Submilliarcsecond VLBI Observations of the Close Pair GC 1342+662 and GC 1342+663

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Differential VLBI has been simultaneously performed on the source pair GC 1342+662 and GC 1342+663 (4.4-arcminute separation) using S-band on the Goldstone/Madrid baseline. These measurements were acquired on two separate observing sessions: 30 December 1982 and 14 May 1983. The change in separation of GC 1342+662 relative to GC 1342+663 between the two epochs was 0.03 ±0.08 milliarcsecond. The differences of the relative position measurements between epochs of GC 1342+662 relative to GC 1342+663 were −0.29 ±0.05 milliarcsecond in right ascension and 0.14 ±0.09 milliarcsecond in declination. These measurements demonstrate submilliarcsecond accuracy and repeatability. The discrepancies outside of the formal uncertainties could be attributed to the intrinsic properties of the sources such as structure and to a lesser probability, proper motion. These discrepancies could also be attributed to excursions in UT1-UTC of about four times the quoted BIH uncertainty.

I. Introduction

VLBI reference frames of several milliarcsecond precision are being used by the Deep Space Network for spacecraft navigation (Refs. 1, 2, and 3). Quasars from these reference frames have served as reference beacons in differential VLBI experiments with the Voyager spacecraft, the Pioneer Venus Orbiter (Ref. 3), and the Viking Orbiter (XX Newhall, private communication).

The potential limiting accuracy attainable for differential VLBI positional measurements, using these reference frames, can be reached by simultaneously observing sources with small angular separations. These close pairs of sources must have angular separations smaller than the beamwidth of each antenna, and therefore can be simultaneously tracked by both antennas of a VLBI baseline, greatly enhancing the cancellation of measurement errors. By observing several close pairs

of radio sources over a several-year period, limits on reference frame stability can be determined.

Observations and results demonstrating the submilliarcsecond accuracy of this technique at 2.3 GHz using the DSN baseline, Goldstone/Madrid, on the close pair GC 1342+662 and GC 1342+663 are presented. These two sources have been identified as quasars (Ref. 4), and have originally been identified as VLBI sources in the DSN full-sky survey program (Ref. 5). Total-flux densities measured during April 1983 indicate that both of these sources have flat spectra (R. Perley, private communication).

II. Observations

The close pair GC 1342+662 and GC 1342+663 was observed at 2.29 GHz with the Goldstone/Madrid baseline. It

was observed by DSS 14 (64 m) and DSS 63 (64 m) on 30 December 1982 for 6 hours and 40 minutes, and by DSS 13 (26 m) and DSS 63 (64 m) on 14 May 1983 for 6 hours. The Goldstone/Madrid baseline has a length of 8400 km and a fringe spacing of 3 milliarcseconds. The observations were performed with right circular polarization. The receiver chain consisted of an S-band traveling wave maser followed by a special phase-stable S-band VLBI receiver, which converted the RF signal to an IF of 50 MHz. The NRAO Mark II VLBI recording system then recorded a 1.8-MHz data bandwidth by digitally sampling at a 4-Mbits/s rate (Ref. 6). Digital sampling and phase stability of the receiver chain were controlled by hydrogen maser atomic clocks. The centroid position of the source pair was used to point the antenna. X-band observations were not performed since the 4.4-arcminute angular separation of this source pair exceeded the half-power beamwidth of the limiting antenna (2 arcminutes), thus making simultaneous observations useless.

The data were correlated on the Caltech/JPL Mark II correlator. The postprocessing software yielded 60-second points of fringe phase for each source. The phases were then input to the JPL Orbit Determination Program (Refs. 7, 8, and 9), where an accurate phase model was applied. The phases were then corrected for cycle ambiguities and differenced. This difference phase was input to a least-squares algorithm where an integral number of cycles was determined and then added to each of the difference phases. The next iteration of the least-squares algorithm was a two-parameter fit that yielded the relative position offsets in right ascension and declination.

