HIGH PRECISION DIFFERENTIAL ASTROMETRY IN LARGE ANGULAR SEPARATION PAIRS OF RADIOSOURCES

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Abstract. We show preliminary results of three of the four radiosource pairs with angular separations ranging from 0.01° to 6° where we have determined such a separation with a typical fractional precision of 10^{-8} using phase delays corrected for structural and ionospheric contributions. In the radiosource 4C39.25 we measure a motion with respect to an external radiosource which is compatible with previously reported internal superluminal motion.

1. Introduction

Recently, the details of superluminal motions observed in compact radiosources have been satisfactorily modelled by numerical simulations (Alberdi *et al.* 1993, Gómez *et al.* 1993) based on the standard relativistic jet model (Blandford and Königl 1979). These simulations show that the source core, and also some source components like, for example, those associated to slight bends in the jet, should appear observationally quasi-stationary. The use of closure phases and amplitudes in hybrid mapping has prevented the validation of these key aspects of the standard model. Were not the VLBI phase 2π-ambiguous, the use of closure phases would be unnecessary and, likewise, instead of using the less precise group delays for astrometry the phase delays would be used. The use of pairs, or triplets, of sources offer the possibility to break the 2π-phase ambiguity in the differenced phase and phase-delays. Our group has successfully phase-connected the differenced phase delays in four pairs of radiosources and has determined the relative sky positions of the sources with a typical fractional precision of 10^{-8} for pairs ranging from 0.01° to 6°. Our results for simultaneous 3.6/13cm observations of the pairs 1038+528A,B (0.01°) and 1928+738/2007+777 (4.6°) have been previously reported (Marcaide and Shapiro 1984, Elósegui *et al.* 1993). We show here preliminary results of the latter pair for 6cm observations and for the pairs 4C39.25/0920+390 (0.8°) and 3C395/3C382 (5.9°) for simultaneous 3.6/13cm observations.

2. Observations and Data Reduction

In Table 1 we show a summary of all our observations. We present preliminary results of those marked by an asterisk. Throughout the MkIII VLBI system has been used. We observed the pairs by alternating the reference and target sources (except for 1038+528A,B that can be observed simultaneously) with cycle times of 6 minutes or less. The typical recorded bandwidths at 3.6 and 13cm were 16 and 12 MHz, respectively, and at 6cm the bandwidth was 28 MHz. After correlating the recorded data we used astrometric analysis of the unambiguous group delays and

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delay rates to model the delay rates of each source to better than 0.1 ps/s and then used these modelled delay rates to eliminate the phase-delay ambiguities, except for a single unknown offset for the delays for any particular source, wavelength, and telescope. We used a hybrid-mapping technique to make images of the two sources to remove structure effects; defined a reference position at each wavelength; estimated the structure contributions to the phase delays for each of these positions; and subtracted them from the total phase delays. We used these unambiguous, "structure-free" phase delays to estimate, and then remove, the ionospheric delay contributions when simultaneous dual-wavelength and/or ionospheric total electron content were available. We then formed the differenced phase-delay observable and obtained consistent sets of Earth orientation parameters and station and source coordinates from GSFC and IERS Annual Reports, and used the current version of our VLBI3 program (Robertson 1975) to analyze the differenced phase-delays and the undifferenced phase-delays of the strongest source of the pair to produce a weighted-least-squares estimate in the J2000 system of the sky position of the source feature selected on the target source relative to that on the reference source.

Table 1 Summary of Phase-Referenced VLBI Observations

Epoch	Target source	Reference source	$\Delta\theta$† (°)	λ (cm)	Telescopes ‡
1981.21	1038+528A	1038+528B	0.01	3.6/13	B,D_{64},G,M_{64},O,S
1982.56	1038+528A	1038+528B	0.01	6	B,F,G,K,O,Y_{27}
1983.36	1038+528A	1038+528B	0.01	3.6/13	B,D_{64},F,G,K,M_{64},O,S,T
*1985.78	1928+738	2007+777	4.6	6	B,F,K,L,O,S,Y_{27}
1988.82	1928+738	2007+777	4.6	3.6/13	B,F,L,M,T
*1990.32	4C39.25	0920+390	0.8	3.6/13	E,L,M,V
1990.46	1038+528A	1038+528B	0.01	3.6/13	B,F,G,K,L,M,O,PT,V
*1990.84	3C395	3C382	5.9	3.6/13	B,K,I,L,M_{34},O,PT,T,Y_{27}
*1991.22	4C39.25	0920+390	0.8	3.6/13	E,I,L,M,V
1991.48	4C39.25	0920+390	0.8	1.3	B,FD,G,K,L,LA,M,OV,PT,T,Y_{27}
1991.70	1038+528A	1038+528B	0.01	6	B,FD,G,K,OV,PT,S,Y_{27}
1991.89	1928+738	2007+777	4.6	3.6/13	B,FD,G,K,KP,L,LA,M,PT,Y_{27}
1991.89	1803+784	2007+777	6.5	3.6/13	B,FD,G,K,KP,L,LA,M,PT,Y_{27}
1992.18	4C39.25	0920+390	0.8	3.6/13	E,I,M
1992.46	3C345	NRAO512	0.5	1.3	B,FD,K,L,LA,OV,PT,Y_{27}

* Preliminary results of these observations are presented in this paper.

