TU WIEN

VieVS Days 2026

Welcome

Hana Krásná
TU Wien, 15.09.2026

TU WIEN

Speakers


Hana


Sigrid


Sofie


Matthias, TUM


Peter


Johannes


Helene

Program, Tue morning

9:00 AM – 10:00 AM

Introduction to geodetic VLBI

Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Krasna, Hana (TU Wien)

10:00 AM – 11:00 AM

Introduction to VieVS

Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Böhm, Sigrid (TU Wien)

11:00 AM – 12:00 PM

Single Session Analysis

Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Steinmetz, Sofie (TU Wien)

12:00 PM – 1:30 PM

Photo + Lunch Break

Break

Program, Tue afternoon

1:30 PM – 2:00 PM

Single Session Analysis
Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Urban, Peter (TU Wien)

2:00 PM – 2:30 PM

Single-band session
Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Krasna, Hana (TU Wien)

2:30 PM – 3:00 PM

Intensive sessions
Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Böhm, Johannes (TU Wien)

3:00 PM – 3:30 PM

New station and radio source
Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Wolf, Helene (TU Wien)

3:30 PM – 4:30 PM

Questions
Contribution | **Location:** TU Wien, DA02E08; “Sem.R. DA grün 02 A”, Wiedner Hauptstraße 8-10; Floor 2

Program, Wednesday

9:00 AM – 9:40 AM

Global VLBI solution
Contribution | **Location:** TU Wien, DA02E08; "Sem.R. DA grün 02 A", Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Krasna, Hana (TU Wien)

9:40 AM – 10:20 AM

VLBI2Satellites
Contribution | **Location:** TU Wien, DA02E08; "Sem.R. DA grün 02 A", Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Wolf, Helene (TU Wien)

10:20 AM – 11:00 AM

VieCompy
Contribution | **Location:** TU Wien, DA02E08; "Sem.R. DA grün 02 A", Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Wolf, Helene (TU Wien)

11:00 AM – 12:00 PM

VieSched++
Contribution | **Location:** TU Wien, DA02E08; "Sem.R. DA grün 02 A", Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Schartner, Matthias (TUM)

12:00 PM – 1:30 PM

Lunch Break
Break

1:30 PM – 4:00 PM

VieSched++
Contribution | **Location:** TU Wien, DA02E08; "Sem.R. DA grün 02 A", Wiedner Hauptstraße 8-10; Floor 2 |
Speaker: Schartner, Matthias (TUM)

Introduction to geodetic VLBI

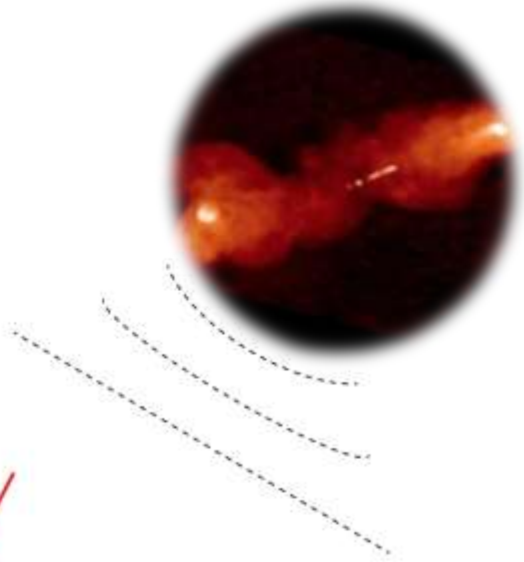
VieVS Days 2026

Hana Krásná
TU Wien, 15.09.2026

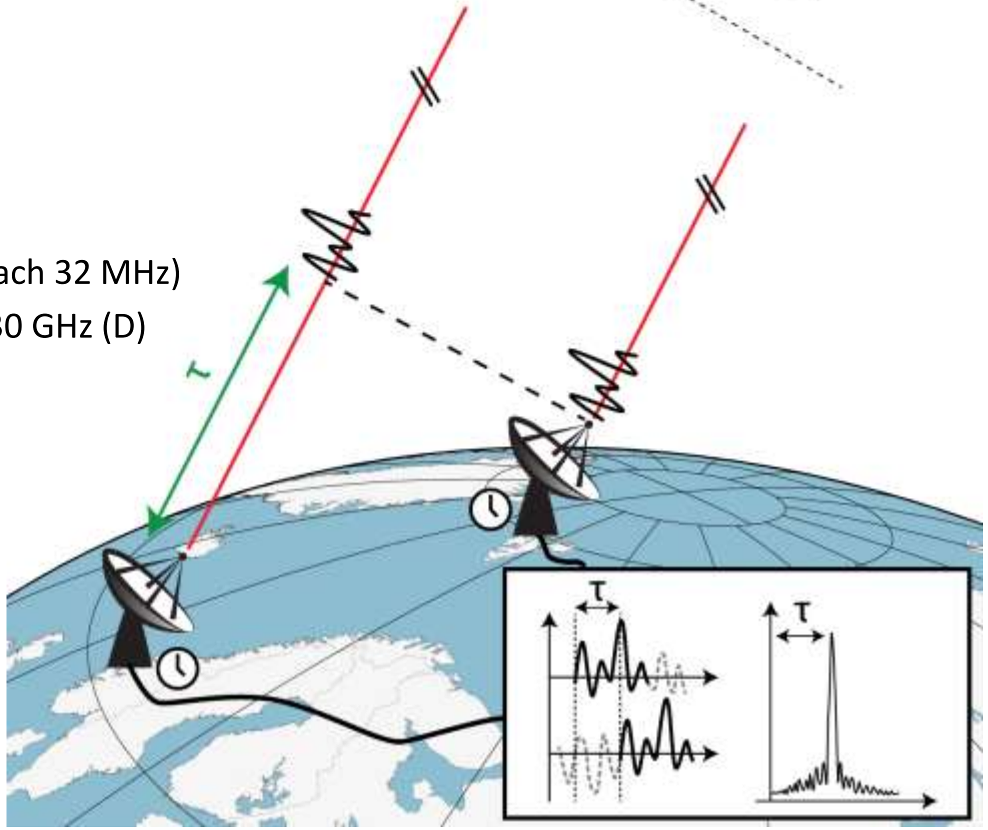
What is geodetic VLBI

- Microwave-based **space geodetic technique** that measures the **difference in arrival times** of signals from a radio source to telescopes by **cross correlation**