III. Results

Figure 1 shows the postfit difference-phase residuals for the 30 December 1982 experiment, which have an rms scatter of 0.028 cycles (90 μarcseconds). Figure 2 shows the postfit difference-phase residuals for the 14 May 1983 experiment, which have an rms scatter of 0.026 cycles (80 μarcseconds). The scatters reported here are in agreement with predicted values and are dominated by the solar plasma. The scatter on the individual 60-second integrated phase points is about 0.003 cycles and is consistent with expected noise levels due to system noise and ionosphere over these time scales.

The correlated amplitudes were converted to source strengths using measured values of system temperatures and antenna efficiency parameters. The resulting correlated flux densities at 2.3 GHz are shown in Fig. 3 for GC 1342+663 and in Fig. 4 for GC 1342+662. Peak correlated flux densities on 30 December 1982 were 0.35 Jy for GC 1342+662 and 0.75 Jy for GC 1342+663, and on 14 May 1983 they were 0.35 Jy for GC 1342+662 and 0.60 Jy for GC 1342+663.

The correlated flux density behavior for GC 1342+663 is essentially flat (see Fig. 3) indicating a lack of detectable structure over the observed hour-angle range. There is, however, a significant variation of correlated flux density over the interferometric hour angle for GC 1342+662 (see Fig. 4) indicating complex structure over the milliarcsecond resolution beam of the interferometer. This variation is consistent with a model of two point sources with equal flux densities (0.175 Jy each) separated by 1.1 milliarcseconds and aligned along a ≈29-degree position angle (defined north through east). The position angle is coincidentally aligned with the position angle between the two sources GC 1342+662 and GC 1342+663, suggesting the possibility of an intrinsic relationship between the sources.

The measured position in arclength of GC 1342+662 relative to GC 1342+663 referred to epoch 1950.0 is given in Table 1 for both experiments. The arclength differences of these relative position measurements between experiments were -0.29 ±0.05 milliarcseconds in right ascension and 0.14 ±0.09 milliarcseconds in declination. The results agree to within 5.8 and 1.5 times the rss of the individual standard deviations for right ascension and declination respectively. Marcaide and Shapiro (Ref. 10) had similar few-sigma discrepancies between epochs of their relative position measurements of 1038+528A and 1038+528B. The change in separation of the GC 1342+662 relative to GC 1342+663 between the two epochs was 0.03 ±0.08 milliarcsecond, implying that the above discrepancies are effectively a rotation in right ascension and declination space. Because most of the discrepancy is in right ascension, timing errors are immediately suspect. However, such errors would require deviations from BIH values of UT1-UTC of about four times the quoted uncertainty (Ref. 11).

Source structure is the most likely cause of the measured discrepancy in the differential position measurements between epochs for GC 1342+662 and GC 1342+663. Proper motion is a possible cause for the discrepancy, but not very probable assuming current cosmological assumptions. To properly understand and distinguish between these effects, more observations need to be performed over a several-year time period.

Marcaide and Shapiro (Ref. 10), Shapiro et al. (Ref. 11), and Gorenstein et al. (Ref. 12) have performed similar experiments on other close pairs. Table 2 displays a summary of these experiments along with the one discussed in this paper.

IV. Conclusion

The improved accuracy and repeatability of simultaneous differential VLBI using the close pair GC 1342+662 and GC 1342+663 with the Goldstone/Madrid baseline has been

demonstrated on two separate observing sessions. The change in separation of GC 1342+662 relative to GC 1342+663 between the two epochs was 0.03 ±0.08 milliarcsecond. The differences of the relative position measurements of GC 1342+662 relative to GC 1342+663 between the two epochs were −0.29 ±0.05 milliarcseconds in right ascension and 0.14 ±0.09 milliarcseconds in declination. Discrepancies between the relative measurements outside the formal uncertainties could be attributed to either source-structure effects or proper motion. Further monitoring of this close pair along with other close pairs will be useful for testing and placing limits on reference frame stability.

Acknowledgments

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Table 1. Relative position measurements

Source	Epoch	Relative right ascension,[a] arcseconds	Relative declination, arcseconds	Total separation, arcseconds
GC 1342+662	30 Dec 1982	−139.58033 ±0.00004	−225.17070 ±0.00006	264.83216 ±0.00006
GC 1342+662	14 May 1983	−139.58062 ±0.00003	−225.17056 ±0.00007	264.83219 ±0.00006

[a]In arclength referred to declination of GC 1342+662.

