U.S. Naval Observatory VLBI Analysis Center

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Abstract This report summarizes the activities of the VLBI Analysis Center at the United States Naval Observatory for calendar years 2021–2022. During this period, Analysis Center personnel analyzed and made timely submissions to IVS of all R4, RV, CRF, and CRD databases and analysis reports; generated seven quarterly EOP updates; made and analyzed VLBA astrometry sessions for ICRF maintenance and enhancement; and engaged in research on active galactic nuclei (AGNs).

1 Introduction

The USNO VLBI Analysis Center is supported and operated by the United States Naval Observatory (USNO) in Washington, DC. It is a part of the Radio Optical Reference Frame Division (RORFD) in the Celestial Reference Frame Department at USNO. The primary services provided by the Analysis Center are the analysis of diurnal and UT1−UTC Intensive sessions and the production of periodic VLBI global solutions for estimation of the Terrestrial Reference Frame (TRF), the Celestial Reference Frame (CRF), and Earth Orientation Parameters (EOP). The Analysis Center continued the submission to the IVS of Intensive (EOP-I) and session-based (EOP-S) Earth Orientation Parameters based on USNO VLBI global solutions. Analysis Center personnel maintain the necessary software required to continue these services to the IVS including periodic updates of the GSFC CALC/SOLVE software package. In addition to operational VLBI analysis, Analysis Center personnel are actively engaged in improving the precision and accuracy of UT1−UTC measurements from Intensives and in research related to future updates of the celestial and terrestrial reference frames. The RORFD also actively performs astrophysical research of active galactic nuclei (AGNs) at radio, optical, and X-ray wavelengths.

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IVS 2021+2022 Biennial Report

2 Analysis Center Activities

2.1 IVS Session Analysis and Database Submission

During 2021–2022, personnel at the USNO VLBI Analysis Center continued the timely analysis and submission to IVS of all R4 sessions within 24 hours of database release from the correlators. The Analysis Center also assumed responsibility for the timely analysis and submission of all CRF and CRD sessions and for the scheduling, analysis, and submission of all RDV sessions. Analysis personnel also analyzed all R1, T2, and OHIG diurnal sessions as well as the INT-1, INT-2, INT-3, and INT-00 Intensive sessions released during the period. Automated analysis of Intensive sessions with nuSolve was tested and found to be satisfactory but is not yet actively being used. Further development will be pursued.

2.2 Quarterly Solutions

The Analysis Center generated three EOP/TRF/CRF quarterly solutions (usn2021a, usn2021b, and usn2021c) during 2021 and four during 2022 (usn2022a, usn2022b, usn2022c, and usn2022d). These quarterly solutions included diurnal EOP series (EOP-S), UT1−UTC Intensive series (EOP-I), and SINEX solution files for diurnal and Intensive sessions. The latest USNO solutions can be found at https://crf.usno.navy.mil/quarterly-vlbi-solution.

2.3 VLBA Intensive Sessions

The Analysis Center continued a program using the Very Long Baseline Array (VLBA), operated by NRAO, to provide a low-latency measurement of UT1−UTC through a variety of Intensive sessions. After 9.5 years of observing VLBA Intensives on the Mauna Kea and Pietown stations of the VLBA, observations on that baseline ceased on April 29, 2021. Simulations from VieSched++ and limited empirical data collected over the preceding decade indicated that Intensives observed on the baseline between the Mauna Kea and Hancock stations would be superior to the existing Intensives. Increased bandwidth to the Hancock VLBA station enabled the Analysis Center to begin testing of 90-minute Intensive sessions observed between the Mauna Kea and Hancock stations in May 2020. The testing validated the simulations, so the Mauna-Kea–Hancock Intensives became the primary VLBA Intensive series on April 30, 2021. At that same time, they began to be scheduled with the VieSched++ package using a semi-automated process to allow for dynamic session scheduling.

2.4 VLBA Celestial Reference Frame Sessions

The Analysis Center scheduled, observed, processed, and analyzed monthly X/S astrometry sessions run on the VLBA for the purpose of ICRF3 maintenance and expansion and for imaging of ICRF3 sources at X/S bands. Approximately 3,000 sources were re-observed multiple times to improve their ICRF positions, and approximately 360 new sources were added to the X/S CRF. Analysis Center personnel also processed and analyzed monthly VLBA and several southern hemisphere sessions at K-band (24 GHz) as part of a collaboration between USNO and personnel at the South African Radio Astronomy Observatory and the Jet Propulsion Laboratory to maintain and expand the ICRF3-K catalog. During the period, approximately 800 K-band sources were re-observed multiple times to improve their positions, and approximately 90 new K-band sources were added to the K-band CRF. Also during the period, the position and the proper motion of Sagittarius A*, the radio source associated with the supermassive black hole at the center of our galaxy, were determined for the first time in the ICRF3 frame at K-band.