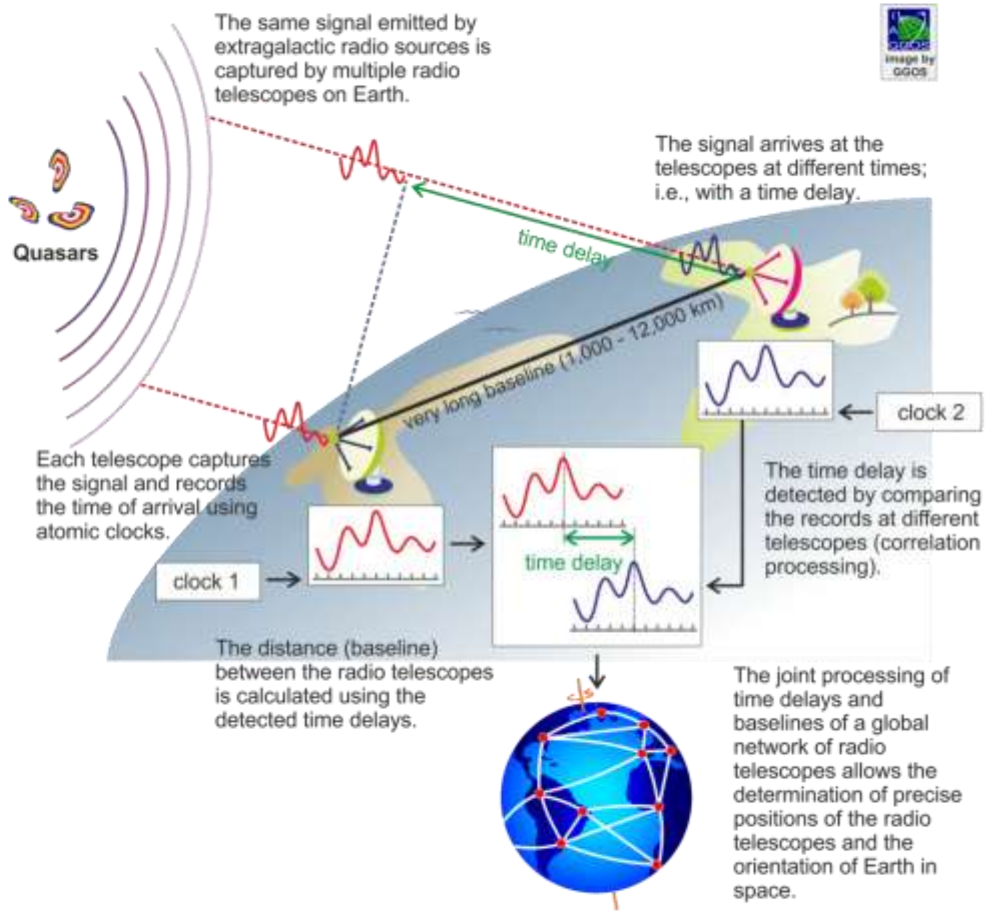
  - Radio sources
    - Extragalactic objects, such as active galactic nuclei
    - Beacons from satellites
  - Microwaves
    - 8.4 and 2.3 GHz, typical for geodetic legacy VLBI
    - New IVS system VGOS: broadband full potential 2 – 14 GHz (4 bands; 32 channels each 32 MHz)
    - Higher astrometric frequencies: 24 GHz (K), 32 GHz (Ka), 43 GHz (Q), 86 GHz (W), 130 GHz (D)



Onsala, Sweden; October 2025



VLBI principle (geodesy + astrometry)



https://ggos.org/item/vlbi/

Time delay τ
Primary observable of the geodetic VLBI

$$\tau = -\frac{1}{c}\vec{\boldsymbol{b}} \cdot \boldsymbol{WSQ} \cdot \vec{\boldsymbol{k}}$$

	b	baseline vector between two stations
	k	unit vector to radio source
EOP	W	rotation matrix for polar motion
EOP	S	diurnal spin matrix
EOP	Q	precession-nutation matrix

Data Products of Geodetic & Astrometric VLBI

IVS Terms of Reference, May 24, 2019

VLBI data products contribute **uniquely** to these important activities:

- defining and maintaining the **celestial reference frame at radio frequencies**,
- monitoring **universal time (UT1),**
- monitoring the coordinates of the **celestial pole (long-term nutation).**

These results are the **foundation of many scientific and practical applications** requiring the use of an accurate quasi-inertial reference frame, such as **high-precision positioning**, **navigation**, and **timing**.

In addition IVS provides a variety of VLBI products with differing applications, timeliness, detail, and temporal resolution, such as:

- all components of **Earth orientation parameters**,
- **terrestrial reference frame**,
- **baseline lengths**, precise length of intercontinental baselines -> stable TRF scale
- **tropospheric parameters**.

Vienna Center for VLBI

United Nations
Global Geodetic
Centre of Excellence

PARTNER

Vienna Center for VLBI
(TU Wien + BEV)

https://www.vlbi.at

Vienna IVS Correlator Center

Bundesamt
für Eich- und
Vermessungswesen

IVS CC since 2018

ASC Austrian Scientific Computing

access provided by TU Wien

Vienna IVS Analysis Center

IVS

IVS AC since 2000 (TU Wien),
since 2018 jointly with BEV

Vienna Analysis Center

ASTRO2GEO

since 2017

Vienna Center for VLBI

International Association of Geodesy (IAG)

a Constituent Association of IUGG (International Union of Geodesy and Geophysics)

International VLBI Service for Geodesy and Astrometry (IVS)

- Service of the IAG and of the IAU
- IVS provides a service which supports geodetic and astrometric work on reference systems, Earth science research, and operational activities.

Vienna Center for VLBI (TU Wien + BEV)

International Astronomical Union (IAU)

IVS Analysis Center VIE at TU Wien

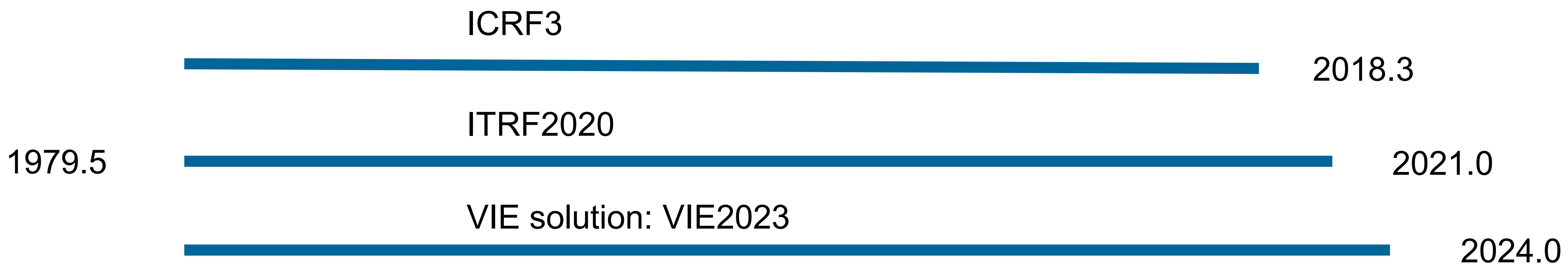
Current members with their main areas of interest:

- **Böhm Johannes**: ESA Genesis mission
- **Böhm Sigrid**: Earth rotation
- **Krásná Hana**: reference frame solutions: TRF + CRF
- **Nothnagel Axel**: consultant, …
- **Steinmetz Sofie**: simulations for ESA Genesis mission
- **Tumler Barbara**: thermal deformation of telescopes
- **Urban Peter**: ambiguity resolution, research on a priori correlations between observations
- **Wolf Helene**: VLBI to satellites

https://www.vlbi.at

VIE2023 solution (TRF + EOP + CRF)