Table 2. Comparison with other investigations

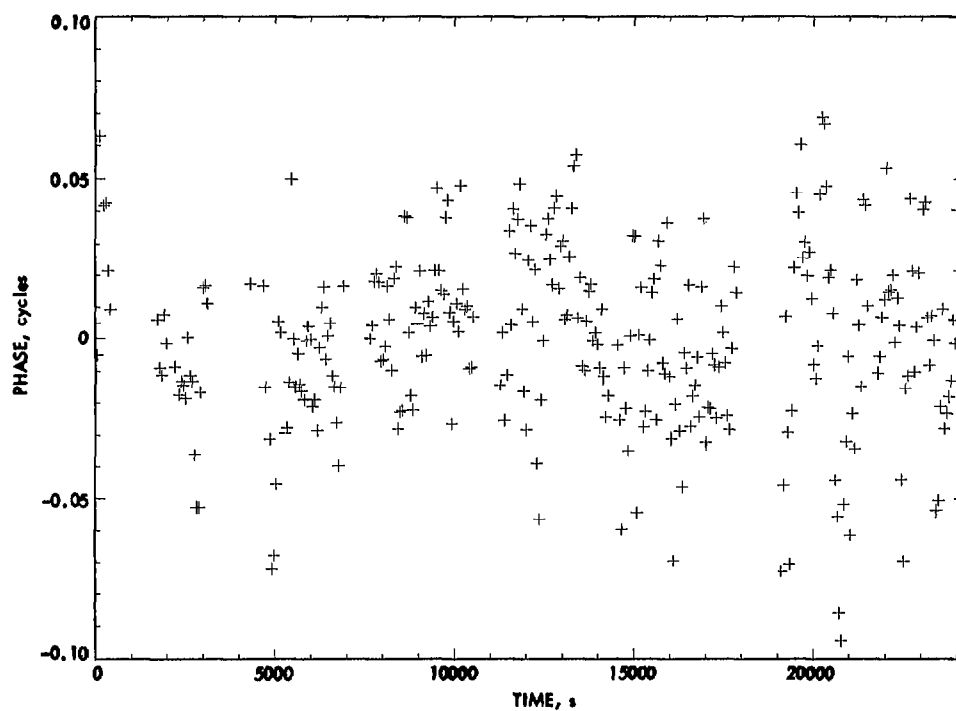| Investigators	Source pair	Angular separation, arcminutes	Measurement accuracy, μarc
Ref. 11	3C 345 NRAO 512	30	500
Ref. 12	0957+561A 0957+561B	0.1	50
Ref. 10	1038+528A 1038+528B	0.6	10
This paper	GC 1342+662 GC 1342+663	4.4	60

