IVS SHAO Analysis Center 2017–2018 Biennial Report

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Abstract This report presents the routine work and the research work carried out at the SHAO VLBI Analysis Center (AC) during 2017 and 2018. The SHAO AC continues the routine VLBI data analysis of IVS 24-hour geodetic/astrometric sessions and takes the responsibility of analyzing the CVN data. Research works related to VLBI astrometry and geodesy during these two years are reported.

1 General Information

The SHAO VLBI Analysis Center is located at Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences, China. It is a part of the Astrometry research group in the Center for Astrogeodynamics at SHAO. Some members are from the VLBI application in the Chinese deep space mission. We are processing the Chinese VLBI Network (CVN) data and IVS 24-hour routine sessions and one-hour Intensive UT1 sessions to provide our results and investigate some interesting topics in VLBI.

2 Component Description

The SHAO Analysis Center analyzed all the IVS sessions by using the Calc/Solve and nuSolve software package, and 16 CVN sessions (including solving ambiguities and determining the ionospheric effect from dual band data). We provided VLBI products, i.e., EOP, CRF, and TRF, for the Chinese EOP Services. We analyzed 347 Intensive sessions and submitted to the IVS in 2017. We continued to investigate the source structure effect in geodetic VLBI and attempted to correct the source structure effect in data analysis.

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3 Staff

During 2017 and 2018, the staff of the SHAO AC consisted of one consultant, Professor Zhihan Qian, group leader Dr. Guangli Wang, and eight employees. Table 1 lists the staff members and their main areas of activity.

4 Current Status and Activities

- We submitted sinex file products from 347 Intensive sessions in 2017 to the IVS Combination Center for the test run of combination analysis of UT1 sessions and regular IVS 24-hour sessions.
- To study source structure effects in geodetic VLBI, we processed the VLBI data of the CONT17 continuous observing campaign, adopting standard geodetic and imaging techniques. From the results, we analyzed the influence of the station dependent errors, such as tropospheric and ionospheric errors, clock and cable length errors, and station position errors, on the combinations of interferometric measurements such as delay closures. Our study shows that source structure is a major contributor to errors in geodetic VLBI, and source structure must be taken into account in the entire VLBI operational

chain. The overall structure-effect magnitudes for 3,417 ICRF radio sources are quantified by closure analyzing of 40 years of VLBI historical data. The evolution of source structure for those sources has also been shown.

- As a subgroup of the IVS, the Asia-Oceania VLBI group for Geodesy and Astrometry (AOV) was founded in 2014. Thirty AOV observing sessions were conducted by the end of 2018. The scheduling of these sessions is shared between three institutes (GSI, SHAO, and UTAS) and the correlation amongst two (GSI and SHAO). From 2015 onwards the APSG sessions' scheduling and correlation is now handled by SHAO, under their commitment to the AOV region.
- The AOV and APSG networks are unique to the astrometry of weak sources in the middle southern hemisphere and the ecliptic plane. We have observed 357 weak sources in 17 AOV/APSG sessions. The observations of 194 target sources from 2015 to 2017 were included in the ICRF3 catalog released in August 2018. It is worth noting that there are 132 new sources firstly observed by the AOV. As shown in Figure 1, with additional data acquired in 2018, we have detected 326 target sources successfully. Among them, 109 sources are old ICRF2 sources with improved positions, 167 sources are newly included in the ICRF3, and 50 sources are newly introduced to the IVS data but not included in the ICRF yet.

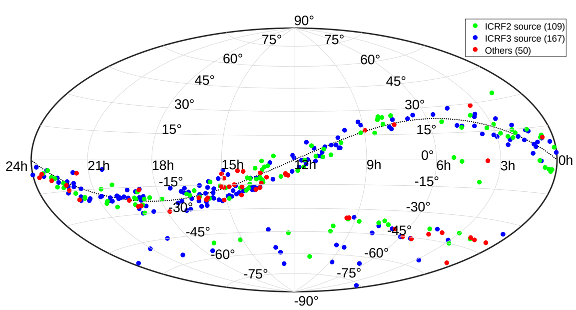

Fig. 1 We have detected 326 target sources successfully.

