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Status and Plan of Geodetic and Astrometric Observations with VERA

Seiji Manabe, Yoshiaki Tamura, Takkaki Jike, Koji Horiai, VERA Team

National Astronomical Observatory of Japan

Contact author: Seiji Manabe, e-mail: manabe@miz.nao.ac.jp

Abstract

The construction of VERA (VLBI Exploration of Radio Astrometry) was completed in 2002 and scientific and system-checking observations are regularly done. In the recent two years since the previous IVS General Meeting there are two important progresses. One is that VERA's promising capability in the phase compensation was demonstrated by using a real observation. The other is that phase referenced maps are obtained with good but not sufficient positional accuracy. There have been some geodetic observations by participating in the Geographic Survey Institute (GSI)'s domestic observations on a once-a-month basis and link of Mizusawa station to the Tsukuba 32m antenna was obtained. Current status and some future plans of VERA are briefly reviewed.

1. Introduction

VERA is a Japanese domestic VLBI network consisting of Mizusawa, Iriki, Ogasawara and Ishigakijima stations. The construction of the four stations was completed at the end of March, 2002. Each station is equipped with a 20m radio telescope and VLBI backends.

The primary scientific goal of VERA is to reveal structure and dynamics of our Galaxy by determinig 3-dimensional force field and mass distribution. Galactic maser sources are used as dynamical probes, positions and velocities of which can be precisely determined by phase referenced VLBI relative to extragalactic radio sources. The distance is measured as a classical annual trigonometric parallax. The target accuracy in the annual parallax determination is 10μas. With this accuracy the distance to annual parallax of an object at a distance of Dkpc is given by D%.

In order for realizing this accuracy it is necessary to remove the effect of atmospheric fluctuation which is the largest error source in conventional VLBI. One of the methods to remove this effect is the phase referenced VLBI observation of two closely separated objects. VERA is equipped with a dual beam receiving system which enables observations of two objects simultaneously.

In this paper some recent progresses and current status of geodetic and astrometric observations will be described. Some future plans will also be presented.

2. Progress in the Recent Two Years

2.1. Proof of Capability of the Phase Compensation

VERA's enormous capability in phase compensation was first shown by Honma *et al.* (2002). Fig. 1 shows the observed fringe phases of the two strong maser souces, W49N and OH43.8-0.1 separated by 0.65°, and the differences between them for Mizusawa-Iriki baseline (1300km). The constant biases are subtracted from the individual phases. It is seen that the fringe phases change almost in parallel (indistinguishable in the figure) and the differences are much smaller than the

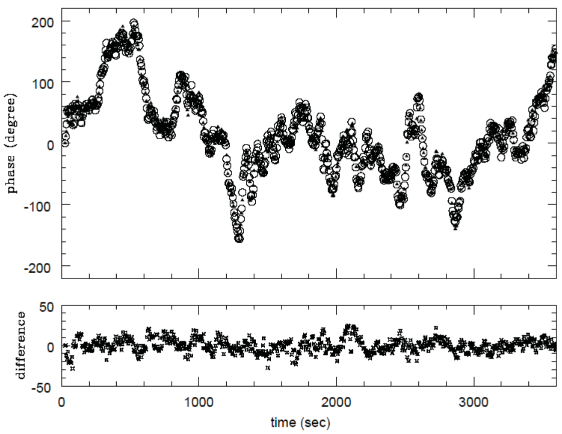

Figure 1. Top: observed fringe phases of W51N (open circle) and OH43.8-01 (triangle). Bottom: differential fringe phases. (Honma *et al.*, 2003)

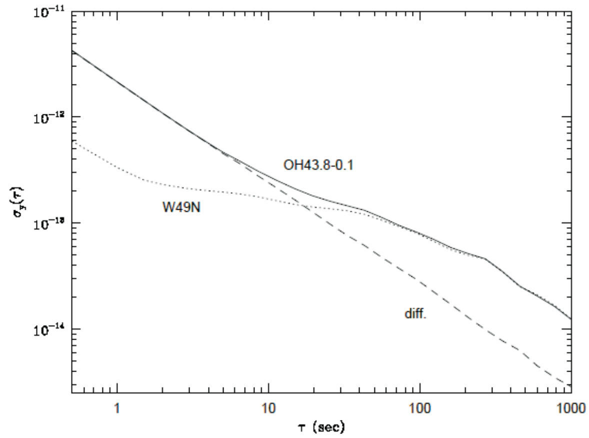

Figure 2. Allan standard deviations of the observed and differential fringe phases (Honma *et al.*, 2003)

variations of the individual fringe phases. The randomness of the differential fringe phases is confirmed in Fig. 2 which shows Allan standard deviations of the original and differential fringe phases. The linearity of the differential fringe phase proves that the spectrum is white and there remains no dominant systematic errors.