DOI: 10.48436/76404-a3492



VieVS – Vienna VLBI and Satellite Software

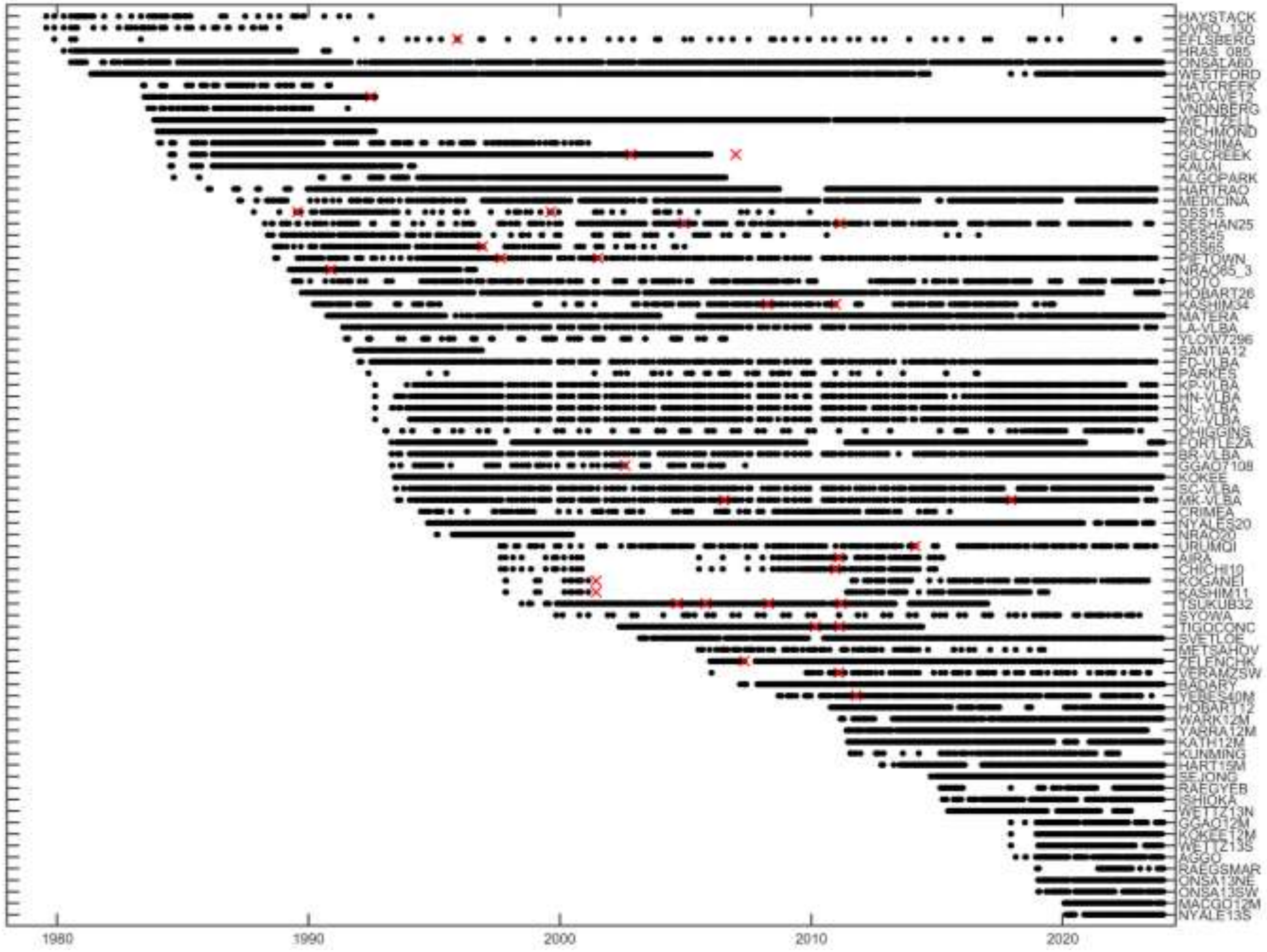
- geodetic VLBI analysis software package, open-source, available on GitHub https://github.com/TUW-VieVS
- Input: group delays provided in the IVS vgosDB format via IVS Data Centers

- Theoretical delay is modelled following the latest IERS Conventions 2010 (+ updates)
- Adjustment of data is done with the Least Squares Method

TRF-VIE2023

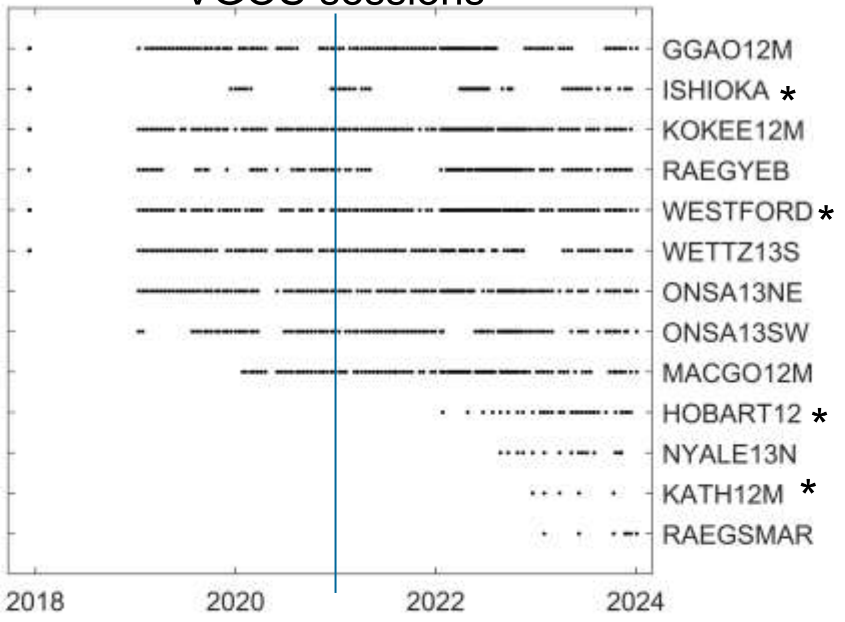
DOI: 10.48436/76404-a3492

Antennas participating in > 50 sessions in VIE2023



- ~7500 24-h IVS sessions (S/X + VGOS)
- 155 VGOS sessions
  - first session in December 2017
  - regular observations since 2019

VGOS sessions



ITRF2020 cutoff date

*regular participation also in S/X sessions

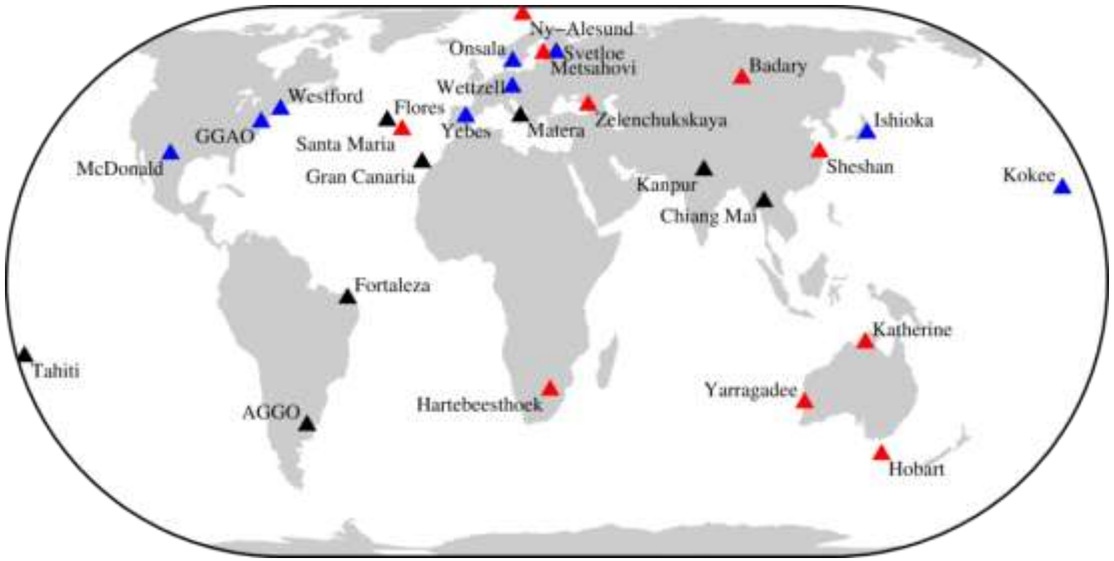
VGOS: The New VLBI Component of GGOS

- Science requirements established by Global Geodetic Observing System (GGOS)
  - accuracy of 1 mm in station position and 0.1 mm/year in station velocity on global scales

- The IVS contribution to GGOS is the VLBI Global Observing System (VGOS)
- Upgrade of the VLBI system to meet the required level of accuracy

VGOS system

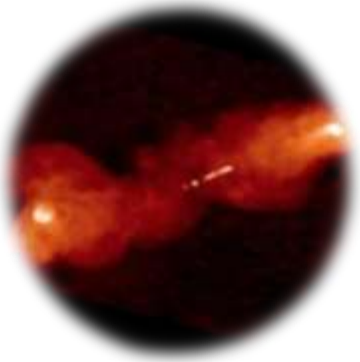
- based on the broadband delay (four frequency bands in the range from 2.5 GHz to 14 GHz)
- fast-slewing, 12-m class antennas with a high data rate of 8 Gbps
- planned to replace the currently employed legacy S/X system as its operational system for geodetic product creation over the next few years



