variety of solar system objects. Based on Chinese VLBI network (CVN), we present the current radar astronomy observations to the Moon, and near-Earth asteroids (NEAs). The spectra of the reflected radio signals were obtained. And the ratio of the powers of the reflected signals with left- and right-hand circular polarizations were determined. The observations of the Doppler shift of the reflected signal frequency were obtained, which allowed the orbital parameters of the asteroid to be improved. The future radar astronomy developments, taking into consideration the possible international joint observations, will be also introduced.

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19 Mar
09:15
O210

Observations of radio sources near the Sun

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Geodetic Very Long Baseline Interferometry (VLBI) data are capable of measuring the light deflection caused by the gravitational field of the Sun and large planets with high accuracy. The parameter γ of the parametrized Post-Newtonian (PPN) formalism estimated using observations of reference radio sources near the Sun should be equal to unity in the general relativity. We have run several VLBI experiments tracking reference radio sources from 1 to 3 degrees from the Sun. The best formal accuracy of the parameter γ achieved in the single-session mode is less than 0.01 percent, or better than the formal accuracy obtained with a global solution included all available observations at arbitrary elongation from the Sun. We also present the resulting electron density model of the solar corona. The strong coronal signal contained in the observations allowed for a determination of the electron density with unpreceded precision. It was for the first time possible to estimate both power-law parameters (hypothetical electron density at the Sun's surface and the radial falloff parameter) at the same time. We are planning more experiments starting from 2020 using better observing conditions near the minimum of the Solar activity cycle.

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19 Mar
09:30
O211

Autonomous observations of VLBI radio telescopes

Alexander Neidhardt[1], Christian Plötz[2]

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Current techniques in software and hardware allow it, to increase the automation of systems. An autonomous, state-driven processing of VLBI schedules from autonomous fetching and preparation of schedules, the operation of observations and the finalization and transfer of the data is possible. Industrial monitoring suites allow a centralized overview, so that a reduced number of operators can quickly get the status of several instruments. Historic values allow it to analyze failure situations and their causes. To increase the automation and to even support autonomous observations, updates and tests are ongoing at the Wettzell observatory. The talk describes the current status.

Poster presentations

Mixed-mode VLBI observations with Chinese stations in APSG40

Poster P201

Xuan He[1], Fengchun Shu[1], Wu Jiang[1], Langming Ma[2], Xuhai Yang[2], Lue Chen[3]

[1]SHAO; [2]NTSC; [3]BACC

Asian Pacific Space Geodynamics (APSG) geodetic VLBI sessions are being regularly performed within the IVS to improve the accuracy of the geocentric coordinates of the participating stations in the Asia-Pacific region. In the experiment APSG40, we conducted mixed-mode observations with participation of 4 Chinese stations which have no standard geodetic recording mode available. Among them, the Chinese deep space stations located at Jiamusi and Kashi have only 100 MHz bandwidth at X and S-band respectively, and the two small antennas located at Jilin and Sanya have a wide frequency coverage of 1.2-9 GHz. The observational data have been correlated and analyzed successfully. For the first time we derived the coordinates of Jilin and Sanya at the 1-2 cm level by geodetic VLBI. We will present the experiment setup, data processing method and initial results.

Intensive sessions with the Mauna Kea VLBA Station

Poster P202

Christopher Dieck[1], Megan Johnson[1], Maria Davis[1], John Gipson[2], Dan MacMillan[2], Sharyl Byram[1]

[1]US Naval Observatory; [2] NVI Inc / GSFC

Due to its location on the Hawaiian Islands in the middle of the Pacific Ocean, the Mauna Kea station (MK-VLBA) of the Very Long Baseline Array (VLBA) is well positioned for Intensive sessions with stations in the continental United States, Western Europe, and East Asia, similar to the K'ke'e Park Geophysical Observatory (KPGO). The United States Naval Observatory (USNO) has been using MK-VLBA in such sessions with other VLBA stations, particularly PIETOWN, in our efforts to develop a VLBA-based, consistent, high quality UT1-UTC series for use in EOP combination. Recently, the IVS and USNO initiated characterization sessions on the MK-VLBA:WETTZELL baseline to explore its potential as an operational backup baseline for the IVS INT1 sessions. To assess the characteristics of these Intensive sessions, we have been developing software tools, called the General Repository of EOP Analysis Tools (GREAT). We present the results of our analyses with GREAT, including the detection of MK-VLBA station position discontinuities due to the Kilauea eruption and associated earthquake.

Poster P203

Roll-out status of the VGOS network

Dirk Behrend[1], Bill Petrachenko[2], Chet Ruszczyk[3], Pedro Elosegui[3]

[1]NVI, Inc.; [2]NRCan; [3]MIT Haystack Observatory

The member organizations of the International VLBI Service for Geodesy and Astrometry (IVS) operate an observational network of VLBI telescopes that currently consists of about 40 stations worldwide. This S/X VLBI network was developed mainly in the 1970s and 1980s. Due to the aging infrastructure but also because of demanding new scientific requirements, the larger IVS community planned and started to roll out a new VLBI system called VGOS (VLBI Global Observing System) at existing and new sites over the last few years. The roll-out effort is ongoing and it is anticipated that the VGOS network may become fully operational in the early 2020s. Once VLBI products can be derived from the new system in an operational manner, the VGOS network will replace the legacy S/X network as the production system of the IVS. In this presentation we describe the current status of the VGOS network and its anticipated evolution over the next several years.

Poster P204

Argentinean-German Geodetic Observatory (AGGO)

Hayo Hase[1], Federico Salguero[2], José Vera[2], Torben Schüler[1], Claudio Brunini[2]

[1]BKG; [2]CONICET

The Argentinean-German Geodetic Observatory (AGGO) is a joint project of the Argentinean National Science and Technology Council. The project aim is to provide full-featured GGOS station. We are presenting the current status of the project.

Poster P205

The effect of source flux catalog latency on IVS-INT01 scheduling

Karen Baver, Daniel MacMillan , John Gipson

NVI, Inc.

Source flux catalogs provide cumulative information about source strength based on observations of the sources in IVS 24-hour sessions. It is important to have up-to-date source fluxes when scheduling IVS-INT01 sessions because INT01 sessions have relatively few observations, and if a source's strength is over-estimated, its observations will be scheduled for too little time, and the observations may fail. It currently takes at least two weeks to correlate and analyze a 24 hour session, so each new source flux catalog has an unavoidable minimum latency of two weeks. But, because source flux catalogs are manually generated and manually retrieved by schedulers, additional latency can be added by the time the catalogs are used for scheduling. This often occurs in practice, with added latencies, at times, of a month or longer. We look at the effect of added source flux catalog latency on IVS-INT01 scheduling.

HartRAO local tie measurements: VLBI and ground survey

Poster P206

Marisa Nickola[1,2], Aletha de Witt[1] Roelf Botha[1] Hana Krásná[3,4], Christopher S. Jacobs[5], Matthias Schartner[3] Ludwig Combrinck[6], Johannes Böhm[3]

[1]HartRAO, SARAO, South Africa; [2]University of Pretoria, South Africa; [3]Technische Universität Wien, Vienna, Austria; [4]Astronomical Institute, Czech Academy of Sciences, Prague, Czech Republic; [5]Jet Propulsion laboratory, California Institute of Technology/NASA, U.S.A.; [6]University of Pretoria, South Africa

A first short baseline VLBI experiment between the Hartebeesthoek site's 26-m legacy and co-located 15-m radio telescopes has been conducted. Such short baseline experiments allow for determining the local tie between the telescopes. It also allows for discovering instrumental effects, as the telescopes share a common location, atmosphere and, for future experiments, a common clock. Once the VGOS telescope has been furnished with receivers, it will be included in these short baseline sessions. The local automated site tie system at HartRAO is currently being implemented and tested. Measurements to various on-site GNSS reference stations, NASA and Roscosmos SLRs as well as to various reference piers are being performed on a regular basis towards fully automating the system. The Hartebeesthoek site's 26-m, 15-m and VGOS radio telescopes will form part of these local tie measurements in due course. The methodology of these two approaches to local tie measurement will be presented and results will be analysed and compared.

