SHAO Analysis Center 2008 Annual Report

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Abstract

Our research activities in 2008 are related to astrometric and geodetic VLBI experiments and data analysis, the astrometry of massive star-forming regions and luminous red supergiants, the processing of VLBI tracking data of satellites, and antenna site surveys. These activities will be continued in the next year. We will prepare software for the next Chinese lunar and Martian exploration projects.

1. General Information

We use the CALC/SOLVE system for routine VLBI data analysis. We are developing software coded in FORTRAN to deal with satellite tracking data using the VLBI, ranging and Doppler techniques. The members involved in the IVS analysis activities are Guangli Wang, Bo Zhang, Shubo Qiao, Zhihan Qian, and Jinling Li.

2. Activities in 2008

We participated in some IERS/IVS campaigns aimed at comparisons of reference frames and/or Earth Rotation Parameters. Our research activities in 2008 are also related to the VLBI experiments and data analysis from the Chinese VLBI Network (CVN), the astrometry of massive star-forming regions and luminous red supergiants, the processing of VLBI tracking data of satellites, and antenna site surveys.

2.1. Astrometric and Geodetic VLBI Experiments and Data Analysis

For the compilation of the next generation of ICRF, we submitted to IVS an extragalactic radio source catalogue and a source coordinate time series from our solutions. We conducted VLBI experiments using the CVN, including the antennas at Shanghai, Urumqi, Beijing, and Kunming, and performed the related data analysis in order to determine the coordinates and velocities for the Chinese space exploration projects, as well as for the Project of Monitoring Network of the Chinese Mainland Geological Environment. Using the Calc/Solve system, we obtained a series of global solutions of astrometric and geodetic VLBI observations by changing the settings of the control parameters. By comparison and statistical analysis of the solutions, we proposed a list of candidate stable sources.

2.2. Astrometry of Massive Star-forming Regions and Luminous Red Supergiants

We have measured trigonometric parallaxes of methanol masers in the high-mass star-forming regions G35.20−0.74 and G35.20−1.74, corresponding to distances of $2.19^{+0.24}_{-0.20}$ kpc and $3.27^{+0.56}_{-0.42}$ kpc, respectively. The distances to both sources are close to their near kinematic distances and place them in the Carina-Sagittarius spiral arm. Combining the distances and proper motions with observed radial velocities gives the locations and full space motions of the star-forming regions. Assuming a standard model of the Galaxy, G35.20−0.74 and G35.20−1.74 have peculiar motions

of ~ 13 km s^{-1} and ~ 16 km s^{-1} counter to Galactic rotation and ~ 9 km s^{-1} toward the North Galactic Pole.

Accurate distances to the hyper-luminous red supergiants (VY CMa, NML Cyg, VX Sgr, AH Sco, and S Per) are very important to understanding the characteristics of this category of sources, such as stellar radius, mass, luminosity, and circumstellar mass loss. We have proposed to measure trigonometric parallaxes and proper motions of the H2O and SiO masers in the Luminous Red Supergiants NML Cyg and AH Sco, to try to achieve distances accurate to better than 5%. Our observations would reference both maser species to the same quasar. This would allow us to measure the H2O and the SiO masers with milli-arcsec accuracy. A future VLA A-configuration observation would determine the size of the radio photosphere and reference the star to the masers. The combined VLBA/VLA results will allow a direct measurement of acceleration around the dust formation zone (between the SiO and H2O maser radii) and hence lead to a better understanding of dust formation. In addition, since supergiants have not lived long enough to wander far from their birth sites in high mass star-forming regions, the parallax observations will add more sources to help map the Milky Way's spiral structure. Observations of the Red Supergiants NML Cyg with the VLBA (7 hours $\times$ 5 epochs, 2008–2009) and AH Sco with VERA (6 hours $\times$ 4 epochs + 5 hours $\times$ 10 epochs, 2008–2009) are on-going. The first three epochs have been analyzed, and the data look excellent.

2.3. Data Analysis in the Chinese Space Exploration Projects

In the Chinese lunar exploration project Chang'E-1 (CE-1), the satellite tracking data consist of range and Doppler measurements as well as the VLBI delay and delay rate. We have developed reduction software to provide the estimation of instantaneous state vectors of the satellite, and we have processed the tracking data of the CE-1 satellite in real-time. A geometric reduction is performed in lieu of an application of dynamic constraints to the observations belonging to different wave-fronts at different epochs, and so the length of tracking arc is not a crucial prerequisite. The software could be used to monitor the quality of tracking data and to identify the evolution of satellite orbits, with the efficiency and speed needed to implement projects.

The next step is to perform the synthesis reduction of VLBI observations of satellites and quasars, especially differential VLBI observations and same beam interferometry observations, which are especially important for the next Chinese lunar and Martian explorations.

2.4. Site Survey at the Sheshan 25-m Radio Telescope

We conducted a site survey at the Sheshan 25-m radio telescope in July and August 2008 in order to develop a strategy of observing and data analysis, to develop software and to check the precision of parameter solutions. This survey is a part of the whole effort to determine the local tie parameters among the sites of VLBI and SLR at Sheshan. Such parameters are important to the compilation of terrestrial reference frames based on various space geodetic techniques.

In a distinct difference from the previous surveys at this telescope, in this survey the local control network was set up as reinforced concrete pillars with stainless steel devices on top for forced centering. With this set up, the long term stability of the control points and the high precision of the height measurement of the instruments and targets could be sustained in comparison to temporary ground marks and survey tripods.

During observing, the network was arranged around the antenna to provide the best possible

geometry given the restriction that the antenna is not centrally located in the observing yard. Also, redundant data were collected in order to sustain the precision of parameter solutions. Especially some improvements to the fitting of arcs and lines in space, were proposed and adopted: specifically, using the transformation of coordinate systems to simplify a 3-dimensional fitting to a planar reduction, which sustains the stability and uniqueness of parameter solutions. For instance, the projection method is usually used to fit to a circle in space—that is, to fit an ellipse projected from a circle in space onto a plane. Results from data simulation show that in the projection method, the solution of parameters is quite unstable and becomes dispersive even with a relatively low level of observation noise. But in the method of coordinate system transformation, the normal direction of the plane inscribed by a circle in space is firstly determined. This direction is taken as the z-axis of a temporary coordinate system, in which the circle becomes planar and could be easily fitted with only three parameters, including two for the planar coordinates of the center and one for the radius. The solution is proved to be quite stable, and the observation noises are well suppressed. Comparatively, in the fitting of a planar ellipse there should be five parameters including two for the center coordinates, two for the semi-major and minor axes and one for the direction of the semi-major axis.

In the WGS84 (G1150) system, the coordinates of the reference mark of the Sheshan 25-m radio telescope are determined from this survey as:

-2831687.3377 m ± 0.84 mm

4675734.2901 m ± 0.99 mm

3275329.0112 m ± 0.88 mm

The reference epoch is MJD54689, and the axis offset is fit to be $3.4 \pm 0.7 mm$. The precision is at the millimeter level, which shows the rationality and validity of the strategy and the implementation of the steps in this survey.

3. Plans for 2009

The above mentioned research activities will be continued in 2009. Specifically, we will accumulate knowledge and develop software for the next Chinese space exploration projects.