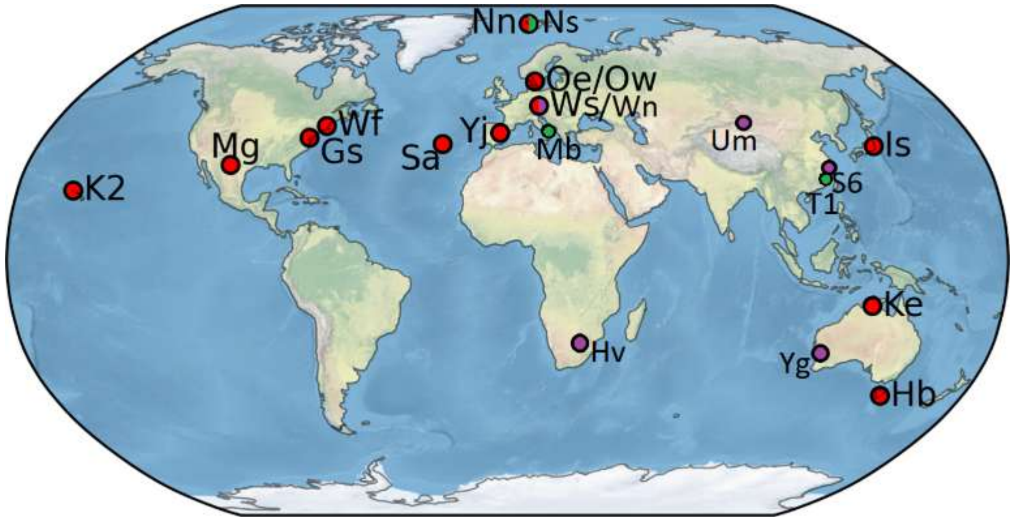
projected VGOS network, status 09/2020

https://ggos.org/item/ivs/

Vienna global products: TRF + CRF + EOP

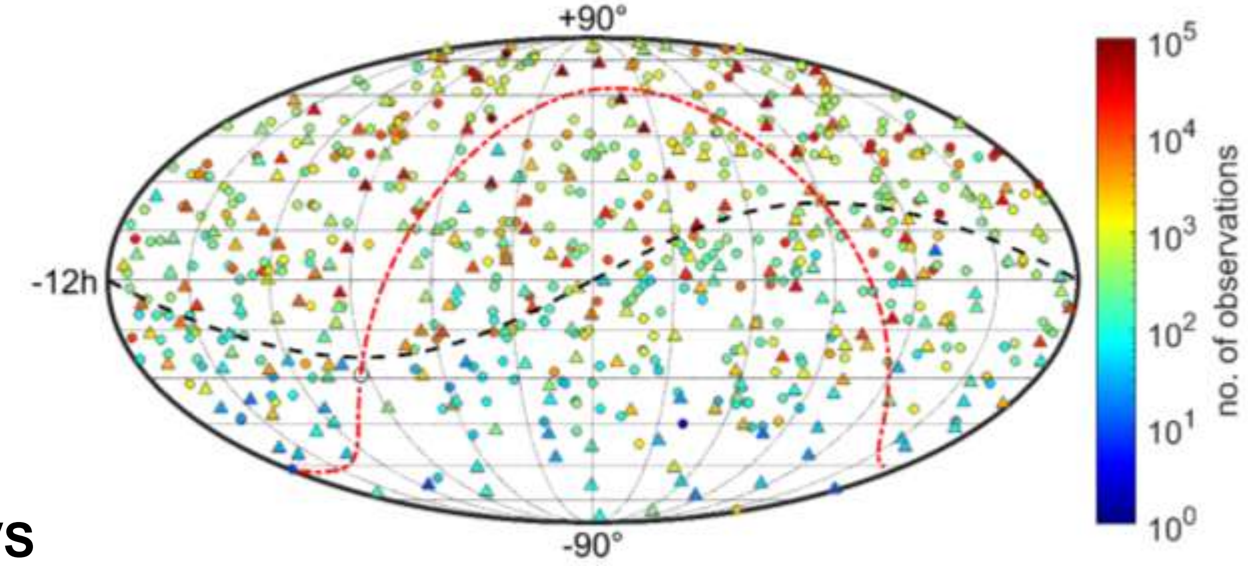


Radio image of the jetted AGN 3C 219
https://info.ira.inaf.it/en/research/science/agn/