Impact of different observing rates on geodetic results

Poster P207

Matthias Schartner[1], Johannes Böhm[1], Arno Müskens[2], Axel Nothnagel[2]

[1]TU Wien, Advanced Geodesy, Department of Geodesy and Geoinformation, Wien, Austria; [2]Rheinische Friedrich-Wilhelms-Universität Bonn, Institut für Geodäsie und Geoinformation, Bonn, Germany

Scheduling is an integral part of every Very Long Baseline Interferometry (VLBI) experiment and, at this stage, already determines the geometric stability of the final solution. Certainly, great care should be taken to create a high-quality schedule. Using a recently developed new VLBI scheduling software called VieSched++ together with other modules of VieVS thousands of schedules and millions of simulations were created and analyzed. This opens up the chance to investigate the connection between optimization criteria and parameters in scheduling with geodetic results gained from simulations. Here, we will present our results for optimizing schedules created by using VieSched++. We will show how combinations of different optimization criteria can be used to optimize VLBI schedules for a given network and scientific goal and how these criteria vary for different sessions. Furthermore, we will demonstrate the benefit of creating multiple schedules per session and selecting one of these schedules based on simulations. We will present an in-depth analysis of the created schedules and simulations, and come up with guidelines on how to create a good schedule.

Poster P208

In-depth analysis of schedules optimized for certain VLBI experiments using VieSched++

Matthias Schartner, Johannes Böhm

TU Wien, Advanced Geodesy, Department of Geodesy and Geoinformation, Wien, Austria

Over the last couple of years, many groups have put a lot of effort into increasing the observing rate of Very Long Baseline Interferometry (VLBI) experiments. In particular, it is one of the main concepts of VGOS to observe with a high data rate of several Gbit/s. While some sessions like the Austral experiments already increased their observing rate to one Gbit/s, most sessions still observe with 128, 256 or 512 Mbit/s. We will investigate the possible benefit of increasing the observing rate for specific VLBI experiments based on large scale Monte-Carlo simulations. Therefore we have scheduled VLBI schedules using VieSched++ with different observing rates, varying from 128 Mbit/s up to multiple Gbit/s. For example, we have created more than one thousand schedules investigating the CONT17 XB network with an assumed observing rate of 128, 256 and 512 Mbit/s as well as 1, 2 and 4 Gbit/s. We will show what benefit can be assumed by increasing the observing rate based on the number of observations but also based on the repeatability of geodetic parameters like station coordinates and earth orientation parameters. Additionally, we will show how the scheduling optimization criteria should be changed to achieve the best possible result.

Poster P209

A modified approach for process-integrated reference point determination

Michael Lösler[1], Cornelia Eschelbach[1], Stefan Riepl[2], Torben Schüler[2]

[1]Frankfurt University of Applied Sciences - Laboratory for Industrial Metrology; [2]Federal Agency for Cartography and Geodesy - Geodetic Observatory Wettzell

The Global Geodetic Observing System (GGOS) calls for continues and automated determination of the geometric reference points of space geodetic techniques such as DORIS, GNSS, SLR and VLBI. Whereas the reference points of DORIS beacons and GNSS antennas can simply be measured by observing well-defined reference markers, the determination of SLR and VLBI reference points are a metrological challenge, because these reference points are inaccessible and non-materialized. Indirect methods are needed to fulfill the requirement of the Global Geodetic Observing System. In this investigation, a modified approach for reference point determination of SLR and VLBI telescopes is presented. The results of the new approach are compared to proven reference point models. The numerical deviations of the estimated reference point coordinates and the axis-offset are $\sim$50 μm and demonstrate the equivalence of the new approach.

High sensitivity astrometry with the AOV

Poster P210

Fengchun Shu, De Wu, Xuan He, Tianyu Jiang, Zhong Chen

SHAO

The AOV network is unique to astrometry of weak sources in the middle southern hemisphere and the ecliptic plane. From 2015 onward, we have observed more than 300 weak sources with the AOV stations. All experiments were performed at 1 Gbps and S/X dual band. 194 target sources have been included in the ICRF3 catalog released in August 2018. Compared with the ICRF2, the ICRF3 has 1122 new sources. Among them, 149 sources (13.3%) were observed by the AOV sessions, and 132 sources have been firstly observed by the AOV. In addition, we increased the data rate of APSG sessions up to 512 Mbps in 2016 and then to 1 Gbps in 2018. Hopefully the APSG can also contribute to astrometry of weak sources in the middle southern hemisphere, as well as achieve its regular geodesy goal.

Vienna correlation activities

Poster P211

Jakob Gruber, Johannes Böhm

TU Wien

At TU Wien, we are correlating VLBI sessions on the Vienna Scientific Cluster (VSC-3) which is a collaboration of several Austrian universities that provides supercomputer resources and corresponding services to their users. For our purpose, we installed the Distributed FX (DiFX) software correlator and the Haystack Observatory Postprocessing System (HOPS) on the VSC-3 in June 2016. One of our main interests is the optimization of correlation and fringe-fitting procedures on the VSC-3. We will show new tools which support the operational correlation and decrease the manual interaction to carry out correlation and fringe-fitting tasks. Furthermore, we will give an overview of correlated sessions and we will present an outlook of the new correlation infrastructure on the VSC-4 with its capacities and technical details.

2018 IVS Network Performance

Poster P212

Ed Himwich, Mario Bérubé

NVI

In 2018, IVS scheduled over 193 VLBI sessions for geodesy and astrometry. These 24-hour sessions involved more than 39 VLBI antennas operating in networks of 4 to 20 stations. As of today, 150 sessions have been correlated and analysed. These sessions required 1436 station-days and 483291 recorded scans. In 2018, over 85% of data recorded at the VLBI stations made it to the correlators. Understanding the reasons for this data loss is critical for maintaining a high performance IVS network. This report will be presenting the main causes of missing data for the 2018 IVS Network with emphasis on stations having participated in 50 sessions or more. The results are also compared with previous years. Effect of RFI on stations will also be presented.

Poster P213

GMVA image database at 86 GHz now online

Dhanya G. Nair[1], Frédéric Jaron[2], Andrei Lobanov[3], Thomas Krichbaum[3]

[1]JIVE; [2]University of Bonn; [3]MPIfR

A new VLBI image database at 86 GHz is online. It contains the results from a large global VLBI survey of ultra-compact extragalactic radio sources carried out in 20102011 (Nair et al. 2019) with the Global Millimeter VLBI Array (GMVA). Images for a total of 162 radio sources are currently available for download. For more scientific details, see Nair et al. (2019). URL: https://www3.mpifr-bonn.mpg.de/div/3mmsurvey/

Poster P214

The progress of CVN Software correlator and its applications

Juan Zhang[1,2], Fengxian Tong[1,2], Li Tong[1,2]

[1]Shanghai Astronomical Observatory, Chinese Academy of Sciences; [2]Key Laboratory of Radio Astronomy, Chinese Academy of Sciences

CVN software correlator had been successfully used in the VLBI data processing. In order to meet the Chang'E missions requirements, besides the correlating function, some special functions were developed, for example, the fringe-search function for the case of low accuracy predicted orbit, the monitor function used for the playback of real-time fringes. CVN software correlator had supported several IVS observation data processing, the results proved that CVN correlator had the same precision with DiFX's. CVN software correlator had already been used in the phase reference VLBI, it supported deep spacecraft, GPS and geosynchronous satellites data processing.

Session 3: Analysis

Oral presentations

Analysis of EOP and scale from the simultaneous CONT17 networks

19 Mar
10:15
O301

Dan MacMillan, John Gipson

NVI, Inc

About every three years, the IVS has carried out a continuous observing campaign with the goal of demonstrating state-of-the art VLBI observing. In 2017, the campaign was unique in two respects: three independent networks ran simultaneously and one of the networks was a demonstration of new VGOS technology. We investigate the network biases between estimates of EOP and scale parameters as well as positions of sources that are common to observing sessions of the different networks. Prior studies could not assess VLBI network biases; for example, comparisons with GNSS could yield estimates of precision but otherwise only the combined technique biases. For CONT17, we can determine polar motion and EOP rate biases of the three VLBI networks with respect to GNSS. In addition, since we have three VLBI networks, we can make an estimate of the precision of each network using 3-corner hat analysis. Previously, estimates of the precision of VGOS networks was made using simulations. Here we carry out simulations in order to validate simulations with respect to observational data.