2.5 Source Position Time Series Analysis

Analysis Center personnel generated several source position time series solutions at both X/S and K-band during the period. These solutions give the position of each source for each epoch for which it was observed. These solutions are being used to study the positional stability of ICRF sources. The latest time series solutions can be found at our website at https://crf.usno.navy.mil/quarterly-vlbi-solution.

2.6 VGOS Session Analysis

Analysis Center personnel are investigating the use of the VGOS Intensive and diurnal sessions for future EOP and TRF solutions. A preliminary VGOS Intensive UT1 series has been generated and is being periodically updated for research purposes. Also, X/S plus VGOS global solutions have been made in order to locate the new VGOS stations into the TRF. But it has been found that these solutions introduce small rotations of the celestial reference frame, indicating some issues in aligning the X/S TRF with the VGOS TRF. Further study is ongoing.

3 Staff

The Analysis Center is composed of seven USNO personnel. Their responsibilities and research areas are listed in Table 1.

Table 1 USNO VLBI Analysis Center staff in 2021–2022.

Name	Responsibilities
Megan Johnson	Diurnal session analysis, quarterly solutions, ITRF2020 solutions, USNO VLBA management, AGN research.
David Gordon	Diurnal session analysis, CRF/TRF/EOP solutions, RV and VLBA scheduling and analysis, ICRF solutions, ITRF2020, VGOS TRF/EOP solutions, source time series analysis.
Christopher Dieck	Intensive and diurnal session analysis, VLBA Intensive analysis and PI, internal software development and support.
Phil Cigan	Quarterly TRF/EOP/CRF solutions, diurnal session analysis, source time series analysis, AGN research.
Remington Sexton	Diurnal session analysis, AGN research at radio and optical wavelengths.
Andrew Sargent	Systems administration, Intensive and diurnal session analysis, AGN research.
Lucas Hunt*	VLBA and RDV calibration and imaging CRF source structure research, VLBA time allocation management.

*Now at NRAO

4 Future Activities

The following activities for 2023–2024 are planned:

1. Continue development of automated Intensive processing.
2. Determine VGOS station positions and velocities in support of operational analysis of VGOS Intensives.
3. Disseminate the master files and vgosDBs of the Mk–Pt and Hn–Mk VLBA Intensives to IVS.
4. Continue maintenance and expansion of the ICRF-X/S and ICRF-K catalogs and participate in the next realization of the ICRF at multiple radio and optical wavelengths.

5 Relevant Publications

1. “A New Wiggle in the Wobble? Uncovering Periodic Signals in Intensive Series”, Christopher Dieck, Megan Johnson, IVS 2022 General Meeting Proceedings, Kyla L. Armstrong, Dirk Behrend, and Karen D. Baver, editors, NASA/CP-20220018789, 2023.
2. “Current CRF Status at X/S and K Bands”, David Gordon, Aletha de Witt, Christopher S. Jacobs, IVS 2022 General Meeting Proceedings, Kyla L. Armstrong, Dirk Behrend, and Karen D. Baver, editors, NASA/CP-20220018789, 2023.
3. “Three Years of ICRF3 Source Positions”, Phil Cigan, David Gordon, Megan Johnson, IVS 2022 General Meeting Proceedings, Kyla L. Armstrong, Dirk Behrend, and Karen D. Baver, editors, NASA/CP-20220018789, 2023.
4. “Sources with Significant Astrometric Offsets Between the S/X and K-band Celestial Frames”, Aletha de Witt, Christopher S. Jacobs, David Gordon, Lucas Hunt, Megan Johnson, IVS 2022 General Meeting Proceedings, Kyla L. Armstrong, Dirk Behrend, and Karen D. Baver, editors, NASA/CP-20220018789, 2023.
5. “ICRF3 Position and Proper Motion of Sagittarius A* from VLBA Absolute Astrometry”, David Gordon, Aletha de Witt, Christopher S. Jacobs, IVS 2022 General Meeting Proceedings, Kyla L. Armstrong, Dirk Behrend, and Karen D. Baver, editors, NASA/CP-20220018789, 2023.
6. “Overview and Status of the International Celestial Reference Frame as Realized by VLBI”, Aletha de Witt, Patrick Charlot, David Gordon, Christopher S. Jacobs, 2022, Universe 2022, 8, 374. (https://www.mdpi.com/2218-1997/8/7/374)
7. “Position and Proper Motion of Sagittarius A* in the ICRF3 Frame from VLBI Absolute Astrometry”, David Gordon, Aletha de Witt, Christopher S. Jacobs, 2023, The Astronomical Journal, 165:49. (https://iopscience.iop.org/article/10.3847/1538-3881/aca65b/pdf)