VIE2025-VG TRF
21 VGOS telescopes

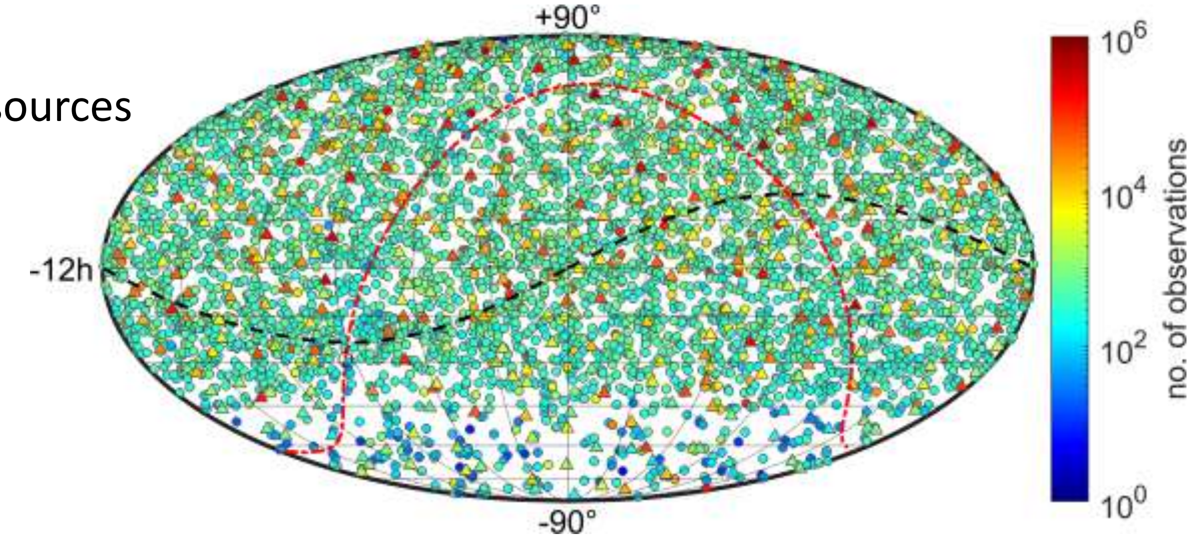
VIE2025-VG CRF
674 radio sources



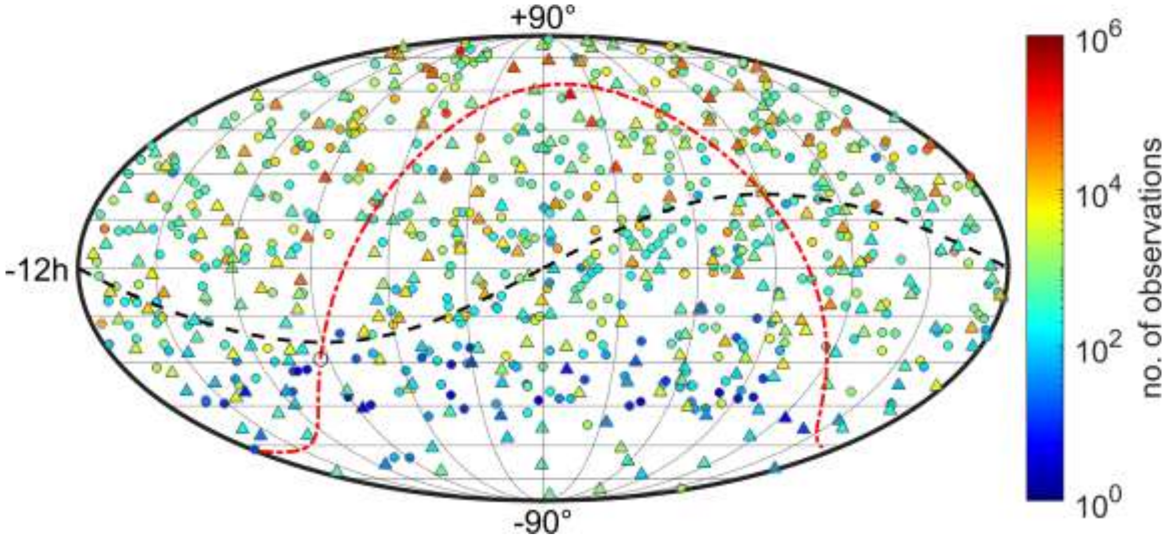
New VGOS system of the IVS

VIE2026a CRFs

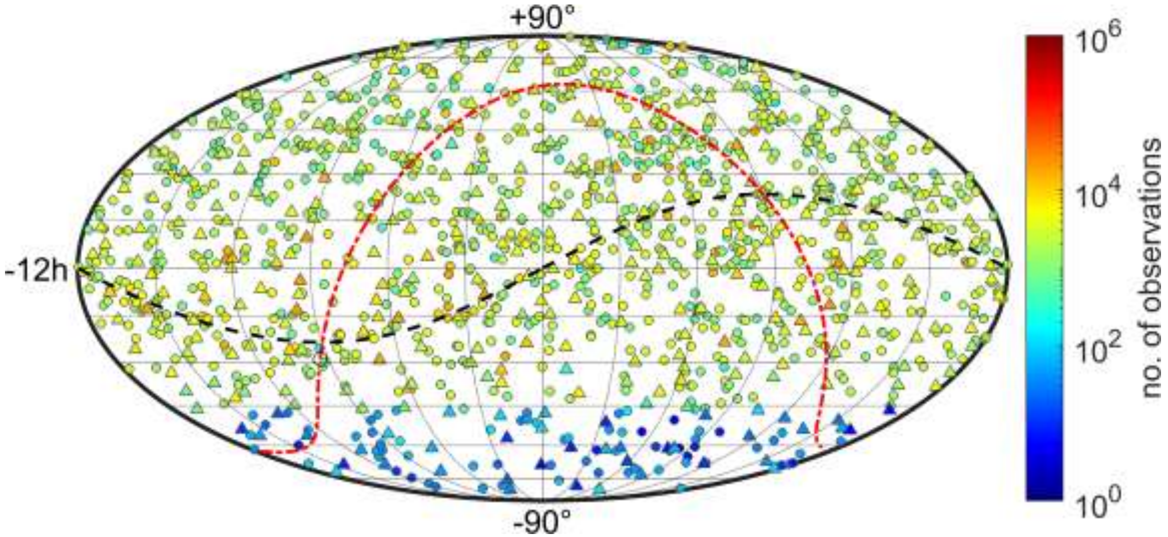
S/X: ~4500 sources



VGOS: 784 sources

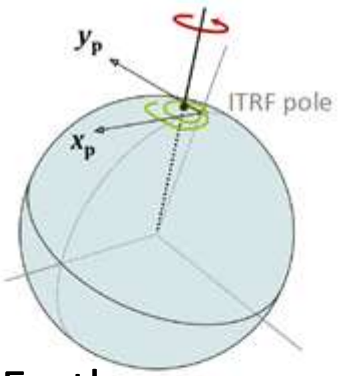


K: ~1300 sources

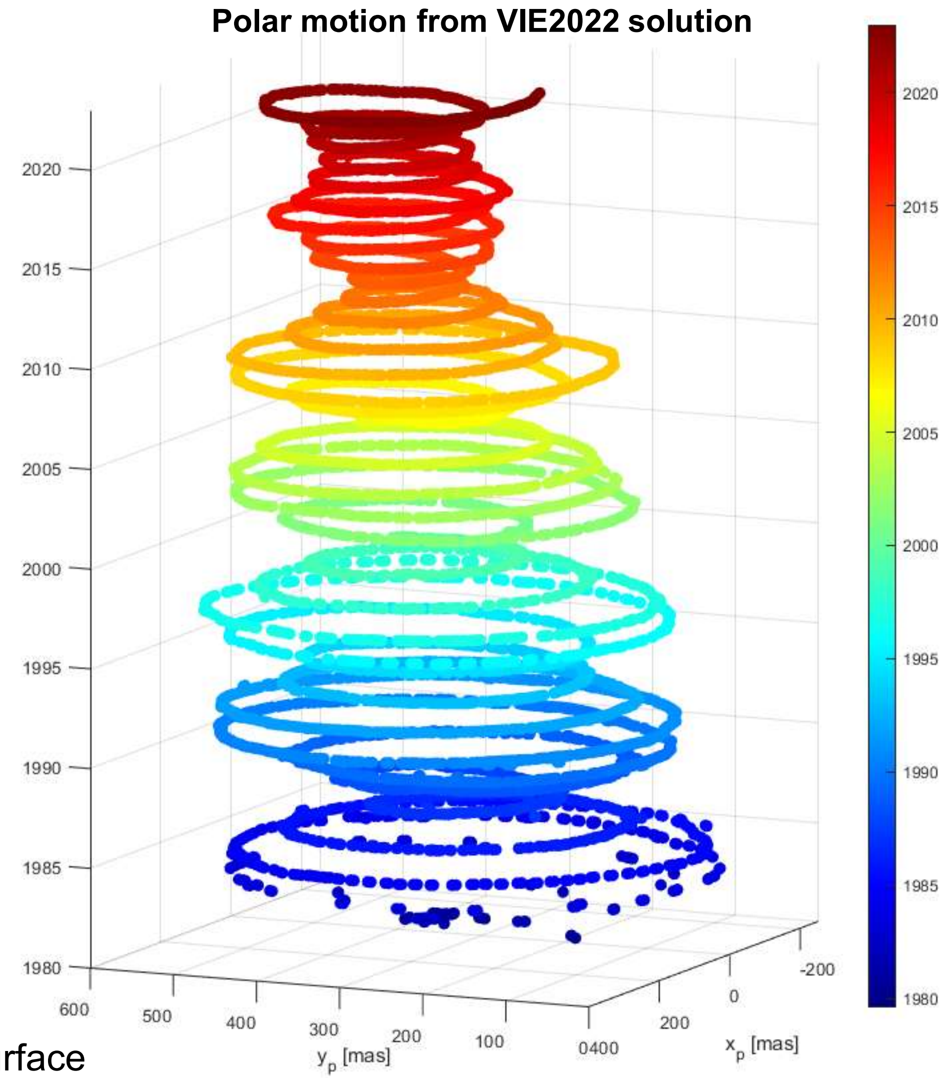


Polar motion

- Motion of the Earth rotation axis w.r.t. an Earth-fixed reference frame



- Main components
  - Chandler wobble: free oscillation of the Earth, period approx. 433 days
  - Annual wobble: caused by annual variations in atmospheric pressure
  - + unpredictable motions