CONT17 from a VieVS perspective

19 Mar
10:30
O302

Johannes Böhm, Sigrid Böhm, Daniel Landskron, Matthias Schartner

TU Wien

CONT17 is a campaign over two weeks of continuous VLBI sessions observed in November and December 2017. It is made up of three independent networks: two legacy networks observing X/S band and one VGOS network with broadband observing for five days. In this presentation we report our experiences with the Vienna VLBI and Satellite Software (VieVS) when analysing the sessions based on vgosDB files. In particular, we compare projected against final accuracies of the session fit, Earth orientation parameters, station coordinates or tropospheric parameters. We do also compare the schedules against those generated with VieSched++, a new scheduling program as part of VieVS. Finally, we also simulate combined legacy networks and mixed-mode approaches.

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19 Mar
10:45
O303

The IERS Rapid Service / Prediction Center UT1-UTC combined solution: Present and future Contributions

Maria Davis, Merri Sue Carter, Christopher Dieck

U.S. Naval Observatory

The IERS Rapid Service / Prediction Center (RS/PC) is responsible for producing a daily combined-solution for Earth Orientation Parameters (EOP), including UT1-UTC. The daily RS/PC EOP solution is designed to produce the most accurate, precise, and robust EOP solution for a given day using the most up-to-date observations and models available. A high-quality 0-day UT1-UTC solution requires low-latency observations that can consistently produce accurate and precise UT1-UTC values. However, the IVS Intensives and UTGPS data series are the only two low-latency UT1 or UT1-like data sources, respectively, used in the RS/PC combined solution. Due to the importance of low-latency data in our daily UT1-UTC combination, we are investigating additional low-latency VLBI baselines that can robustly contribute to the UT1-UTC solution in circumstances where the standard IVS antennas become inoperable. Therefore, we are in the process of characterizing a potential backup Intensive series using the VLBA Mauna Kea antenna together with the 20-meter Wettzell and new Wettzell North 13-meter VGOS antennas. If the characterization is successful, this will provide additional alternative baselines for operational use in the future, should they be necessary.

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19 Mar
11:15
O304

Analysis of regular and specific intensive sessions

Anastasiia Girdiuk, Dieter Ullrich, Gerald Engelhardt, Christian Plötz, Daniela Thaller

Bundesamt für Kartographie und Geodäsie (BKG)

Currently hourly intensive sessions monitor Earth Rotation variations every day almost without breaks. There are three types of regular intensive sessions: INT1, INT2 and INT3 collect data from different networks at different days of the weeks. Also, the post-observational part is performed at different correlators. The goal of the routine regular intensive sessions processing is to survey ongoing changes in dUT1 with very low latency so that an estimate of dUT1 is available for every day. The hourly intensive experiments provide these dUT1 variations by solving each one independently. In a different approach these observations can be stacked over a long time span in order to take advantage of the common reference frame. Here we examine such kind of stacked solution and corresponding parameterization. Besides, we discuss a trial parameterization and further perspectives for a specific intensive experiment between twin telescopes at Wettzell observatory.

Scheduling of twin telescopes and the impact on troposphere and UT1 estimation

19 Mar
11:30
O305

Armin Corbin, Rüdiger Haas

Chalmers University of Technology

Recently several VGOS twin telescopes, especially in Europe, were completed. A new scheduling approach for networks of VGOS telescopes including twin telescopes is used to examine the use of those twin stations. This approach is based on integer linear programming and creates uniform distributed observations over time. Several intensive sessions are rescheduled involving twin stations and the impact on the troposphere and UT1 estimation is investigated.

VLBI tie between the KOKEE12M and KOKEE20M antennas

19 Mar
11:45
O306

Arthur Niell[1], Mike Titus[1], John Barrett[1], Roger Cappallo[1], Brian Corey[1], Pedro Elosegui[1], Ganesh Rajagopalan[1], Chet Ruszczyk[1], Sergei Bolotin[2]

[1]MIT Haystack Observatory; [2]NVI

Accurate position ties between collocated geodetic systems are required in order to obtain the highest accuracy for the International Terrestrial Reference Frame. These ties can be achieved between both similar and dis-similar systems by optical measurements and between similar systems by intra-technique measurements. As an example of the latter we conducted four sessions of VLBI observations in 2016 March to measure the vector baseline between the 12-m VGOS antenna and the 20-m legacy S/X antenna at Kokee Park Geophysical Observatory. The available time interval for the measurements was limited on the early side by completion of the 12-m and on the late side by scheduled replacement of the azimuth bearing of the 20-m antenna. The 12-m antenna used the VGOS broadband system while the 20-m observed with the legacy Mk4 S/X backend. The standard R1/R4 frequency sequence was observed in this mixed-mode configuration. Either the WESTFORD or GGAO12M antenna was tagged along in each session. Although both utilize the VGOS broadband system, the schedules were optimized for the proximity of the KPGO antennas. However, the subset of common scans was processed as both legacy-broadband (mixed-mode) and broadband-only (VGOS mode). Due to the short distance between the two antennas, the effect of the differential ionosphere was negligible, allowing only X-band to be processed for the tie. Group delay across X-band was used as the observable. The four sessions ranged in duration from 0.75 to 22 hours. The estimated positions had WRMS residuals to the means of less than 1 mm in the horizontal components and approximately 1.5 mm in the local vertical. Additional sessions are planned in order to improve the tie and to assess any change due to the 20-m primary reflector removal and replacement. It is also planned to replace the 20-m S/X signal chain, from feed to recorder, with the VGOS broadband system. A similar evaluation of the relative positions of the antennas will be made before and after the signal chain replacement.

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19 Mar
12:15
O307

Gravitational deformation investigations and their impact on global telescope coordinates: The Onsala 20 m radio telescope case

Axel Nothnagel[1], Rüdiger Haas[2]

[1]Institute of Geodesy and Geoinformation, University of Bonn; [2]Onsala Space Observatory, Chalmers University of Technology

With two types of measurements, gravitational deformation effects of a radio telescope need to be monitored to infer the respective path length or time delay correction model. The first one is needed for determining the deformation of the main reflector at different elevation angles. Ideally, this is done with terrestrial laser scanning (TLS). The second is needed for monitoring the variations of the distance between the vertex of the main reflector and the sub-reflector (for a Cassegrain system). This can be carried out with any high-quality, remotely controllable distance measurement device. Both sets of measurements have been performed at the Onsala 20 m telescope. In this presentation, we describe the intricacies of the delay correction modeling. This includes the interaction with the thermal expansion model leading to the development of a complete Gravitation and Thermal Deformation Model (GTD). Furthermore, we elaborate on the impact of the GTD model on the global telescope coordinates.

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19 Mar
12:30
O308

Gravitational deformation of VLBI antennas and the impact on the TRF

John Gipson

NVI, Inc

All VLBI radio telescopes are subject to gravitational deformation which changes the length of the signal path of incoming radio signals and hence changes the measured delays. This effect can be as large as 300 ps for large antennas. For azimuth-elevations the change in signal path is elevation dependent. In 1988 T.A. Clark and P. Thomsen presented the first discussion on how the antenna is deformed. The equation, used since 1988, to describe the deformation is $\Delta L(el) = \Delta_F \alpha_F(el) + \Delta_V \alpha_V(el) + \Delta_R \alpha_R(el)$. Among the few antennas for which the gravitational deformation has been measured or modeled include Gilcreek, Efflelsberg, Medicina and Noto. Each of these antennas has a different functional form for the gravitationally induced delay. We show that this delay for all the antennas can be well approximated (RMS residual < 0.5 ps) by giving the delay at a set of tabular points and using cubic splines to interpolate. We use this later form to incorporate gravitational delay VLBI analysis. We compare geodetic estimates done with and without gravitational deformation and discuss the impact on the TRF and other estimated parameters. We also derive an alternative way to predict the impact of a model of the gravitational induced delay. Using least squares we decompose the delay model into the four terms: $A = sin(el)$, $B = 1$, $C = 1/sin(el)$, D=residual. The A and B terms are the partials for local Up and Clock, respectively, and the C term is approximately the partial for tropospheric delay. We expect that the dominant effects of gravitational deformation will be changes in the Up, Clock and tropospheric delay. We compare the predicted changes based on the above decomposition with the actual change as measured by comparing VLBI solutions done with and without deformation.

