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Multi-wavelength differential astrometry of the S5 polar cap sample

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Abstract. We report on the status of our S5 polar cap astrometry program. Since 1997 we have observed all the 13 radio sources of the complete S5 polar cap sample at the wavelengths of 3.6 cm, 2 cm and 0.7 mm. Images of the radio sources at 3.6 and 2 cm have already been published reporting morphological changes. Preliminary astrometric analyses have been carried out at three frequencies with precisions in the relative position determination ranging from 80 to 20μas. We report also on the combination of our phase-delay global astrometry results with the μas-precise optical astrometry that will be provided by future space-based instruments.

1. Introduction

We are conducting a multi-wavelength astrometric study of the "complete S5 polar cap sample", consisting of thirteen radio sources from the S5 survey (Kühr et al. 1981, Eckart et al. 1986) defined by the following criteria: (i) $\delta \geq 70°$, (ii) $| b_{II} | \geq 10°$, (iii) $S_{5\,\mathrm{GHz}} \geq 1\,Jy$ at the epoch of the survey, and (iv) $\alpha_{2.7,5\,\mathrm{GHz}} \geq -0.5$ ($S \sim \nu^{+\alpha}$). All sources in this sample have large flux densities, well defined ICRF (International Celestial Reference Frame; Ma et al. 1998) positions, and relative separations less than about 15°, which guarantees astrometric precisions better than 0.1 mas via the application of phase-delay differential astrometry techniques. The goal of this program is to determine the absolute kinematics of all the sources using maps properly registered through different epochs. Given the variety of source structures in the sample and its completeness, our program will result in a definitive check of the standard jet model (Blandford & Königl 1979).

We have observed all 13 members of the sample at λ3.6 cm, at λ2 cm and at λ7 mm (see Table 1) with the VLBA, using a multiple triangulation approach. Data were correlated at the VLBA Array Operations Center. In each of the 24-hour observations at each wavelength, each source has been tracked over an average time of 5 hr (with a total integration time of 2 hr), enough to produce high-quality hybrid maps. In this contribution we report briefly some astrometric results from the epochs already analyzed.

Table 1. S5 polar-cap sample observations

Epoch	Wavelength		
	λ3.6 cm	λ2 cm	λ7 mm
1997.93	√		
1999.41	√		
1999.57		√	
2000.46		√	
2001.04		√	√
2001.09	√		
2001.71			√
2004.62		√	√

2. Results

The maps of all 13 radio sources for the first two epochs at λ3.6 cm and λ2 cm have already been published (Ros et al. 2001; Pérez-Torres et al. 2004). At these wavelengths, these authors found that most of the sources of the sample have one-sided jet structures, but also found the existence of intriguing compact structures (i.e., 0615+820). Combining maps of different epochs, they have analyzed and modeled the strong morphological changes found in some sources (i.e., 0016+731, 0836+719, 1928+738, and 2007+777, amongst others). Combining maps at both frequencies, and using spectral index estimates, they have determined that for most sources the brightest feature can be identified with the core. These findings are essential to properly define a suitable astrometric reference point on the structure of each source, and will be necessary for a meaningful interpretation of the astrometric results.

Preliminary phase-delay astrometric work has been carried out at all frequencies, involving all data jointly and using bootstrapping techniques (see Ros et al. 1998). The root-mean-square noise of the differenced phase-delay residuals ranges from ~30 ps at λ3.6 cm (Ros et al. 1998) to ~3 ps at λ7 mm (similar to that obtained by Guirado et al. 2000; see Fig. 1). If we take into account all systematic errors, the average precision of the relative position determination of all 43 radio source pairs in the sample is ~80μas at λ3.6 cm, ~50μas at 2 cm and ~20μas at 7 mm. With a time span of more than seven years, our program will set bounds of 5-10 μas/yr to the proper motion of the core of the S5 sources. This result will show that the study of the absolute kinematics of a complete sample of sources can be done, almost routinely, using the phase-delay

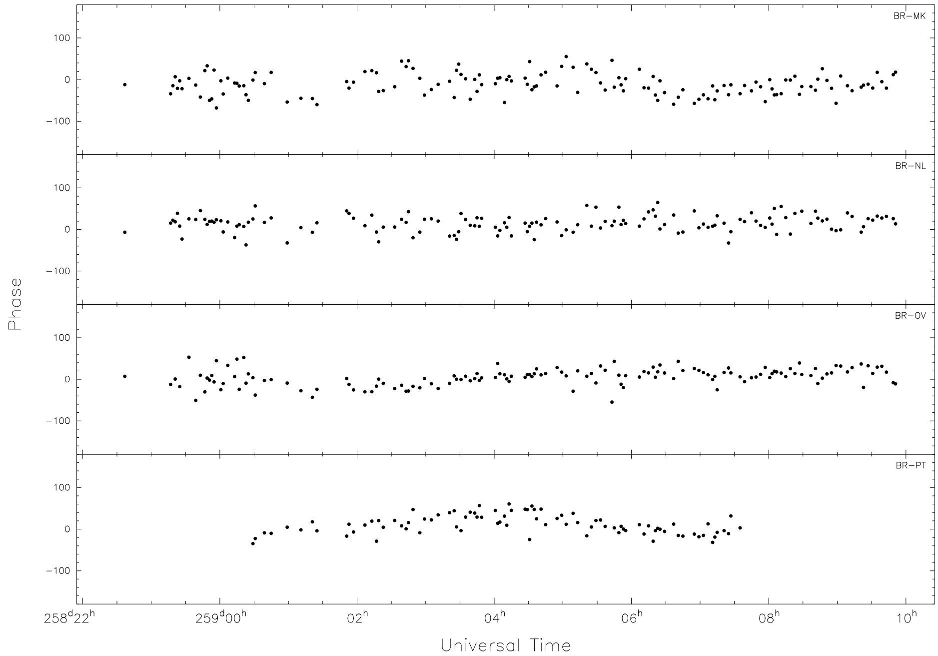

Fig. 1. Residual $\lambda 7$ mm phases for 2007+777 referenced to those of 1928+738 for a representative set of baselines at epoch 2001.71. Notice the absence of systematic effects. The average root-mean-square noise of the residuals is $\sim$3 ps (one phase-cycle at $\lambda 7$ mm corresponds to 23 ps of phase-delay).

observable.

Our program opens the possibility to extend phase-delay astrometry to large portions of the sky, if not the entire sky, acting as a more precise complement of the ICRF realizations. In a sense, there is a need for such μas-precise global astrometry; a variety of AGN phenomena are expected to be observed by space-based astrometric missions, such as the Space Interferometry Mission, SIM (Unwin & Shao 2000), which will yield μas-precise positions, and proper motion of a few μas/yr (Unwin et al. 2002), at levels comparable with those obtained in our project. The well-known structures of the S5 sources and the precise monitoring of the absolute kinematics, when combined with SIM optical data, will be essential to answer fundamental questions regarding stability of the radio/optical reference frame tie, or the location of the optical emission. The combination of both high-precision radio and optical positions will show that astrometry is a useful tool to understand the nature of AGNs.

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