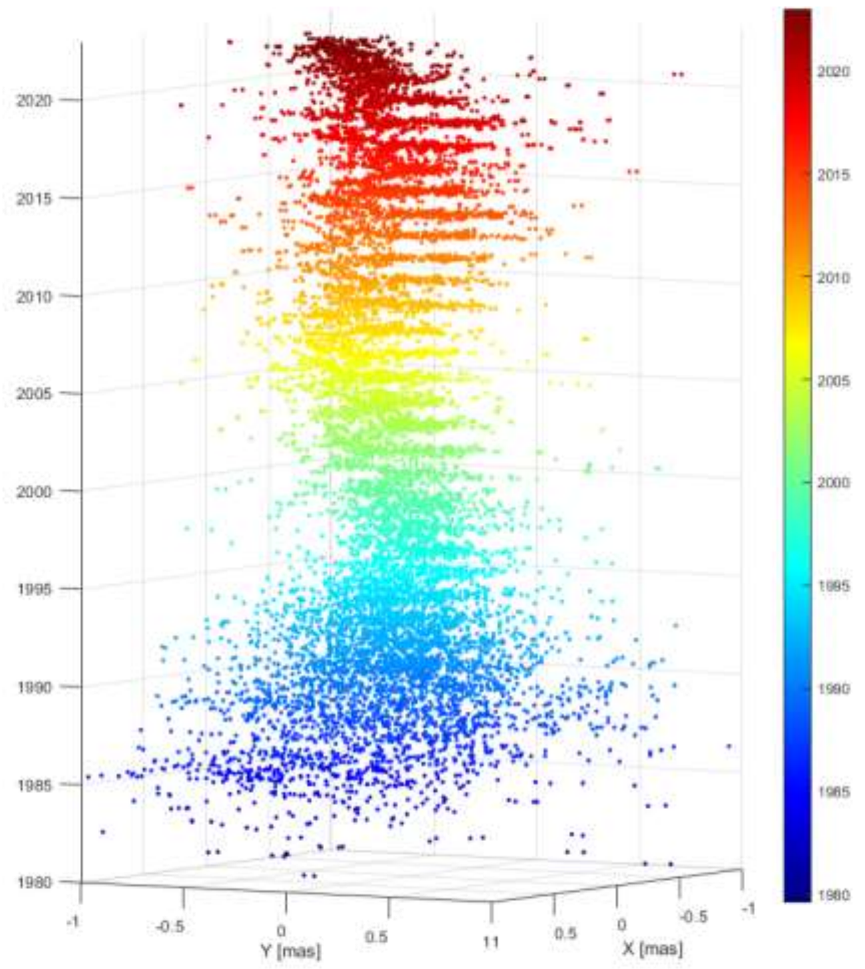


30 mas ≈ 1 m at the Earth surface

Precession / nutation

- Location of the rotation axis w.r.t. a space-fixed reference frame
  - Two components: X, Y
  - The main part is described using a model (currently IAU 2006/2000A)
  - The residuals (dX, dY) to the model are measured by means of geodetic VLBI
  - Residual signal mainly due to Free Core Nutation (FCN)

CPO from VIE2022 solution



Tropospheric delays from VLBI

Case study done for one K-band VLBA session: UD015L, 2022 June 09

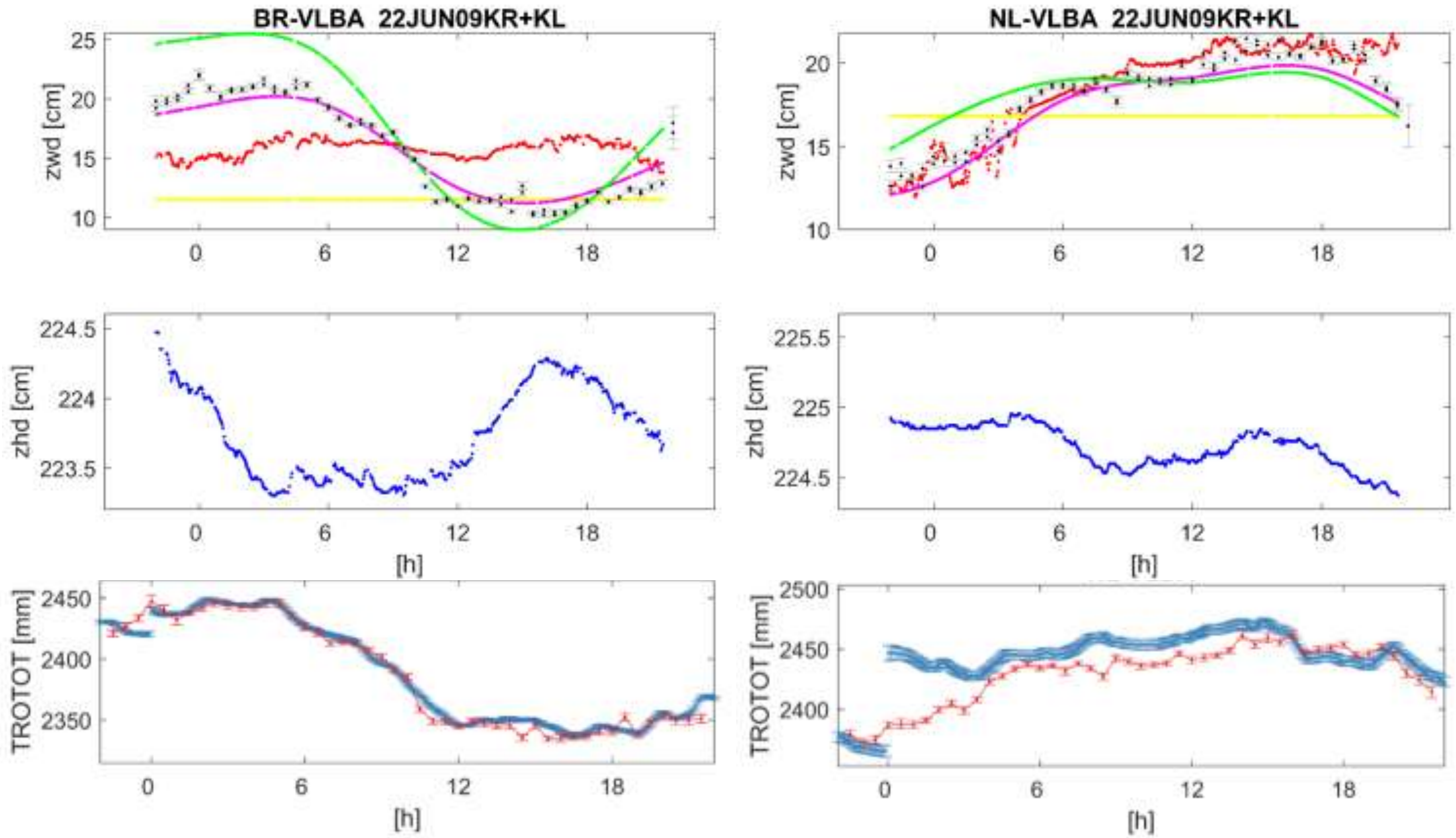
Comparison of wet troposphere models

VMF3 (Landskron & Böhm, 2018, JGeod 92)
VMF1 (Böhm et al., 2006, *JGR* 111)
in situ e + Askne (Askne & Nordius, 1987)
GPT3 e (Landskron & Böhm, 2018) **+ Askne**
e - water vapor pressure

Modeled zenith hydrostatic delay
(Saastamoinen, 1972)