†Angular separation of the source pair.

‡The telescope symbols are the following: B, 100m, Effelsberg (Bonn, Germany); D, 70m, DSS14, Goldstone (CA, USA); D_{64}, 64m, DSS14, Goldstone (CA, USA); E, 18m, Westford (MA, USA); F, 26m, Fort Davis (TX, USA); FD, 25m, VLBA-Fort Davis (TX, USA); G, 43m, Green Bank (WV, USA); I, 32m, Noto (Italy); K, 37m, Haystack (MA, USA); KP, 25m, Kitt Peak (AZ, USA); L, 32m, Medicina (Italy); LA, 25m, Los Alamos (NM, USA); M, 70m, DSS63 (Madrid, Spain); M_{64}, 64m, DSS63 (Madrid, Spain); M_{34}, 34m, DSS65 (Madrid, Spain); O, 40m, OVRO (CA, USA); OV, 25m, VLBA-OVRO (CA, USA); PT, 25m, Pie Town (NM, USA); S, 25m, Onsala (Sweden); T, 20m, Onsala (Sweden); V, 18m, Wettzell (Germany); Y_{27}, phased-VLA (NM, USA).

3. Results

In Figures 1 and 2 we show the resulting postfit residuals for the differenced phase delays for a small representative sample of baselines for each source pair. In these preliminary results some small systematic trends are still visible. Table 2 shows the

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statistical standard errors obtained in each case in right ascension and declination. Figure 2c shows the superluminal motion of 4C39.25 with respect to the external reference source 0920+390 which appears pointlike. This "absolute motion" measured is compatible with the internal motion previously reported and modelled (e.g. Alberdi *et al.* 1993).

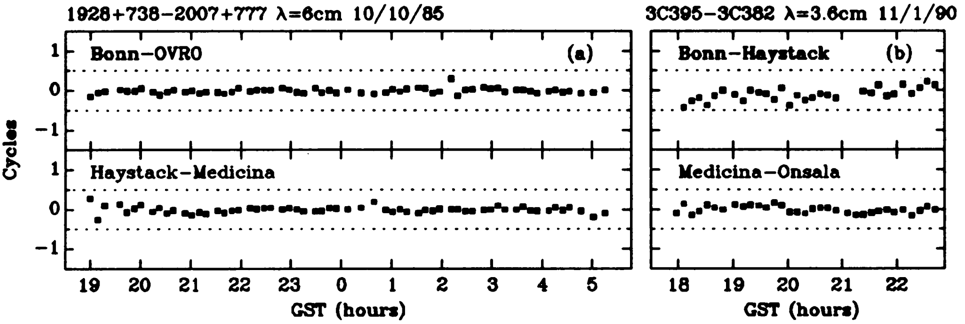

Figure 1. Postfit residuals for the differenced phase delays of the pairs 1928+738/2007+777 *(a)* and 3C395/3C382 *(b)*.

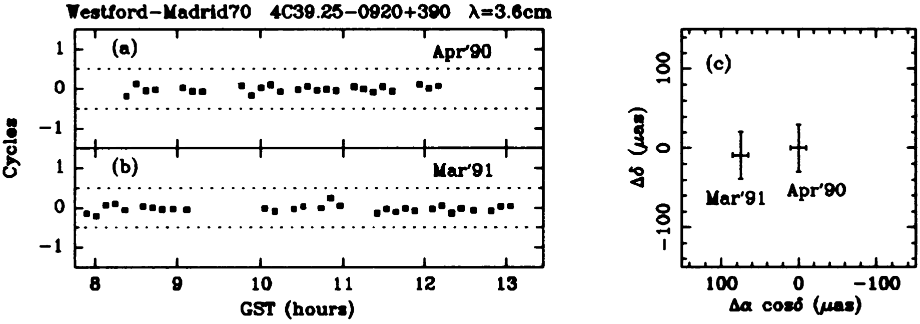

Figure 2. Postfit residuals for the differenced phase delays of the pair 4C39.25/0920+390 at epochs 1990.32 *(a)* and 1991.22 *(b)*. The position of 4C39.25 relative to 0920+390 at both epochs is shown in *(c)*. The origin corresponds to the position at epoch 1990.32.

Table 2 Statistical Standard Errors in the Relative Position Determinations

Epoch	Source Pair	σ_α (μas)	σ_δ (μas)
1985.78	1928+738/2007+777	50	60
1990.32	4C39.25/0920+390	10	30
1990.84	3C395/3C382	60	80
1991.22	4C39.25/0920+390	10	30

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