2.2. Phase-Referenced Maps of QSOs and Astrometric Precision

Fig. 3 shows the first phase referenced maps of 3C345 with respect to NRAO512 (Rioja *et al.*, 2003, private communication). Comparing the detailed map obtained by VLBA, it is seen that the overall features are recovered although fine structures are not resovled because of the small number of the stations and the short lengths of the baselines. The S/N ratio of the phase referenced map is almost the same as that of the non-phase referenced self-calibrated map.

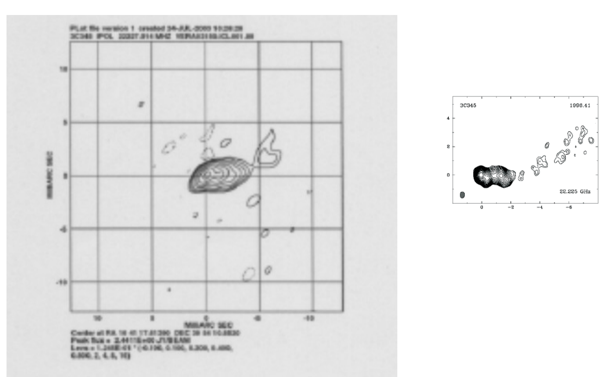

Figure 3. Left: map of 3C345 with reference to NRAO512 obtained with VERA. Right: map of 3C345 otained with VLBA.

In order to see the reliability of observation, maps of NRAO512 at three different epochs are compared in Fig. 4. The beam shape of the right map is fairly elongated because only Mizusawa, Iriki and Ishigakijima which are almost collinearly located participated in the observation. The positions of the brightness peaks coincide with the accuracy of 0.1mas which is better than that of HIPPARCOS by almost one order of magnitude although it is an order larger than the target accuracy.

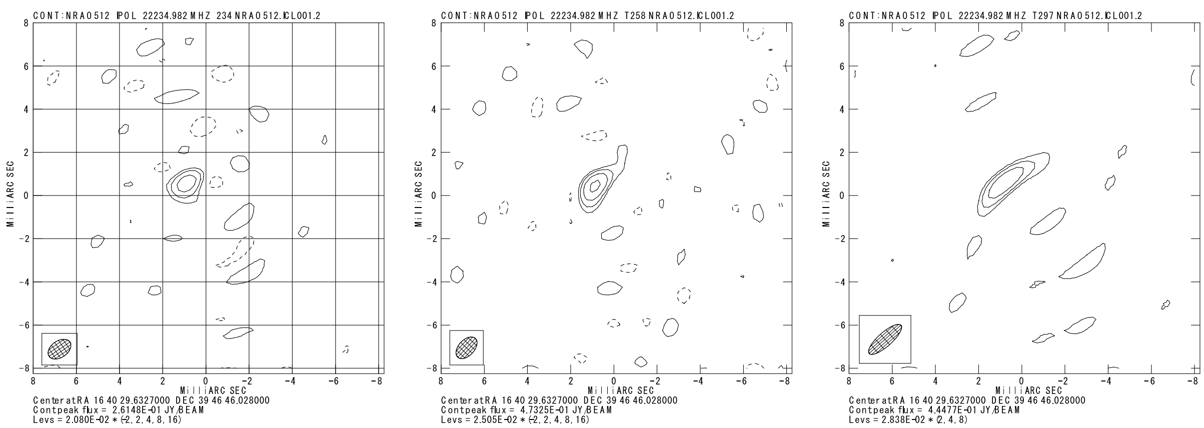

Figure 4. Phase referenced maps of NRAO512 with respect to 3C345 on doy 234, 258 and 297 in 2003.

3. Status of the Geodetic Observations

Very high accuracy of antenna positions is crucial to realize the target accuracy of radio source positions. For determining annual parallaxes with accuracy of 10μas a few mm is required for annual component in the antenna positions. Geodetic observation can be regarded as one of the calibration processes of VERA in this respect. However, if the target accuracy, say 2mm, is achieved in the antenna positions, the data series will be a wealth of geophysical information.

The simultaneous receiving system in S and X bands are installed at all four stations of VERA for conventional geodetic observations. The general features of this system are described in Tamura et al.(2002). The other frequency bands, namely K and Q, are expected to be usable in the future. The most important point of the VERA geodetic observing system is that only Mizusawa station has a data aquisition system compatible with K4 and other three stations have only DIR2000 DAS. No station has currently compatibility with Mark IV or Mark 5. Therefore, the three stations except for Mizusawa cannot directly be linked to the international VLBI network.