Comparison of TROTOT
K-band UD015L/RCP
GNSS

15.0 cm



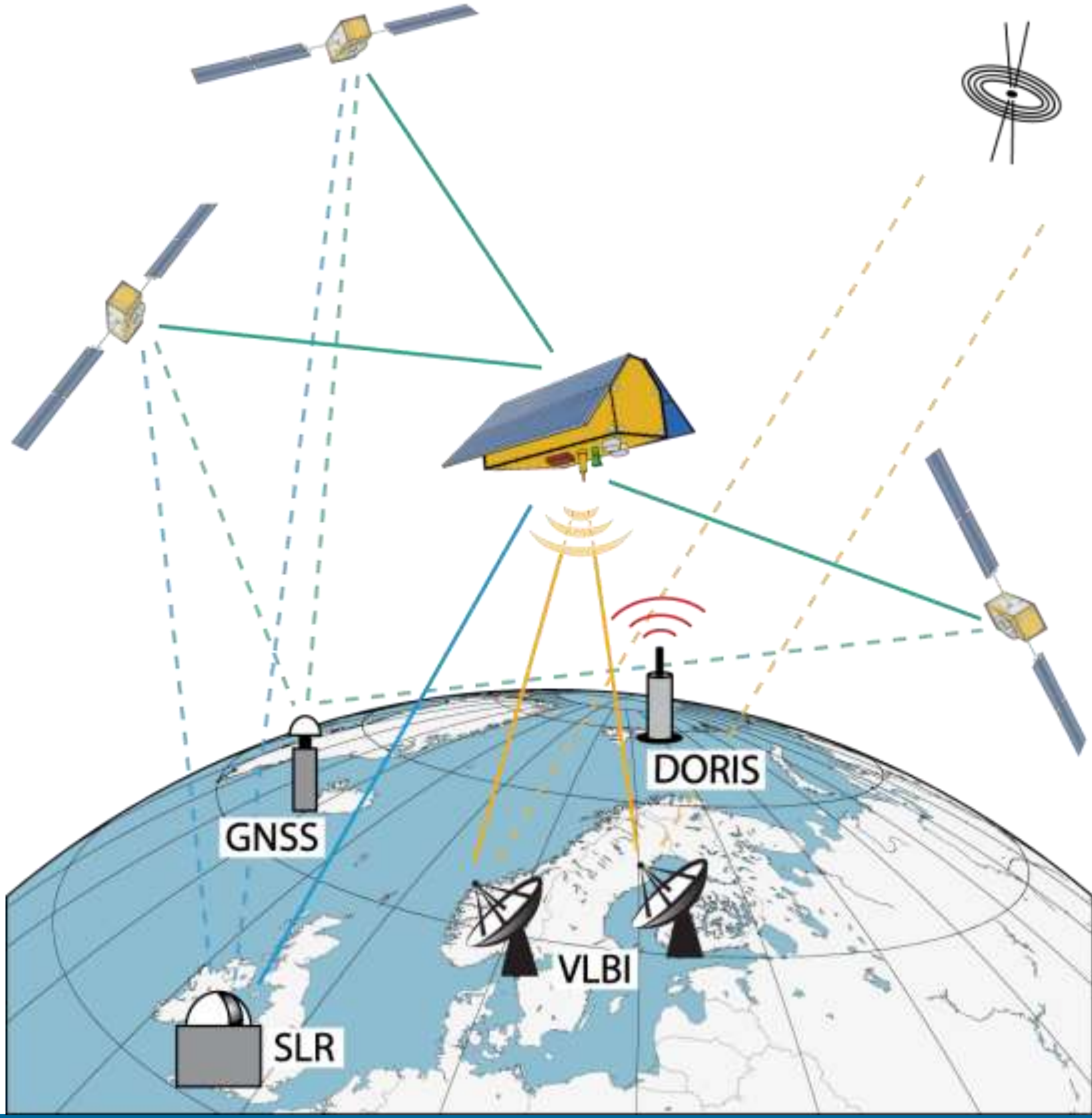
Johannes, Helene, Sofie, Lisa

ESA Genesis satellite

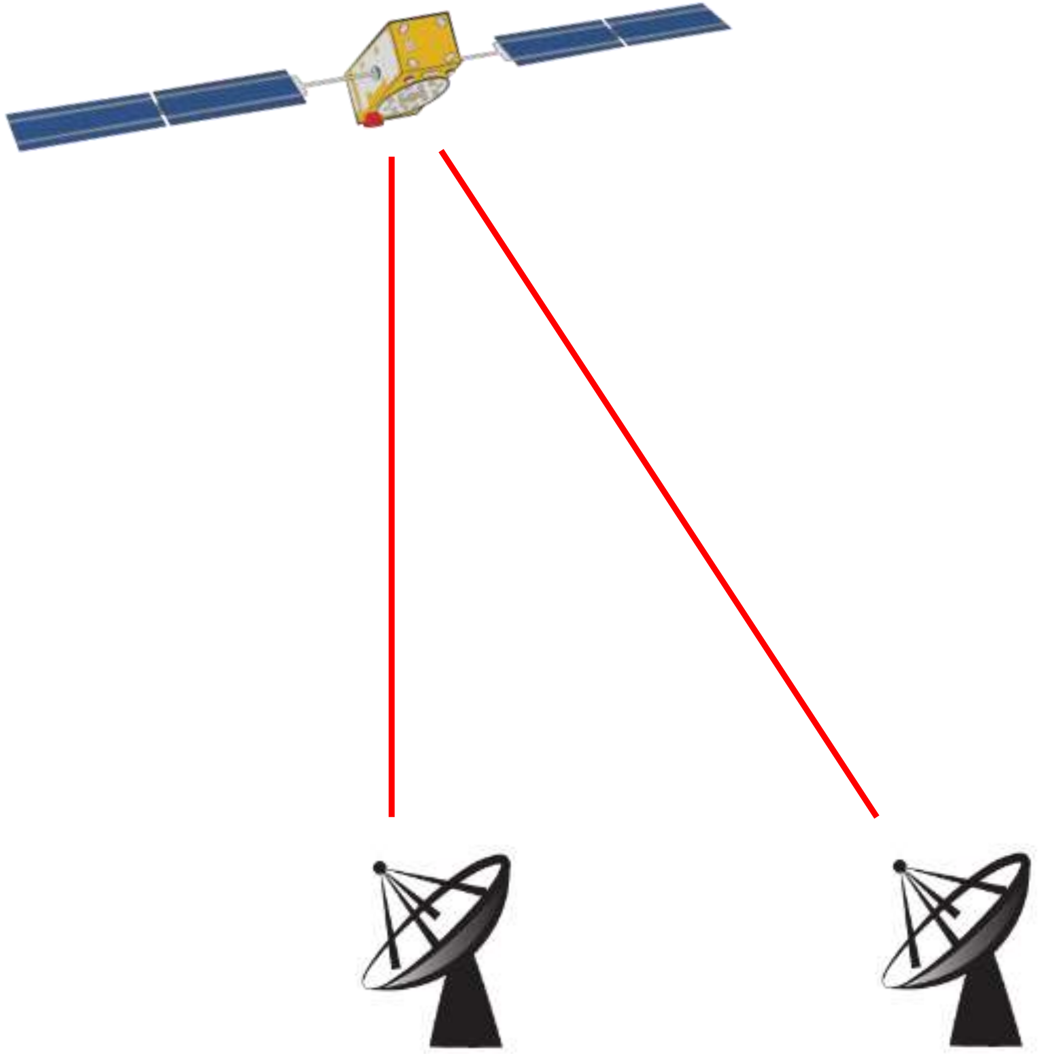
- Co-location satellite
  - GNSS receiver
  - DORIS receiver
  - SLR retro-reflector
  - VLBI transmitter

- Planned launch in 2027/2028
- Circular orbit with 6000 km altitude

→ Improve accuracy and stability of the International Terrestrial Reference Frame



VLBI observations to satellites



Recent extentions of the **VieVS package**

- ❖ **VieVS-VLBI** for processing VLBI observations to satellites
  - estimation of satellite orbit
  - estimation of station coordinates