Impact of non-tidal loading in VLBI analysis

19 Mar
12:45
O309

Matthias Glomsda, Mathis Bloßfeld, Michael Gerstl, Younghee Kwak, Manuela Seitz, Detlef Angermann, Florian Seitz

DGFI-TUM

Due to various geophysical processes, the positions of reference points fixed to the Earth's crust change over time. When estimating the long term linear motion of these points in the context of Terrestrial Reference Frames (TRF), the instantaneous positions are regularized by subtracting a number of short term periodic displacements. A part of the latter is induced by tidal loading effects, which are generated by the gravitational forces of Sun and Moon (solid Earth tide, tidal atmospheric and tidal ocean loading) or the centrifugal forces of Earth rotation (pole tide, ocean pole tide). Non-tidal loading effects, however, are generally not included in the regularization step and often caused by rather local and irregular changes in atmospheric pressure and the mass distribution of ocean or land water (hydrology). According to the latest IERS Conventions of 2010, they are supposed to be less accurately modelled and can hardly be distinguished in space geodetic measurements. On the other hand, recent studies indicate that non-tidal loading effects can actually be identified with the current level of precision in VLBI. Furthermore, the underlying geophysical models have been improved, and the IVS Analysis Centers are already asked to incorporate non-tidal atmospheric loading in their official solutions. In this presentation, we hence revisit the impact of including non-tidal loading in the analysis of VLBI at observation level. We use two different sources of corresponding models, the International Mass Loading Service (IMLS) and the GFZ contribution to the Global Geophysical Fluid Center (GGFC), and reprocess the complete history of VLBI sessions available at DGFI-TUM with our proprietary software DOGS.

How does geophysical loading affect Earth rotation? Simulations and reality

19 Mar
13:00
O310

Kyriakos Balidakis[1], Susanne Glaser[1], Henryk Dobslaw[1], Robert Dill[1], Tobias Nilsson[1], Benjamin Männel[1], Harald Schuh[2]

[1]GFZ, German Research Centre for Geosciences, Potsdam, Germany; [2]Technische Universität Berlin, Institute of Geodesy and Geoinformation Science, Berlin, Germany

In this work, we investigate the impact of mass redistribution within Earth's fluid envelope on EOP estimated by VLBI. The influence of geophysical loading on Earth rotation is twofold: via (i) atmospheric, oceanic, and hydrological angular momentum exchanges with the solid Earth; and via (ii) errors induced by displacements of stations that collect the observations based on which Earth rotation parameters are estimated. While the first effect causes actual variations in Earth rotation, the latter results in errors in the estimation of Earth rotation parameters by space geodetic techniques. Herein, we deal with the latter. Based upon the analysis of real observations from all 24-hour IVS sessions, unmodelled geophysical loading can cause errors in the seasonal variations of 1 microarcsecond in terrestrial polar motion, 9 microarcseconds in celestial pole motion, and 0.5 microseconds in dUT1. Additionally, high-frequency variations at the level of 20 microarcseconds in terrestrial polar motion, 10 microarcseconds in celestial pole motion, and 1 microsecond in dUT1 are caused by surface loading effects.

However, in the analysis of the one-hour long, single-baseline intensive VLBI sessions, the seasonal variations attributed to unmodelled geophysical loading even reach 5 microseconds in dUT1, and are highly dependent upon the baseline configuration. Since normally only two stations participate in the intensives and no residual coordinates are estimated in the data analysis, unaccounted station motion variations inescapably propagate into dUT1 estimates. In the framework of VGOS, where an 1 microsecond dUT1 accuracy is sought for, it is clear that non-tidal geophysical loading must be considered at the observation equation level. However, unlike polar motion, there is no technique capable of providing dUT1 more accurately than VLBI, in an absolute sense; thus, there is no absolute reference for validation. To this end, we have carried out a number of Monte Carlo simulations where clock stability and thermal noise, atmospheric turbulence, and solid Earth loading deformation noise are considered. Group delays for 11,000 intensive sessions were simulated. The simulator is additionally driven by ray-traced delays and atmospheric turbulence structure constants from ECMWF's fifth-generation reanalysis, ERA-5, and displacements induced by atmospheric, oceanic, and hydrological loading from GFZ (ftp://ig2-dmz.gfz-potsdam.de/LOADING/). The impact of loading on dUT1 is assessed within the simulation environment as well as from the actually observed group delays. The high-frequency characteristics of the residual dUT1 signal are studied as well.

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19 Mar
14:15
O311

Comparison of troposphere delays from GNSS and VLBI in R1 and R4 sessions

Víctor Puente[1], Yaiza Gómez-Espada[1], Esther Azcue[1], Susana García-Espada[2], Marcelino Valdés[1]

[1]National Geographic Institute of Spain; [2]RAEGE Santa Maria - National Geographic Institute of Spain

The delay induced by the troposphere in the signal propagation is an important error source in the analysis of the observations of space geodetic techniques such as the Global Navigation Satellite Systems (GNSS) and Very Long Baseline Interferometry (VLBI). The magnitude of this delay depends on the atmospheric conditions (temperature, pressure, humidity) and also on the antenna location. In this contribution, the differences in the troposphere Zenith Total Delay (ZTD) between both techniques are analysed in several stations in which GNSS and VLBI antennas are co-located. This analysis has been carried out using series of troposphere products from IVS (International VLBI Service for Geodesy and Astrometry) Analysis Centers as well as series estimated ad-hoc for this work using VieVS 3.1. The dataset analysed corresponds to R1 and R4 sessions spanning from 2013 to 2018. In addition, a modification to VieVS 3.1 has been included to use GNSS-based ZTD as initial value in VLBI processing. Results in terms of ZTD, Earth Orientation Parameters and baselines repeatability are also presented and compared to those obtained with the baseline version of VieVS 3.1.

Comparison of tropospheric delay estimation using VLBI CONT14 data and WVR for the Onsala station

19 Mar
14:30
O312

Periklis-Konstantinos Diamantidis, Rüdiger Haas, Gunnar Elgered

Chalmers University of Technology

Very Long Baseline Interferometry (VLBI) relies on the time delay of the arrival of the same radio signal between different radio telescopes. The atmospheric effects that alter the signal path act as error sources and must be accounted for. The delay, in particular, due to the existence of the water vapour in the troposphere, also called the wet delay (WD) is modelled and estimated during the VLBI analysis. The application of a Kalman filter (KF) in VLBI analysis allows for the Zenith Wet Delay (ZWD) to be modelled as a stochastic process, however it also treats it as a markovian process and thus a quantity that is temporally dependent. The spatial and temporal dependence in estimating WD from VLBI underscores, in the case of a KF, the choice of correct noise parameters of the stochastic model used. A Water Vapour Radiometer (WVR) provides measurements of the WD that are spatially and temporally independent. WVR can be thus a valuable tool for validating the results obtained from VLBI analysis. On this basis, the CONT14 data were analyzed using a KF in the c5++ analysis software and the resulting ZWD series at Onsala were compared with those obtained by a collocated WVR.

An assessment of the tropospheric parameters estimated from the CONT17 campaign

19 Mar
14:45
O313

Tobias Nilsson[1], Kyriakos Balidakis[2], Tong Ning[1]

[1]Lantmäteriet, The Swedish Mapping, Cadastral and Land Registration Authority, Gävle, Sweden; [2]GFZ, German Research Centre for Geosciences Potsdam, Germany

CONT17 was a 15-day long continuous geodetic VLBI campaign performed from 28 November until 12 December 2017. Different from the former CONT campaigns, there were three networks observing in parallel. Two networks consisted of legacy S/X VLBI telescopes, while the third consisted of new broadband VGOS telescopes. The VGOS network, however, only observed for five days. In this work, we look at the tropospheric parameters, i.e. zenith tropospheric delays and horizontal gradients, estimated from CONT17. A special emphasis is on the results from the new VGOS antennas. We compare the results obtained from the different networks at stations with co-located VLBI antennas, e.g. Wettzell and Kokee Park. Furthermore, we make an external validation by comparing with the results from co-located GNSS antennas, as well as the tropospheric parameters calculated from ECMWF's fifth-generation reanalysis numerical weather model, ERA5. We show that the tropospheric parameters estimated from the VGOS data have similar or better precision compared to the those estimated from the legacy VLBI data.

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19 Mar
15:00
O314

An analytical VLBI delay formula for Earth satellites

Frédéric Jaron, Axel Nothnagel

University of Bonn

VLBI observations of Earth satellites have the potential of becoming an important technique for improving the frame ties between celestial and terrestial reference frames. The near-field VLBI delay models developed so far include iterative numerical computations, which may become expensive in terms of computation time, especially when partial derivatives are to be computed. Furthermore, since all of these models are formulated in the BCRS they require large numbers. I will present an analytical expression for the VLBI delay for Earth satellites and show results from comparing this analytical formula with numerical computation.