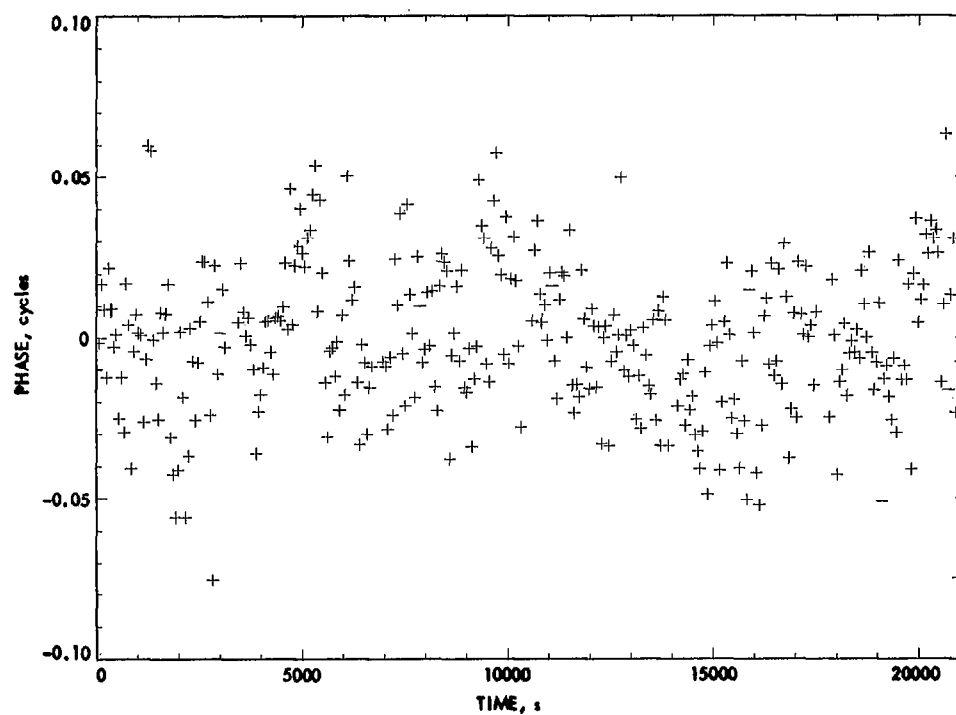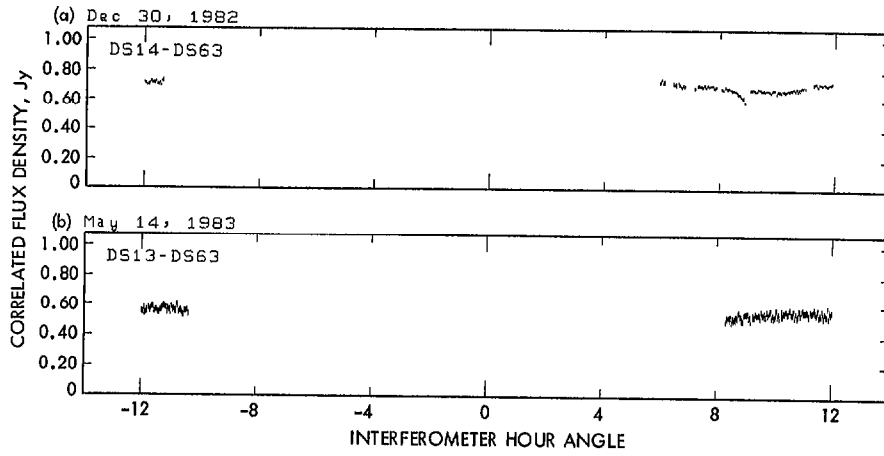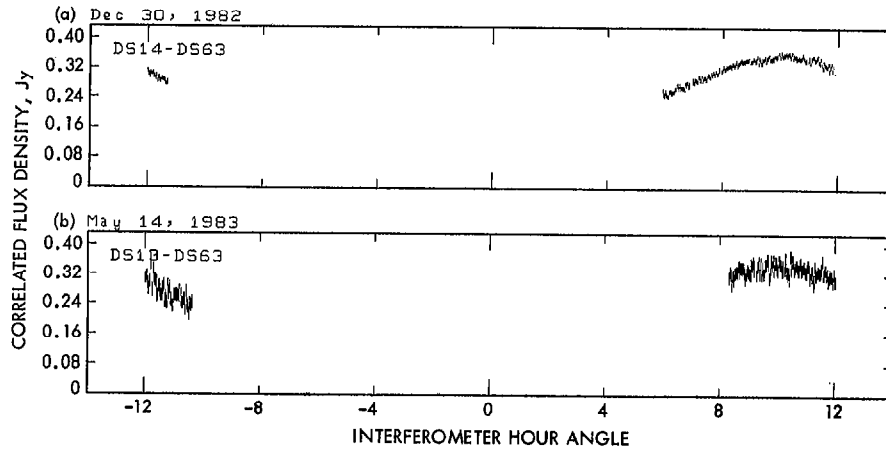Fig. 1. Postfit residual difference phase, 30 December 1982, baseline DSS 14/DSS 63

Fig. 2. Postfit residual difference phase, 14 May 1983, baseline DSS 13/DSS 63

Fig. 3. Correlated flux density vs interferometer hour angle for GC 1342+663:
(a) first experiment; (b) second experiment

Fig. 4. Correlated flux density vs interferometer hour angle for GC 1342+662:
(a) first experiment; (b) second experiment