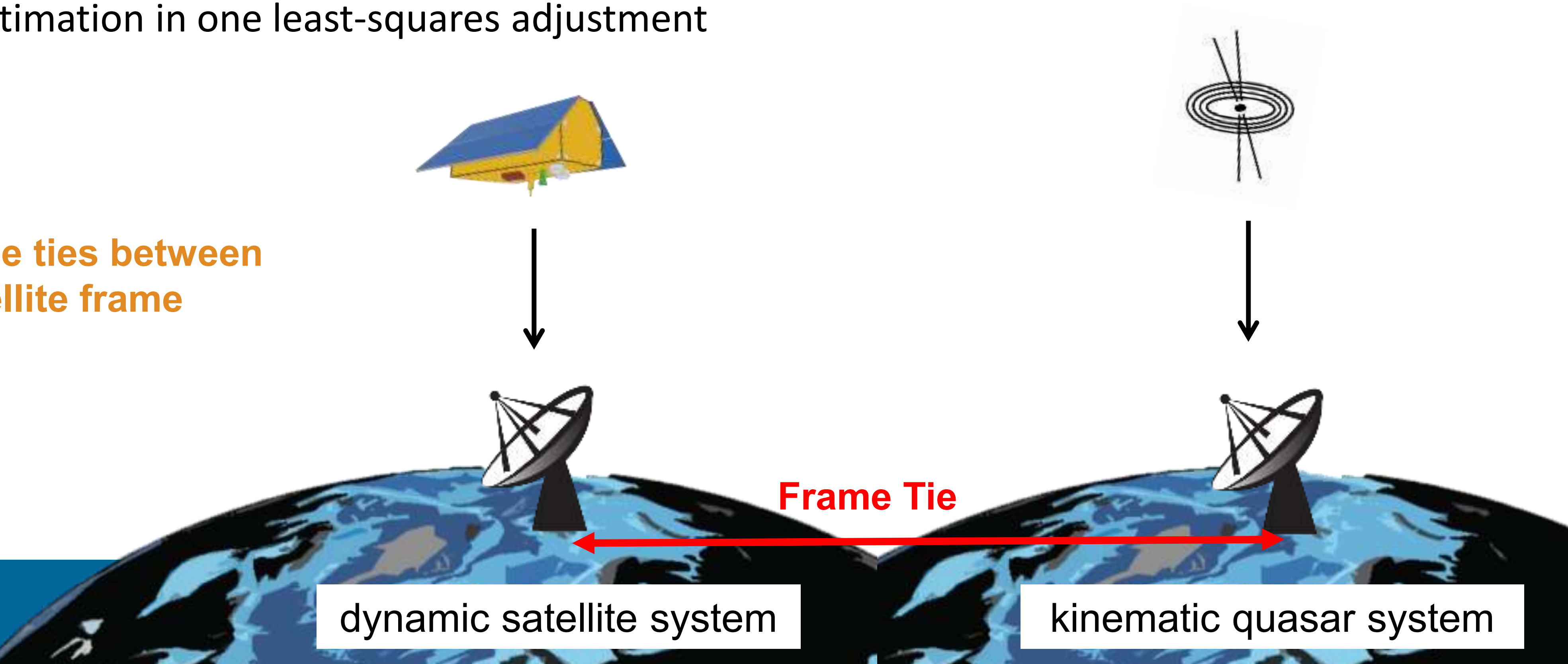
- ❖ **VieCompy** for combining NEQ systems containing
  - parameters associated with different observation types (quasar/satellite)
  - new parameters, e.g. satellite orbit

Johannes, Helene, Sofie, Lisa

VLBI observations to satellites

❖ Estimation of **station coordinates** based on
- all observations
- satellite observations only
- quasar observations only
- separate estimation in one least-squares adjustment

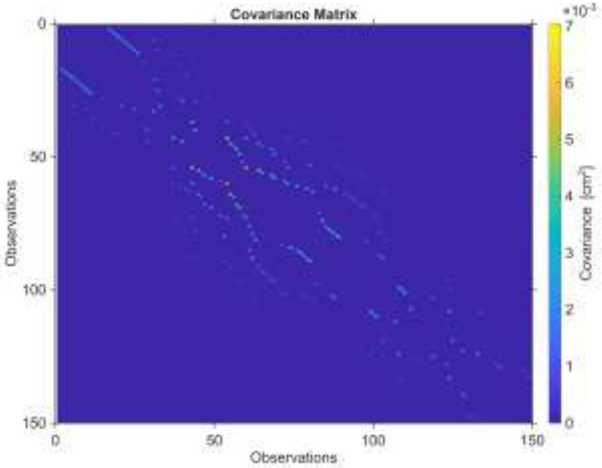
→ **analysis of frame ties between quasar and satellite frame**



Peter, Hana

Optimization of the VLBI stochastic model

- Consideration of a priori correlations between observations
- Accounting for correlations avoids overly optimistic or unrealistic formal errors of estimated geodetic parameters
- Station-specific, turbulence-based a priori correlation model for geodetic VLBI observations

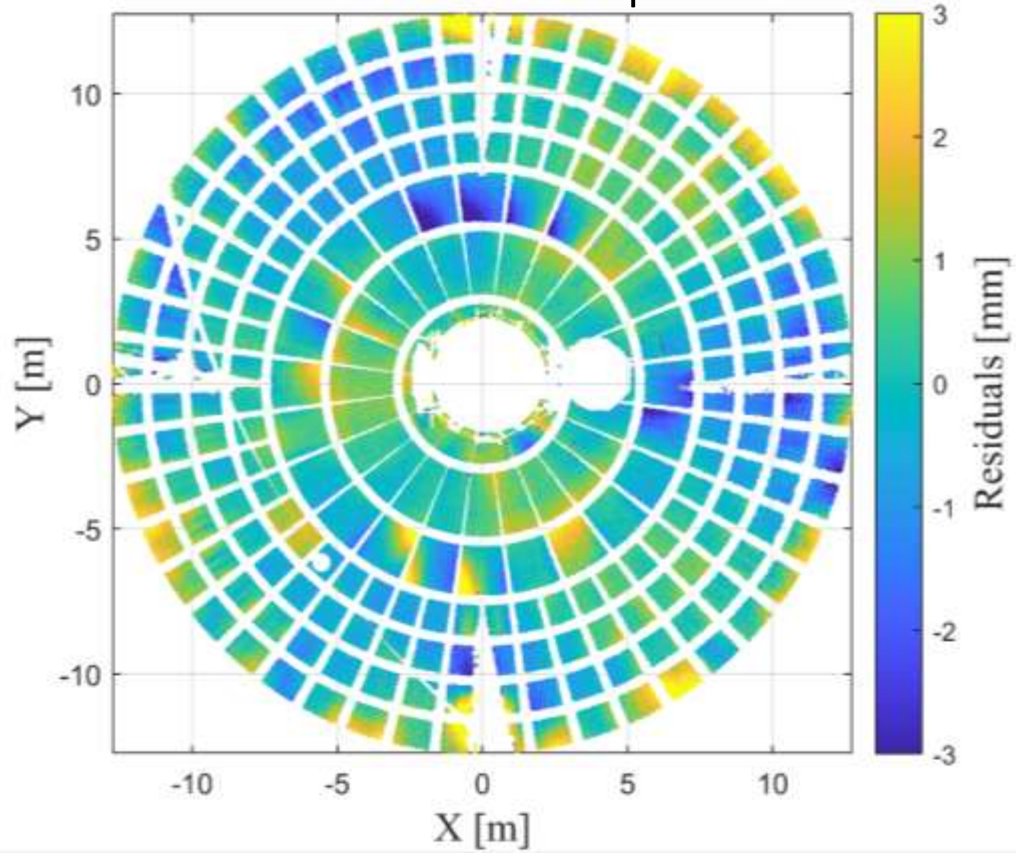


Onsala, Sweden; October 2025

Gravitational deformation analysis of HartRAO 26 m radio telescope

Laser scanner

Results: Panel deformations up to ±3 mm
→ elevation and azimuth dependent model



And there is much more research being done …

- Investigation of **TRF scale** differences from VLBI with respect to ITRF2020 (Kern et al., 2025)
- Evaluating the potential of Indian stations in augmenting the **UT1–UTC precision** of VGOS Intensive sessions (Laha et al., 2025)
- Evaluation of VGOS and legacy S/X VLBI observations with **non-tidal loading corrections** (Singh et al., 2025)
- Extension of VieVS with the **ionospheric delay** calibration of the dual-band sessions (e.g., S/X) and a state-of-the-art calculation of **effective frequencies** (Nothnagel et al., 2026)
- Investigation of **geodetic** results computed from **K-band VLBI** (Krásná et al., submitted)
- Time-series of **radio source** coordinates (Hodgson et al., 2026; Zhang et al., 2026)
- …