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19 Mar
15:30
O315

Geodetic VLBI observations of lunar radio sources – Current status and recommendations for future research

Grzegorz Klopotek[1], Thomas Hobiger[2], Rüdiger Haas[1], Frédéric Jaron[3], Laura La Porta[3,4], Axel Nothnagel[3], Zhongkai Zhang[3], Songtao Han[5], Alexander Neidhardt[6,7], Christian Plötz[6]

[1]Chalmers University of Technology; [2]University of Stuttgart; [3]University of Bonn; [4]Reichert GmbH; [5]Beijing Aerospace Control Center; [6]Geodetic Observatory Wettzell; [7]Technical University of Munich

Numerous lunar programs have been carried out in the past with the purpose to study the Moon. A recent example is the Chinese Chang'e 3 (CE-3) mission where a lander and rover have been deployed onto the north-west part of the visible side of the Moon. Taking this opportunity, a project was launched to observe the CE-3 lander with the use of a global network of VLBI telescopes. The corresponding VLBI experiments referred to as OCEL (Observing the Chang'E Lander with VLBI) broaden the knowledge and resulted in valuable insights concerning geodetic VLBI observations of artificial lunar radio sources.

We summarize results from the analysis of OCEL sessions and discuss the performance of these 24-hour experiments in terms of the position determination of the CE-3 lander on the surface of the Moon. This includes scheduling, observing setup and data analysis for the target parameter estimation. In addition, we highlight technical difficulties related to observations and processing of such data. Moreover, we include recommendations that could enhance the presented concept leading to application of geodetic VLBI to high-precision lunar positioning and studies of the Moon.

Ionospheric calibration for K-band celestial reference frames

19 Mar
15:45
O316

Benedikt Soja[1], Christopher S. Jacobs[1], Thomas Runge[1], Charles Naudet[1], Richard Gross[1], Alet de Witt[2], David Gordon[3], Jonathan Quick[2], Jamie McCallum[4], Hana Krásná[5,6]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, United States of America; [2]SARAO/HartRAO, Krugersdorp, South Africa; [3]NVI Inc, NASA/GSFC, Greenbelt, MD; [4]University of Tasmania, Hobart, Tasmania; [5]Technische Universität Wien, Vienna, Austria; [6]Astronomical Institute, Czech Academy of Sciences, Prague, Czech Republic

The International Celestial Reference Frame (ICRF) has traditionally been composed of radio source coordinates estimated from VLBI observations in S- and X-band. The ICRF3, released in 2018, included for the first time a CRF based on observations at K-band. A major benefit of observations at higher frequencies is that source structure effects are smaller. A disadvantage of the K-band data is that the single-frequency observations require external ionospheric calibrations. If the ionospheric corrections are of sufficient quality, a K-band CRF could have an astrometric accuracy better than the 20-30 μas source-structure-induced noise floor of current S/X-based CRFs.
In the case of the ICRF3, the K-band observations were corrected using two-dimensional global ionospheric maps with a two-hour temporal resolution. In this study, we investigate the improvement in the K-band CRF when using calibrations based on ionospheric data with increased resolutions. In particular, we (1) test ionospheric products from JPL with a temporal resolution of 15 minutes and (2) evaluate a potential improvement in spatial resolution by assuming functioning GNSS equipment at all ten VLBA sites (currently, only five have GNSS stations that are contributing to ionospheric products).

Time stability of the K-band catalog sources

19 Mar
16:00
O317

Karine Le Bail[1], Alet de Witt[2], Christopher S. Jacobs[3], David Gordon[1]

[1]NVI, Greenbelt, MD, U.-S.; [2]SARAO/HartRAO, Krugersdorp, South Africa; [3]Jet Propulsion Laboratory, California Inst.Technology/NASA, Pasadena, CA, U.-S.

The ICRF-3 is imposed on three frequency components. We examine the relative temporal stability of two of those, S/X and K bands.
The ICRF3 was adopted by the IAU in August 2018 and became effective January 1, 2019. It differs from ICRF and ICRF2 by the addition of two catalogs at higher frequencies, including a K-band catalog. The K-band data differs from the S/X data in that 1) the K-band in the north is VLBA-only; 2) the K-band data since 2015 are all at a high data rate of 2 Gbps; and 3) K-band is less affected by source structure. Thus it may be possible to construct a more stable frame at K-band than at S/X band.
We studied two source position time series solutions generated at GSFC using Calc/Solve. These two solutions present very different sampling. The K-band observations cover the period May 2002 to November 2018 for a total of 48 sessions while the S/X observations cover the period August 1979 to November 2018 for a total of 6200 sessions. We first compare the two sets of time series as an independent solution and then we limit the data sets to a core of more frequently observed sources on the similar time period.

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19 Mar
16:45
O318

ICRF3, the new realization of the International Celestial Reference Frame

Patrick Charlot[1], Christopher Jacobs[2], David Gordon[3], Sébastien Lambert[4], Alet de Witt[5], Johannes Böhm[6], Alan Fey[7], Robert Heinkelmann[8], Elena Skurikhina[9], Oleg Titov[10], Felicitas Arias[4], Sergei Bolotin[3], Géraldine Bourda[1], Chopo Ma[3], Zinovy Malkin[11], Axel Nothnagel[12], David Mayer[6], Dan MacMillan[3], Tobias Nilsson[8], Ralph Gaume[13]

[1]Laboratoire d'Astrophysique de Bordeaux; [2]Caltech/Jet Propulsion Laboratory; [3]NASA/Goddard Space Flight Center; [4]Observatoire de Paris/SYRTE; [5]Hartebeesthoek Radio Astronomy Observatory; [6]Technische Universität Wien; [7]U. S. Naval Observatory; [8]Helmholtz Centre Potsdam; [9]Institute for Applied Astronomy; [10]Geoscience Australia [11]Pulkovo Observatory and Kazan Federal University; [12]Institut für Geodäsie und Geoinformation; [13]National Science Foundation

This presentation reviews the main properties of ICRF3, adopted as the new realization of the International Celestial Reference Frame during the XXXth IAU General Assembly last August. ICRF3 incorporates nearly 40 years of VLBI data at the standard geodetic and astrometric frequencies (2.3 and 8.4 GHz) along with additional data collected at higher frequencies (24 GHz and 8.4/32 GHz) over the past 15 years. The modeling integrates for the first time the effect of the Galactocentric acceleration of the Solar System which, if not considered, produces significant deformation of the frame due the data span. ICRF3 contains positions for 4536 extragalactic sources, as measured at 8 GHz, 303 of which, uniformly distributed on the sky, are identified as defining sources and as such serve to define the axes of the frame. Positions at 8 GHz are supplemented with positions at 24 GHz for 824 sources and at 32 GHz for 678 sources. In all, 600 sources have three-frequency positions available. The positions were estimated independently at each of the three radio frequencies in order to preserve the underlying astrophysical content behind such estimates. ICRF3 is aligned onto the International Celestial Reference System to within the accuracy of ICRF2. Compared to ICRF2, the median position uncertainty in ICRF3 is reduced by a factor of 3.5, while the noise floor in the individual source coordinates is now at the level of 30 μas. Comparing ICRF3 with the Gaia CRF2 optical frame, which is part of the Gaia Data Release 2, shows that there are no deformations above the level of 30 μas between the two frames, in agreement with the ICRF3 noise level. ICRF3 is in effect since January 1, 2019, as per IAU 2018 Resolution B2.

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19 Mar
17:00
O319

Toward imaging 3000+ ICRF sources from closure quantities from 1979–present

James M. Anderson[1,2], Ming Hui Xu[1,2,3,4], Suxia Gong[2], Robert Heinkelmann[2], Susanne Lunz[2], Harald Schuh[1,2]

[1]Technical University of Berlin; [2]GFZ German Research Centre for Geosciences; [3]Huazhong University of Science and Technology; [4]Shanghai Astronomical Observatory

Source structure contributes significant errors to the analysis of geodetic VLBI data. Virtually all geodetic VLBI sources are spatially resolved on the nearly Earth-diameter baselines utilized by geodetic VLBI observations, with source structure varying with time, frequency, and polarization. Relative source structure leads to group delay errors larger than 1 ns at X band for geodetic sources with significant structure, with lower

frequencies typically exhibiting even larger structure errors. As the source structures evolve with time, including flaring of components, ejections of new components from the core, and motions of components away from the core, the effective astrometric positions of sources, analyzed as if they are point sources, change. Changes in observing networks and viewing geometries also change the effective source positions. Source structure features, including systematic differences as a function of observing frequency (such as steep-spectrum jets), introduce systematic and time-dependent position offsets in the positions of individual sources. This leads to position offsets between celestial frames observed at different frequencies and/or at different times, and can, for example, contribute to the observed systematic position offsets along the radio jet directions between the VLBI and Gaia frames. In order to mitigate the multitude of problems introduced by source structure, we aim to develop images and source structure models of as many geodetic VLBI sources as possible, as a function of time whenever possible, using the same VLBI observations used for geodesy and astrometry. As part of our work in the ECORAS2 (extension of the coordinate parameterization of radio sources observed by VLBI) project, we have produced closure phase and closure amplitude quantities from all public IVS datasets since 1979, and have more than 3400 sources with enough (≥ 100) closure quantities to make at least rudimentary images. We will report on our progress in developing appropriate imaging software, initial comparisons to visibility-derived images for a small sample of sources, and developing a pipeline to image and determine source structure parameters for all ICRF sources with suitable closure data, for the entire history of IVS observations. In future work we will apply group delay and rate corrections derived from the image structure to correct the historical data archive.