- For VLBI astrometry, we have measured a trigonometric parallax of the semi-regular variable RT Vir from multi-epoch Very Long Baseline Array observations of its circumstellar H2O masers at 22 GHz. The parallax of 4.417 $\pm$ 0.134 mas, corresponding to a distance of 226 $\pm$ 7 pc, is significantly different from the Hipparcos parallax of 7.38 $\pm$ 0.84 and the Gaia DR2 parallax of 2.050 $\pm$ 0.291 mas but is consistent with a distance derived from the period luminosity relation (PLR). This suggests that the optical parallax suffers from systematic bias, possibly owing to a variable photo-center for this giant star. As such, VLBI parallax measurements will serve as an important cross-check for Gaia (Zhang et al., 2017).
- We reported astrometric results of VLBI phase-referencing observations of 22 GHz H2O maser emission toward the red hypergiant VX Sgr (Figure 2), one of the most massive and luminous red hypergiant stars in our Galaxy, using the Very Long Baseline Array. A background source, J1820-2528, projected 4.4 degrees from the target VX Sgr, was used as the phase reference. Due to the low declination of these sources, such a large separation normally would seriously degrade the relative astrometry. We use a two-step method of tropospheric delay calibration, which combines the VLBI geodetic-block (or GPS) calibration with an image-optimization calibration, to obtain a trigonometric parallax of 0.64 $\pm$ 0.04 mas. The measured proper motion of VX Sgr is 0.36 $\pm$ 0.76 and -2.92 $\pm$ 0.78 mas/yr in the eastward and northward directions. The parallax and proper motion confirm that VX Sgr belongs to the Sgr OB1 association (Xu et al., 2018).
- We compared the parallaxes of stars from VLBI astrometry in the literature to those in the Gaia DR2 catalog (Figure 3). Our full sample contains young stellar objects, evolved AGB stars, pulsars, and other radio stars. Excluding AGB stars, which show significant discrepancies between Gaia and VLBI parallaxes, and stars in binary systems, we obtain an average, systematic, parallax offset of -75 $\pm$ 129 uas zero-point between -100 and 0 uas (Xu et al., 2019).
- We have evaluated the relative astrometric accuracy of the KVN and VERA Array (KaVA) with quasar-quasar observations. We confirmed that KaVA can potentially achieve positional accuracies of 20 uas in right ascension and 40 uas at K-band. With our result, KaVA opened the phase referencing mode for the first time in 2019 (KaVA Status Report for 2019A).

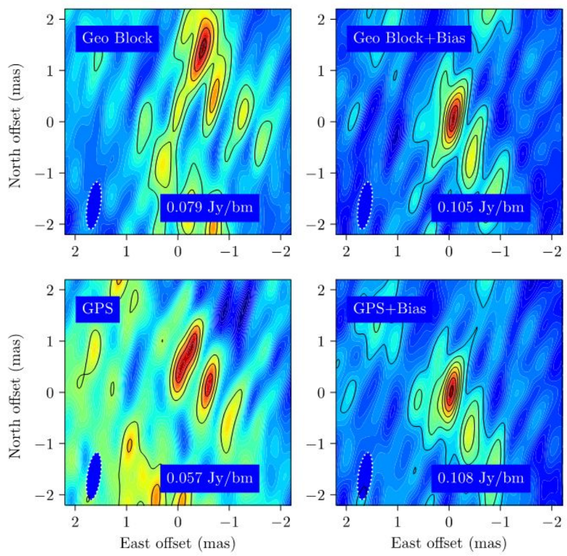

Fig. 2 Phase-referenced images with geodetic-like observations (upper left panel), with geodetic-like observations plus bias correction (upper right panel), with GPS data (bottom left panel), and with GPS data plus bias correction (bottom right panel) (Xu et al., 2018).

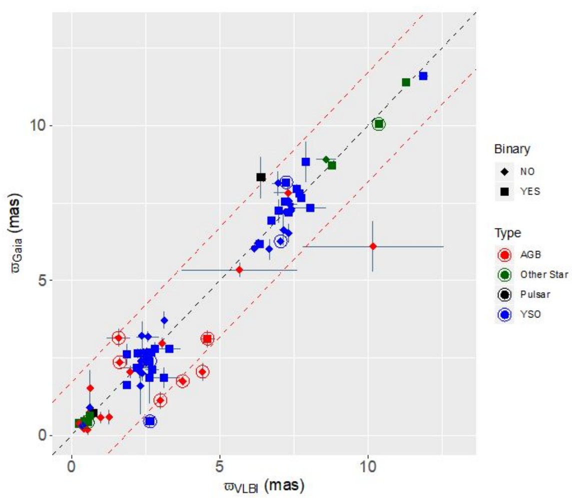

Fig. 3 Gaia DR2 vs. VLBI parallaxes. Colors denote different stellar types, and known binaries are shown in different shapes (Xu et al. 2019).

- We have been working on building a VGOS-type antenna in the yard of the new Tianma 65-meter antenna. The station is ready for testing.
- Most of our group is deeply involved in the Chang'E-4 mission, on s/c (spacecraft) post-correlation and positioning in real time.

5 Future Plans

We will mainly focus on data analysis of observations made by VGOS-type antennas in China and continue to participate in IVS routine analysis work.

Table 1 Staff members and their main tasks.

Dr. Guangli Wang	VLBI2010, data analysis, and leader
Dr. Jinling Li	Positioning, VLBI2010, and data analysis
Dr. Minghui Xu	Data analysis and imaging
Dr. Zhibin Zhang	Data analysis
Dr. Li Guo	Positioning and data analysis
Dr. Bo Zhang	Phase referencing and imaging
Dr. Shuangjing Xu	Imaging and data analysis
Dr. Fengchun Shu	Schedules, correlation, and data analysis
Prof. Zhihan Qian	Consulting
Dr. Liang Li	Data analysis and CRF