IAA VLBI Analysis Center Report

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Abstract This report presents an overview of the IAA VLBI Analysis Center activities in the 2023 – 2024 period and future plans.

1 General Information

The IAA IVS Analysis Center (IAA AC) operates in the Institute of Applied Astronomy of the Russian Academy of Sciences, in St. Petersburg, Russia. The IAA AC contributes to IVS products, such as TRF- and CRF-solutions and rapid and long-term series of EOP obtained from the IVS observational sessions. The IAA AC generates NGS files from VGOS files for use by the QUASAR and OCCAM/GROSS software packages. Besides IVS VLBI data, the IAA AC deals with the data treatment of the domestic observations produced by both the RT-32 radio telescopes (SVETLOE, ZELENCHK, and BADARY) and the RT-13 VGOS radio telescopes (ZELRT13V, BADRT13V, and SVERT13V).

2 Staff

- Dr. Sergey Kurdubov: Development of the QUASAR and analysis software.
- Dr. Elena Skurikhina (until July 2024): Team coordination, VLBI data processing, and OCCAM/GROSS and QUASAR software development.
- PhD Student Renata Urunova: Development of the QUASAR software, VLBI data processing, and global solutions.
- PhD Student Alexey Kudelkin (until October 2024): VLBI data processing, studies in the field of stochastic data modelling, and development of new techniques of scheduling VLBI observations.
- PhD Student Arseniy Serbin: Studies in the field of structural delay modelling and source structure effects.

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3 Activities During the Past Two Years

During 2023 and 2024, the IAA AC analyzed data of IVS (Legacy S/X and VGOS) and domestic observations, submitted to the ITRF2020-u2023, and made some investigations.

3.1 Routine Analysis

In 2023 and 2024, the IAA AC continued to generate daily SINEX (DSNX) files from analysis of IVS-R1 and IVS-R4 sessions using QUASAR software. The IAA AC didn't submit DSNX files since the last half of 2022 due to the necessity of upgrading the QUASAR software.

The IAA AC operationally processed the 24-hour and Intensive VLBI sessions using the QUASAR software and submitted the results to the IERS and the IVS on a regular basis.

3.2 Domestic Session Analysis

The IAA Analysis Center processes all observational data of domestic VLBI programs RI, R, and test sessions.

The IAA AC uses the standard IVS designation of the stations: Sv – Svetloe, Zc – Zelenchukskaya, and Bd – Badary for RT-32 and Bv – Badary, Zv – Zelenchukskaya, and Sw – Svetloe for RT-13.

Observational data from all these sessions are transmitted to the correlators using e-vlbi data transfer. The processing of RI sessions is fully automated. The calculated UT1-UTC time series is available at ftp://quasar.ipa.nw.ru/pub/EOS/IAA/veopi-ru.dat.

In 2023 and 2024, 729 RI sessions were observed using the QUASAR Legacy network (usually Badary–Zelenchukskaya, but Svetloe can replace one of the stations if needed), and 3943 sessions were observed using the QUASAR VGOS three-station network. RI sessions are the most rapid. The latency is about 2.5 hours. The latency for the R sessions is about six hours.

Program X is the experimental series at the S/X/Ka range. It was of 0.5 hour or one hour duration, on baseline BvZv.

3.3 Analysis of the Earth's Free Core Nutation

This section presents the results of a study on the Earth's free core nutation (FCN), based on long-term VLBI observations. The purpose was to develop an improved empirical model for predicting corrections to the celestial pole coordinates [1].

This study analyzed corrections to the celestial pole offsets (CPO) from 1979–2022 using VLBI observations processed with the QUASAR software.

The traditional model of FCN uses a single frequency of about -430 days, but it is limited to the observation period on which it was derived. To extend prediction capability, spectral analysis was applied to the CPO time series. The Lomb–Scargle periodogram was used for uneven data and compared with Fourier spectra from uniform IERS EOP series.

Analysis showed that the corrections can be described as the superposition of two harmonics. Using least-squares fitting, their periods were determined as -422 and -441 days. The new dual-frequency model provides more accurate and reliable predictions of CPO than the single-frequency approach.

3.4 Accounting for Source Structure

In 2023, studies were conducted to examine the feasibility of accounting for structural delays in VLBI observations. The results of the study were described in a paper [2], where quasar 0014+813 was used as the object of study, as it is one of the most luminous quasars in the Universe and has a pronounced extended structure.

The study utilized radio brightness maps from the Astrogeo database[1]. Rather than using radio brightness map pixels, the study utilized Gaussian functions approximating the radio brightness maps, which are located in the same files as the maps themselves. Residual delay residuals obtained after adjusting geodetic VLBI observations were also used, as the structural delay makes a significant contribution. This contribution manifests itself in systematic deviations of the residuals in their dependence on stellar time.

During the study, a program was developed for selecting Gaussian functions. The selection criterion was the maximum reduction in the standard deviation of the residuals. The study demonstrated that using all structural elements of quasar radio brightness maps does not allow for the structural delay to be correctly accounted for, while using the brightest structural elements of a quasar reduces the difference between the structural delay plots constructed from maps for different dates. This may be explained by the fact that the main contribution to the structural delay is made by the brightest components close to the quasar's center, which are less variable.

4 Current Status

The IAA AC processes the data of all kinds of VLBI geodetic observation sessions. We use the QUASAR and the OCCAM/GROSS software packages for VLBI data analysis. All observation models in these packages

[1] https://astrogeo.org

are compliant with the IERS Conventions (2010). Both packages use NGS files as input data. The QUASAR and the OCCAM/GROSS software packages are supported and are being developed. The QUASAR software was modified in accordance with the next realization of the ITRF2020 requirements.

5 Future Plans

- To continue submitting all types of IVS product contributions,
- To continue investigations of EOP, station coordinates, and tropospheric parameter time series,
- To improve algorithms and software for processing VLBI observations,
- To return to the submission of DSNX files.

References

1. R. Urunova, S. Kurdubov. Analysis of the Earth's Free Core Nutation Based on VLBI Observations Processing, in Transactions of IAA RAS. 2024. Vol. 70. pp. 50–55.
2. S. Kurdubov, A. Serbin. Accounting for the structure of a radio source in the processing of geodetic VLBI observations using the 0014+813 source as an example, in Transactions of IAA RAS. 2023. Vol. 66. pp. 18–28.