VLBA Imaging of ICRF 3 sources

19 Mar
17:15
O320

Lucas Hunt, Alan Fey, Megan Johnson, John Spitzak

United States Naval Observatory

We present results from an imaging campaign of sources used for the third iteration of the International Celestial Reference Frame (ICRF) using the Very Long Baseline Array (VLBA). Imaging these sources allows use to determine spectral index, peak flux density, compactness and source structure index. This information is crucial to understanding source structure and variability which better allows us to determine if a source is suitable for inclusion in the ICRF and suitability as a phase reference calibrator. We also present the current status and future of the Radio Reference Frame Image Database which is being updated to include not only images of the sources in this observing campaign, but also ancillary data files that might be of use.

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19 Mar
17:30
O321

The Bordeaux VLBI Image Database (BVID)

Arnaud Collioud, Patrick Charlot

Laboratoire d'Astrophysique de Bordeaux

The Bordeaux VLBI Image Database (BVID) delivers VLBI images to the international VLBI community since 2008. We are pleased to announce the opening of a new version of the BVID. This second version, with more than 6000 VLBI images and associated data (especially those that qualify the source structure, i.e. compactness and structure indices information) has an enhanced clean and modern interface. In this talk, we will present the new user interface as well as some new functionnalities and tools (sky maps, charts, tables) available to query and navigate into the BVID-2. We will also discuss the value of this database for astrometric and astrophysical applications.

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19 Mar
18:00
O322

Structure effects in broadband VGOS data

Ming Hui Xu[1,2,3], James M. Anderson[2,4], Suxia Gong[14], Robert Heinkelmann[4], Susanne Lunz[4], Harald Schuh[4,2], Guang Li Wang[3]

[1]Huazhong University of Science and Technology; [2]Technical University of Berlin; [3]Shanghai Astronomical Observatory; [4]GFZ German Research Center for Geosciences

Source structure has been demonstrated to be the dominate error source in the residuals of geodetic VLBI data analysis for the S/X system (Anderson & Xu, 2018). For the broadband systems, as pointed out by Neill et al. (2018), the structure effects can compromise the benefit of broadband systems. Recently, the IVS has already released the CONT17 VGOS data, which **do** show significant improvements in terms of measurement noise and allow us to study the structure effects in the real broadband data. In this work, we will present the structure effects indicated by the CONT17 VGOS by analyzing phase and amplitude observables from the four individual bands and the group delay, phase, and amplitude observables from the broadband fringe measurement process. The comparison of intrinsic structures at different frequencies based on the simultaneous observations will be highlighted in this presentation. To better understand the potential impacts on the goals of VGOS, simulations of structure effects based on the same observing network, the same frequency setup, and the same sample of sources of CONT17 VGOS observations will be done.

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19 Mar
18:15
O323

The source structure effect in broadband observations

Sergei Bolotin, Karen Baver, Olga Bolotina, John Gipson, David Gordon, Karine le Bail, Daniel MacMillan

NVI, Inc.

Analysis of the VGOS CONT17 observations showed that the broadband delays are sensitive to brightness distributions of radio sources. In this presentation we discuss the impact of source structures on the broadband observations and the application of source structure models (two points model, multiple points model, etc.) in data analysis.

Source structure effects in the next-generation of VLBI observations

19 Mar
18:30
O324

Simin Salarpour, Stanislav Shabala, Lucia McCallum

University of Tasmania

Next generation of VLBI observations (VGOS) will struggle with the source structure issue to determine accurate celestial and terrestrial reference frames. Observation over a wide range of 2-14 GHz will be influenced by source structure which is highly frequency dependent. Moreover, the structure of a quasar often evolves on timescales of months. To calculate visibility phase changes over the broadband frequency range, the source structure module of the Vienna VLBI Software (VieVS) is extended. So far, we have focused on a single source (0133+476) to obtain these effects as a function of frequency and time for varying geometries. By using this approach and simulated VGOS networks, we can estimate the number of observations within a session that may be affected by source structure on the dependence of the source's evolution over time as well as baseline length and observing geometry.

Remaining problems in geodesy/astrometry VLBI and approaches to their solutions

19 Mar
18:45
O325

Leonid Petrov

NASA GSFC

The purpose of this talk is to provide an overview of outstanding problems that remained in astrometry/geodesy VLBI after 50 years of developmentand encourage discussion. That includes a) discussion of scientific obtained and expected results from VLBI/Gaia position offset analysis; b) discussion of the contribution of source structure to astrometry and geodesy results; c) investigation of the impact of polarization impurity in legacy and VGOS hardware; d) discussion of approaches for mitigation of RFI on data analysis; e) discussion of approaches to reduce the data for antenna deformations induced by gravity and ambient temperature variations.

Poster presentations

Poster P301

Vienna VLBI Analysis Center (VIE)

Andreas Hellerschmied[1], Johannes Böhm[2], Sigrid Böhm[2], Michael Franzen[1], Jakob Gruber[2], Hana Krásná[2], Daniel Landskron[2], David Mayer[1], Markus Mikschi[2], Jürgen Otter[1], Matthias Schartner[2], Helene Wolf[2], Ernst Zahn[1]

[1]Federal Office of Metrology and Surveying; [2]Technische Universität Wien

TU Wien has been running a Special Analysis Center (VIE) of the International VLBI Service for Geodesy and Astrometry (IVS) since 2000. In this role, VIE has been involved in numerous operational and research tasks. It contributed to important geodetic products such as the ITRF2014, or the determination of the ICRF3 with its own VLBI solutions based on the Vienna VLBI and Satellite Software (VieVS). Since July 2018, following the signing of a Memorandum of Understanding with the President of BEV, the Federal Office of Metrology and Surveying in Austria, VIE is run as a joint Analysis Center between TU Wien and BEV aiming at increased participation in the operational generation of geodetic products, such as the routine determination of Earth orientation parameters. In this contribution we present the current operations at VIE. We depict the data analysis workflow based on vgosDB databases provided by the IVS and present recent results and products. Furthermore, we discuss future prospects and plans of our joint VLBI activities, especially with respect to scheduling, correlation, and fringe-fitting with an independent processing pipeline based on VieVS for standard X/S- and VGOS observations.

Poster P302

The X/Ka-band 2019a celestial frame:

Christopher S. Jacobs[1], Cristina García-Miró[2], Shinji Horiuchi[3], Lawrence G. Snedeker[4], Mattia Mercolino[5], Iona Sotuela[2], Leslie A. White[1]

[1]Jet Propulsion Laboratory, California Institute of Technology/NASA [2]Madrid Deep Space Communications Complex/NASA, ISDEFE, Spain [3]Canberra Deep Space Communications Complex/NASA, C.S.I.R.O., Australia [4]SaiTech/NASA, Goldstone, CA [5]ESOC, ESA, Darmstadt, Germany

The ICRF-3 is now multi-wavelength consisting of components at S/X (2.3/8.4 GHz), K (24 GHz) and X/Ka (8.4/32 GHz). This paper discusses the X/Ka celestial reference frame which was constructed using a combined NASA and ESA Deep Space Network from about 172 observing sessions over which 678 sources were detected covering the full 24 hours of right ascension and the full range of declinations. Observations at X/Ka-band are motivated by their ability to access more compact source morphology and reduced core shift relative to observations at the historically standard S/X-band. In addition, the factor of four increase in interferometer resolution at Ka-band should resolve out some types of astrophysical systematics. Comparison of 500 X/Ka sources in common with S/X-band (2.3/8.4 GHz) frames yields evidence for systematic errors at the level of 100-200 micro-arcseconds. Observation correlations from tropospheric turbulence effect the solution and will be discussed.

