USNO Analysis Center for Source Structure Report

Megan Johnson, Lucas Hunt, Phillip Cigan, Christopher Dieck, Nicole Geiger

Abstract This report summarizes the activities of the United States Naval Observatory Analysis Center for Source Structure for the 2019 and 2020 calendar years.

1 Analysis Center Operation

The Analysis Center for Source Structure is supported and operated by the United States Naval Observatory (USNO). The charter of the Analysis Center is to provide products directly related to the IVS determination of the "definition and maintenance of the celestial reference frame." These include, primarily, radio frequency images of International Celestial Reference Frame (ICRF) sources, intrinsic structure models derived from the radio images, and an assessment of the astrometric quality of the ICRF sources based on their intrinsic structure.

The primary service of the Analysis Center is maintaining a Web accessible data archive of radio frequency images of ICRF sources. We are currently in the midst of updating, improving, and expanding our archive. Historically, this Web accessible data archive was called the Radio Reference Frame Image Database (RRFID). We are changing the name of the archive to the Fundamental Reference Image Data Archive (FRIDA) and debuting an improved, more functional interface, which will be made publicly available in 2021.

FRIDA will contain tens of thousands of images from the Very Long Baseline Array (VLBA) as well as other radio VLBI networks at frequencies of 2.3, 8.4, 24, and 43 GHz. FRIDA will also contain 74 images of 69 Southern Hemisphere ICRF sources using the Australian Long Baseline Array (LBA) at a radio frequency of 8.4 GHz.

Images of ICRF sources can also be obtained from the Bordeaux VLBI Image Database (BVID) at

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http://bvid.astrophy.u-bordeaux.fr
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2 Current Activities

2.1 VLBA Imaging

Very Long Baseline Array (VLBA) observations for maintenance of the celestial and terrestrial reference frames have been carried out since approximately 1994. Since 1997, these VLBA RDV (Research and Development VLBI) observations have been part of a joint program between the USNO, Goddard Space Flight Center (GSFC), and the National Radio Astronomy Observatory (NRAO). During each 24-hour VLBA RDV session, approximately 100 ICRF sources are observed at S/X-band (2.3/8.4 GHz) using the VLBA together with up to ten additional geodetic VLBI antennas. Images are produced from these observations and made available through the FRIDA.

Beginning in January 2017, USNO entered into a 50% timeshare agreement with the VLBA, under which we began observing ICRF sources for the purposes of astrometry, geodesy, and imaging. Since the start of the 50% timeshare agreement, in collaboration

with GSFC, USNO has been running a series of observations called the UF/UG/UH-series. This series is observed at S/X-band (2.3/8.4 GHz) and is dual purpose in that the 24-hour experiments are designed for astrometry and geodesy but scheduled to optimize the *uv*-coverage of each source for imaging. The UF/UG/UH-series contains roughly 300 sources per session, most of which are primarily from the VLBA Calibrator Survey (VCS) catalog. Understanding the source structure characteristics of the objects in the VCS catalog is paramount to improving and maintaining the ICRF because of the high number and density of VCS sources in the current ICRF-3 iteration.

In addition to the UF/UG/UH-series, USNO has also been supporting a VLBA project at K-band under our timeshare agreement. The principal investigator of this project is Dr. Aletha de Witt from Hartebeesthoek Radio Astronomical Observatory (HartRAO). Nearly all of the K-band data that are included in the recently adopted ICRF-3 have come from this project. These observations are also maximized for imaging, and we plan to include these K-band images in our FRIDA Web accessible data archive once they become available.

3 Staff

The staff of the Analysis Center during 2019 consisted of Megan C. Johnson, Alan L. Fey, Lucas R. Hunt, John Spitzak, Christopher A. Dieck, and Nicole P. Geiger. The staff of the Analysis Center changed during 2020 with the retirement of Alan L. Fey and changes to the contractors; thus, it consisted of Megan C. Johnson, Lucas R. Hunt, Phillip Cigan, Christopher A. Dieck, and Nicole P. Geiger.

4 Future Activities

The Analysis Center currently has a program of active research investigating the effects of intrinsic source structure on astrometric position determination. Results of this program are published in the scientific literature.

The following activities for 2021 are planned:

- Continue with the imaging and analysis of VLBA 2.3/8.4 GHz experiments.
- Continue the development of the Fundamental Reference Image Data Archive (FRIDA) as a Web accessible database of radio frequency images of ICRF sources.
- Continue maintenance work of source structure for ICRF-3.

5 Relevant Publications

Publications of relevance to Analysis Center activities are:

- "The Precious Set of Radio-optical Reference Frame Objects in the Light of *Gaia* DR2 Data," Makarov, V. V., Berghea, C. T., Frouard, J., Fey, A., & Schmitt, H. R., 2019, ApJ, 873, 132
- "Toward the ICRF3: Astrometric Comparison of the USNO 2016A VLBI Solution with ICRF2 and *Gaia* DR1," Frouard, J., Johnson, M. C., Fey, A., Makarov, V. V., & Dorland, B., 2018, AJ, 155, 229
- "Astrometric Evidence for a Population of Dislodged AGNs," Makarov, V. V., Frouard, J., Berghea, C. T., Rest, A., Chambers, K. C., Kaiser, N., Kudritzki, R.-P., & Magnier, E. A., 2017, ApJ, 835, 30
- "Second Epoch VLBA Calibrator Survey Observations: VCS-II," Gordon, D., Jacobs, C., Beasley, A., Peck, A., Gaume, R., Charlot, P., Fey, A., Ma, C., Titov, O., & Boboltz, D., 2016, AJ, 151, 154
- "The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry," Fey, A., et al., 2015, AJ, 150, 58
- "Relativistic Jets in the Radio Reference Frame Image Database. II. Blazar Jet Accelerations from the First 10 Years of Data (1994-2003)," Piner, B. G., Pushkarev, A. B., Kovalev, Y. Y., Marvin, C. J., Arenson, J. G., Charlot, P., Fey, A. L., Collioud, A., & Voitsik, P. A., 2012, ApJ, 758, 84
- "Characterization of long baseline calibrators at 2.3 GHz," Hungwe, F., Ojha, R., Booth, R. S., Bietenholz, M. F., Collioud, A., Charlot, P., Boboltz, D., & Fey, A. L., 2011, MNRAS, 418, 2113
- "The Position/Structure Stability of Four ICRF2 Sources," Fomalont, E., Johnston, K., Fey, A. L., Boboltz, D., Oyama, T., & Honma, M., 2011, AJ, 141, 91