3.1. VERA Internal Geodetic Observations

The baseline of the observation strategy is that DIR2000 DAS is used for geodetic observations among the VERA network. The data are recorded on magnetic tapes and correlated at the Mitaka correlation center. The recording rate is 1Gbps. It is planned that in order for determining the antenna positions with sufficient accuracy considerable observation time, say 60-80 24-hour observing sessions per year, will be allocated for geodetic observations until characteristics of antenna position variations become clearly understood.

Experimental observations for very short time have been tried and fringes have been detected by using DIR2000 DAS. However, full 24-hour geodetic observations have not yet be tried because of insufficient stability of the observation system. They will be tried this year.

The observed data are correlated with the Mitaka correlator and raw visibilities are stored in the form of CODA File System. Then, they are bandwidth synthesized to obtain group delays and phase delay rates. These data are analysed to derive geodetic information by using the software developed at NAOJ. Some improvements of the software, in particular GUI, is under way.

3.2. International Link via the Tsukuba 32m Antenna of GSI

As describe above, only Mizusawa station is equipped with the K4 system and coordinates of the other stations have to be determined relative to those of Mizusawa. Therefore, in order to link VERA station positions to an international frame, for example ITRF, it is necessary to link Mizusawa to an international frame. This is realized by determining Mizusawa's position relative to the Tsukuba 32m antenna of GSI. Mizusawa participates in the GSI's domestic observation programs once a month and some results with internal precisions of 5-10mm have been obtained. However, since the number of successful observations is limited up to now, the international link is not yet considered to be strong enough.

3.3. Domestic Network

In addition to VERA three VLBI stations have been established at universities. They are Yamaguchi (32m), Gifu (11m) and Tomakomai (11m). The former two have strong interests in geodetic observations. Mizusawa made an experimental observation with Gifu and it was the first successful observation in the S and X bands for Mizusawa. Gifu is linked to GSI and Mitaka via an optical fiber network and performing regular observations with GSI. Geodetic as well as astrometric observations with VERA are expected for these radio telescopes in the near future.

4. Astrometry and Contribution to CRF

VERA is a dedicated instrument for astrometry and expected to be able to determine star positions very accurately. However, this does not mean that positions of VERA's main target sources, which are Galactic masers sources, are accurate in the sense of absolute coordinate determination. This is also the case when relative positions of two QSOs separated closely are determined. It is logically possible to construct a global reference frame by weaving a net of relative positions of extragalactic objects. However, a global reference frame is only realizable after covering the whole sky with this method and required resources may be too large to share observation time with maser astrometry. Therefore, VERA is not an outstanding instrument for constructing a global reference frame such as ICRF. However, the phase referenced VLBI by VERA may be useful for checking accuracy of a position catalogue by determining relative positions of some numbers of pairs of QSOs included in catalogues. The result shown in Fig. 4 can be considered to be a first step for contribution to CRF.

5. Future Plans

The most urgently needed task for VERA's geodetic observations is to stabilize the VERA system, in particular DIR2000 DAS. In addition a K5 DAS has to be installed at least at Mizusawa in order to keep the compatibility with the GSI 32m whose K4 DAS will be abandoned in 2005. Improvement of the analysis software is also an urgently needed task.

There is strong radio interference in the S-band from cellular phone at Mizusawa. The interfering noise is filtered out and the S-band is usable at least for VLBI. However, it is foreseen that we have to abandon the S-band in coming several years. In order to shift to the higher frequencies, the possibility of experiments in X- and K-bands with K-bands used for ionospheric correction are being investigated. Phase referenced astrometry of QSO pairs in K- and Q-bands mentioned in the previous section is also planned.

In the further future a new large correlator must be constructed to replace the Mitaka FX correlator which was built 10 years ago.

VERA will be used as main ground telescope to track lunar orbiters in the RISE project which aims to determine a precise and detailed gravity map of both the near and far sides of the Moon. VERA is expected to improve orbital accuracy near the lunar limbs. The rocket is scheduled to be launched in 2005 and the main observation period is in 2006.

Korea is constructing the Korean VLBI Network (KVN) consiting of three stations. If VERA and KVN are used, the coverage in the *uv* plane will be greatly improved, since VERA lacks short baselines and KVN is fairly compact. KVN's antennas do not have dual-beam capability. However, their high slew speed will make it possible to perform phase referencing by fast switching of antenna directions. It is strongly desired and expected that VERA and KVN closely cooperate in the future.

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