VLBI analyses at the National Geographic Institute of Spain

Poster P303

Esther Azcue[1], Víctor Puente[1], Susana García-Espada[2], Yaiza Gómez-Espada[1], Marcelino Valdés[1]

[1]National Geographic Institute of Spain; [2]RAEGE Santa Maria - National Geographic Institute of Spain

The National Geographic Institute of Spain (IGN) is committed to expand its contribution to geodetic VLBI in terms of data analysis. Apart from its involvement on the VLBI observing network by means of the RAEGE project, an analysis team has been working on the data analysis with different software packages for the last two years. In this poster, the results of the last processing campaigns using different software packages are presented, as well as different comparisons in order to test the solution.

Earth orientation parameters estimated from K-band VLBA measurements

Poster P304

Hana Krásná[1,2], David Gordon[3], Aletha de Witt[4], Christopher S. Jacobs[5], Benedikt Soja[5]

[1]Technische Universität Wien, Vienna, Austria; [2]Astronomical Institute, Czech Academy of Sciences, Prague, Czech Republic; [3]NVI, NASA Goddard Space Flight Center, USA; [4]SARAO/HartRAO, South Africa; [5]Jet Propulsion Laboratory, California Institute of Technology/NASA, USA

The Earth Orientation Parameters (EOP) which connect the Terrestrial and Celestial Reference Frame are regularly estimated by Very Long Baseline Interferometry (VLBI). The UT1-UTC and nutation components of EOP can only be measured using the VLBI technique. Until recently, published VLBI estimates of EOP were based solely on observations from the S/X frequency band. We present VLBI estimates of EOP from an observing frequency independent of the traditional S/X-band using Very Long Baseline Array (VLBA) measurements at K-band (24 GHz, 1.2 cm). We will have over two years of regular VLBA experiments conducted with telescopes located in U.S. territory. We investigate the potential of K-band VLBI to produce more accurate EOP because of its reduced source structure effects relative to SX-band. We will compare our K-band EOP to S/X VLBA results and the IERS C04 data. Acknowledgements: We acknowledge our respective sponsors: HK acknowledges the Austrian Science Fund (FWF, Project T697-N29). SARAO/HartRAO is a facility of the National Research Foundation (NRF) of South Africa. Portions of this work done at Jet Propulsion Laboratory, California Institute of Technology under contract with NASA. We gratefully acknowledge the grant of observing time on the VLBA under the USNO time allocation.

Poster P305

AUA047: Students at TU Wien organize their own VLBI session

Helene Wolf[1], Matthias Schartner[1], Jakob Gruber[1], Johannes Böhm[1], Lucia McCallum[2], Jamie McCallum[2], Warren Hankey[2]

[1]TU Wien; [2]University of Tasmania

As part of the lecture 'Space Geodetic Techniques' at TU Wien, students had the task to carry out the VLBI experiment AUA047 on Tuesday, 4th of December 2018. More than 30 students participated in this course and worked independently in groups to perform all necessary steps, including large-scale Monte-Carlo simulations, scheduling, correlation and analysis. As a result of a cooperation with the University of Tasmania, it was possible to observe the VLBI session successfully with Australian telescopes. The schedule was created by each group independently using the software VieSched++. The students could decide if they want to generate a geodetic, astrometric or intensive-like schedule using different strategies to create the best schedule for their scientific goal. Simulations of the produced schedules were carried out for assessing the accuracy of the earth orientation parameters (EOP) and station coordinates. The schedule from one group was finally picked and observed by our Australian colleagues. After the session was observed, the students got an introduction to the correlation of VLBI sessions and a presentation of the correlation on the Vienna Scientific Cluster (VSC-3). The analysis of the VLBI session was done with VieVS using different strategies, for example by varying the mapping functions or changing the frequency of piecewise linear offsets.

Poster P306

The K-band (24 GHz) Celestial Reference Frame

Aletha de Witt[1], David Gordon[2], Christopher Jacobs[3], Hana Krásná[4,5], Jamie McCallum[6], Jonathan Quick[1], Benedikt Soja[3] Shinji Horiuchi[7]

[1]SARAO/HartRAO, Krugersdorp, South Africa; [2]NVI, NASA GSFC, Greenbelt, MD; [3]Jet Propulsion Laboratory, California Institute of Technology/NASA, Pasadena,CA; [4]Astronomical Inst., CAS, Czech Republic; [5]Technische Universität Wien, Austria; [6]University of Tasmania, Hobart, Tasmania; [7]C.S.I.R.O/CDSCC, Australia

A K-band (24 GHz) celestial reference frame of 914 sources covering the full sky has been constructed using over 0.6 million observations from about 70 observing sessions from the VLBA and HartRAO-Hobart. Observations at K-band are motivated by their ability to access more compact source morphology and reduced core shift relative to observations at the historically standard S/X-band (2.3/8.4 GHz). The factor of three increase in interferometer resolution at K-band should resolve out source structure which is a concern for AGN centroid stability. K median RAcos(dec) precision is comparable to the SX ICRF-3 precision (for common sources) thereby raising the question of which frame is more accurate. The accuracy of the K CRF is quantified by comparison of 800 sources in common with the current S/X-band producing wRMS agreement of 80 μas as in RA cos(Dec) and 135 μas in Dec. There is evidence for systematic errors below the 100 μas level. The success of the Gaia optical astrometric space observatory motivates work to tie the radio and optical frames. K-band data and Gaia Data Release-2 data give a frame tie precision of 15 μas (1-sigma, per 3-D rotation component). If K-band precision can be pushed below 20-30 μas, the K frame has potential to produce a tie to Gaia that is superior to S/X due to reduced astrophysical systematics at K relative to S/X.

Comparison of integrated LOD values from GNSS and AAM to dUT1 from VLBI

Poster P307

Markus Mikschi, Johannes Böhm, Sigrid Böhm, Dzana Horozovic

TU Wien

Although VLBI is unique among the geodetic space techniques, as it is the only one that delivers dUT1 values, other geodetic space techniques such as GNSS are able to measure the rate of change of dUT1, which is called Length Of Day (LOD). Thus, it is possible to estimate dUT1 over time by integrating LOD and adding the known dUT1 value at t0.

The main drivers of variations in the Earth rotation rate are the variable mass distribution of the atmosphere and zonal winds as well as zonal tides of the solid Earth and oceans. The latter can be calculated from the IERS (International Earth Rotation and Reference Systems Service) model, while the atmosphere's variations are available as Atmospheric Angular Momentum (AAM) functions. The bachelor thesis' aim is to test how well dUT1 measurements from VLBI can be bridged by integration of LOD values obtained by both GNSS and AAM (+zonal tides). Preliminary combinations of both AAM and GNSS data by means of a Kalman filter deliver quite promising results with maximal dUT1 deviations compared to VLBI intensive sessions of 300's and an average deviation of 50's over a time span of 28 days. This is using one day solutions of a global network of GPS and Galileo satellites implementing the ECOM solar radiation model. Investigation of a longer period as well as comparisons between different GNSS LOD data, such as 1- and 3-day solutions of GPS or GPS + Galileo are planned.

Simulated combined effect of extended source structure and baseline geometry to geodetic parameters estimated with VLBI

Poster P308

Niko Kareinen[1], Nataliya Zubko[1], Tuomas Savolainen[2], Markku Poutanen[1]

[1]Finnish Geospatial Research Institute FGI; [2]Aalto University Metsähovi Radio Observatory

indexauthorsKareinen! N., Zubko! N., Savolainen! T., Poutanen! M.

The VLBI Global Observing System (VGOS) is currently being expanded by multiple radio telescopes globally and moving towards operational use. Electromagnetic radiation from extra-galactic radio sources propagates through the atmosphere and is observed by the telescopes. Along with atmospheric errors, the radio source structure is expected to be a major contributor to the VGOS error budget. An ideal geodetic source is a point-like and strong radio source. However, most of them exhibit finite structure. We focus on sources having an elongated structure due to the alignment of their relativistic jets with respect to the observing baseline. Typically the effect of source structure has been classified by so-called structure indices derived from the median structural delay. As an alternative approach, we model the source structure in terms of the jet size and orientation relative to the observing baseline. Using simulations we estimate in terms of the estimated geodetic parameters the effect having sources with elongated structure in the observing schedule. We determine a limit when it becomes advantageous to either drop or downweight the observing baseline. Starting with the CONT17 schedules, the source structure effects are added via simulations and evaluated with respect to the estimated geodetic parameters. Here we present preliminary results from this study.

Poster P309

Combination of IVS intensive sessions - approach, benefit, and operability

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In this contribution we present the status of the combination of VLBI intensive sessions. Combined IVS products for station coordinates and Earth orientation parameters are well-established within the VLBI community. So far, only 24 h sessions are routinely combined using the contributions of various IVS Analysis Centers (ACs). Currently, very few IVS ACs provide datum free normal equations in form of SINEX files for intensive sessions. Consequently, our presentation will show first results of our approach to establish a combined IVS product for the intensive sessions based on datum free normal equations. Furthermore, we discuss the benefit of such a combined product as well as the possibilities and challenges to install an operational IVS product.

Poster P310

Radio source position offsets among various radio frames and Gaia

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Since the inauguration of the ICRF3 there is not only the S/X band realization of the ICRS made publicly available but also realizations in K and X/Ka band. In addition, Gaia DR2 provides radio source positions at the same level of accuracy but in the optical band. In theory, the positions of a radio source at different radio frequencies should be separated due to core shift and in addition align with its jet direction. It is reasonable to think that the position derived by Gaia observations should in general also be along the jet direction. Naturally, problems due to time variability arise when looking into heterogeneous data sets. Thus it is a task to compare the reference frames at different frequencies using measurements from the same time windows. Kovalev et al. (2017) and Petrov et al. (2018) showed that VLBI and Gaia position offsets favor the respective jet directions of the radio source. We use this approach to look into VLBI reference frames at different frequencies. Our first objective is to investigate whether or not radio source positions at different frequencies are aligned along one direction. The second objective is to compare the results with the jet angles provided by Kovalev et al. (2017) which were derived from images. We categorize the position offsets between the different reference frames and look into the origin of artifacts of the celestial reference frames that are visible in the analysis.

Comparison of ionospheric delays between VLBI and GNSS

Poster P311

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VLBI is a differential technique observing at multiple frequencies. Thus, it can independently provide ionospheric delays. GNSS can supply precise ionospheric delays as well, often with comparable or even better spatial coverage. In this presentation, we compare the VLBI differential ionosphere from two sites with multiple VLBI antennas with the co-located GNSS ionospheric calibrations. In S/X VLBI, a linear combination of X-band and S-band delays is used to provide a calibrated group delay measurement that is free of ionospheric effects to first order. In contrast, the VGOS system is designed to provide group delay and ionospheric delay through a simultaneous fit to measurements in 4 frequency bands distributed over a wide frequency range. The CONT17 VGOS data have been calibrated in terms of ionosphere in advance and thus directly provide TEC for each observation. In this work we compare the extracted ionospheric delays from dual-frequency observations of GNSS with the ones from dual-frequency S/X VLBI and from co-located VGOS stations in the CONT17 experiment to better understand how well VLBI can contribute to the study of the ionosphere. Since both source structure and ionosphere effects on geodetic VLBI data analysis are dispersive, in the future we will introduce an optimal match for VLBI and GNSS and compare ionospheric delays obtained from different radio sources to help to improve the modeled structure effect.

NT-VGOS - Mitigating the source structure errors in the VGOS era

Poster P312

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The ambitious goal of the VLBI Global Observing System (VGOS) is to obtain 1 mm accuracy in station position and 0.1 mm/year accuracy in station velocity. To achieve this, tropospheric delay fluctuations, which are considered to make the largest noise contribution in the current geodetic VLBI observations, will be reduced significantly in the VGOS observations through rapid source changes allowed by fast-slewing telescopes. However, it is expected that after mitigation of random tropospheric errors, the systematic errors due to non-pointlike extragalatic radio source structure will dominate the error budget. The VGOS delay accuracy requirements translate to source position accuracies of the order of 1/30 of the global interferometer beam size and it is not clear whether there are any sources that would have point-like structure at this level of precision. Furthermore, the extragalactic radio sources are relativistic jets of plasma that are highly variable both in time and over frequency, and mitigating their unwanted effects on the accuracy of the future VGOS observations will require geodecists and astronomers to work closely together. We have recently started such a cross-disciplinary project, called "NT-VGOS", between the Aalto University Metsähovi Radio Observatory and the Finnish Geospatial Research Institute. Here we describe the project goals and issues to be tackled. These include the development of imaging capability for the VGOS array in order to measure structural correction terms directly from the VGOS data and characterization of frequency-dependency of the source positions of typical geodetic

VLBI targets over the VGOS observing band. For the latter, we also discuss the pilot observations carried out with the Very Long Baseline Array to test methods for measuring this so-called core-shift effect using different phase-referencing techniques.

Poster P313

Inter-comparison of GNSS and VLBI tropospheric parameters at co-located sites in Italy

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Troposphere is one of the main error sources in space geodetic techniques at radio frequencies (such as GNSS and VLBI) and it is used to measure water vapor, a key parameter of the greenhouse effect important in weather and climate process.
The main purpose of this investigation is to inter-compare tropospheric parameters (namely the zenith total delay and the linear horizontal gradients) estimated at the three Italian stations: Matera, Medicina and Noto where a GNSS antenna and a VLBI radio telescope are collocated.

Poster P314

Comparison of VLBI-based series of celestial pole offsets

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Very Long Baseline Interferometry (VLBI) is the only space geodesy technique that can directly observe the celestial pole offsets. These values are time-dependent corrections to the IAU200A/2006 precession-nutation model that are estimated by different VLBI analysis centres. The celestial pole offsets, together with the rest of Earth Orientation Parameters (EOP) are combined by the IERS and disseminated in official series.
The purpose of this contribution is to compare the differences between the celestial pole offsets from different VLBI-based series fully consistent in terms of software configuration. Series estimated for this work using VieVS software package (University of Vienna) and Where software package (Norwegian Mapping Authority) and series provided by the International VLBI Service for Geodesy and Astrometry (IVS) are analysed. The celestial pole offsets estimation series from each source are used as pseudo-observations for a least-square harmonic fitting to obtain different corrections to nutation terms.

Comparison between time series of closure analysis and source positions since 1980

Poster P315

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Source structure has been demonstrated to be the dominate error source in the residuals of geodetic VLBI data analysis for the S/X system (Anderson & Xu, 2018).
In this presentation we show the results of our closure analysis of all the VLBI observations available from IVS archives. The application of closure analysis to the long-term dataset clearly reveals evolution of source intrinsic structure at various time scales for most sources. The evolution of intrinsic structure necessarily leads to changes in the reference position, which can be detected by estimated source positions from geodetic VLBI. Apart from ICRF2 special handling sources, some ICRF2 defining sources have also been reported to have obvious variations in their estimated source positions. This work will present the comparison between the evolution of intrinsic structure and the source position variations. The conclusion of this work is that the evolution of intrinsic source structure detected by closure analysis is correlated with position variations.
The results of this complete study show that besides the instantaneous structure median group delay a quality measure for the structure evolution with time should be considered in order to quantify astrophysical suitability of radio sources for geodetic and astrometric VLBI.

Diurnal and sub-diurnal EOP variations from VLBI global solution

Poster P316

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We processed almost all available VLBI data in order to improve coefficients of the model of the diurnal and sub-diurnal EOP variations. Amplitudes of the EOP variations were computed by global solution including VLBI series from 1979 to 2019. The estimated model were used for global solution, CONT17 VLBI campaign and Lunar Laser Ranging (LLR) data processing. It was shown that the new model slightly improves the VLBI and LLR data representation.

EVGA 2019 Organization

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The local government of Gran Canaria Island is ruled by the Cabildo. This institution with more than 100 years of history is in charge of many infrastructures, nature protected areas, tourism, culture, etc. The Cabildo of Gran Canaria is not only supporting the EVGA meeting but also the deployment of the future radiotelescope for VLBI purposes in the island.

Established as a non-profit making Foundation, it is born thanks to the joint efforts of local public institutions and private companies of the tourist sector. It is actually composed of the following members: Tourist Board of Gran Canaria, The Town Hall of Las Palmas de Gran Canaria, Foundation Las Palmas de Gran Canaria Auditorium, The Canarian Institution of Trade Fairs, Expomeloneras, The Hotel, Restaurant and Cafe Business Employers Federation of Las Palmas and Chamber of Commerce, Industry and Navigation Services Gran Canaria.

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