HIGH PRECISION ASTROMETRY WITH VLBI: FROM THE TRIANGLE 1803+784/1928+738/2007+777 TO THE COMPLETE S5 POLAR CAP SAMPLE

E. ROS
Max-Planck-Institut für Radioastronomie, Bonn, Germany

AND

J.M. MARCAIDE, J.C. GUIRADO AND M.A. PÉREZ-TORRES
Dept. d’Astronomia i Astrofísica, U. de València, Spain

1. Introduction

The Very Long Baseline Interferometry (VLBI) technique can image compact radio sources with a resolution of the order of the milliarcsecond and can determine astrometrically relative positions to precisions of the order of tens of microarcseconds. This technique is ideal to construct a precise celestial reference frame. Up to the present, the group delay observable has been regularly used in such a task. The use of the more precise phase delay observable should constitute an immediate improvement in accuracy. Furthermore, the phase-delay, if used differentially over radio source pairs, becomes the most accurate observable in astrometry. The technique of phase-delay differential astrometry has been applied to several source pairs, with separations ranging from 33'' (1038+528 A/B, Marcaide & Shapiro, 1983) to 5°9 (3C 395/3C 382, Lara et al., 1996). The pair 1928+738/2007+777 (4°6 separation) has also been studied (Guirado et al. 1995, 1998) yielding precisions of ~200 µas. Recently, we added a new source 1803+784 to the latter pair to take advantage of the constraints introduced by a triangular geometry in the determination of the angular separations (Ros et al., 1998). It represents a first step towards extending the differential phase-delay astrometry from pairs to a whole sky radio source frame.
2. The Triplet 1803+784/1928+738/2007+777.

We observed the radio sources of the triangle formed by the BL-Lac objects 1803+784 and 2007+777, and the QSO 1928+738 on epoch 1991.89 with an intercontinental interferometric array simultaneously at the frequencies of 2.3 and 8.4 GHz (Ros et al., 1998). We determined the angular separations among the three radio sources with submilliarcsecond accuracy from a weighted least squares analysis to the differential phases, after removing most of the contribution due to the geometry of the array and the atmosphere. The radio source structure contributions to the phase delays were also modeled using hybrid mapping images of the radio sources from the same observations. We checked the consistency of our astrometric determination through the use of the so-called Sky-Closure. The Sky-Closure was defined as the circular sum of the angular separations of the three radio sources, determined pairwise and independently. In our case the result was consistent with zero, and verified satisfactorily the data process followed. The final accuracy of the astrometric determinations was of 130 µas.

One important aspect in the astrometric work is the excess propagation delay due to the ionization of the propagation medium, mainly the ionosphere. The ionospheric contribution to the delays had been determined in the past from dual-band VLBI observations. Sardón et al. (1994) showed that the total electron content (TEC) of the ionosphere can be determined with high accuracy by using dual frequency Global Positioning System (GPS) data. We used their method to estimate the plasma contribution by using TEC estimates of the ionosphere obtained from data from different GPS sites neighbor to the VLBI stations (see Ros et al. 1998, 1999).

3. The S5 Polar Cap Sample.

Proper Motions in 1928+738. The comparison of the measurements of the separations of the pair 1928+738/2007+777 with those presented by Guirado et al. (1995; 1998) for epochs 1985.77 and 1988.83 allows us to register adequately the absolute position of 1928+738 relative to 2007+777. We estimate the proper motion of components in 1928+738, and identify the position of the radio source core even though it is unseen at cm-wavelengths, as shown in Fig. 1. The average proper motion of the components emerging from the core region is of 0.30±0.15 mas/yr towards the South.
Figure 1. Astrometric alignment of the maps of 1928+738. We infer a proper motion of the components of about 0.3 mas/yr towards the south, and also that the nucleus of the radio source is near, but north of, the northernmost component of the 1988.83 map, at the position indicated in the central figure. The components have been convolved with circular gaussian beams (bottom, left) of diameters 0.7, 0.4, and 0.4 mas, showing slightly overresolved images.

Separations less than 15° can be studied also astrometrically. These sources are the quasars 0016+731, 0153+744, 0212+735, 0615+820, 0836+710, 1039+811, 1150+812, and 1928+738, and the BL Lacertae objects 0454+844, 0716+714, 1749+701, 1803+784 and 2007+777. We observed this set of radio sources at 8.4 GHz over 24 hours on epoch 1997.93. We imaged the 13 radio sources using hybrid mapping techniques. On these images we defined reference points and then removed the structure contributions from the corresponding astrometric observables. After it, we used the differential phase-delays to obtain a global solution of all the source positions. Fig. 2 shows our preliminary results. A similar trend of systematic effects, which will cancel out when making the differences, is conspicuous.

With respect to the determination of the ionosphere contribution to the data, the density of the GPS network increased notably from 1991 to 1997, making the bias removal and the accuracy of the TEC determination much better. Now it is possible to have Global Ionospheric Maps from the Global Positioning System and thus estimate the ionosphere contribution to the astrometric observables of a single-wavelength VLBI observation and to remove the plasma effects from them with high accuracy.
4. Conclusions

The differential phase-delay astrometry has recently undergone important improvements. The phase-connection process has been extended to larger sets of radio sources with larger source separations, and the ionosphere contribution to the astrometric observables has been successfully removed using GPS data. We have determined with submilliarcsecond precision the relative separations in the triangle of radio sources 1803+784/1928+738/2007+777, and we have observed astrometrically the complete S5 polar cap sample, that among the 13 sources within 20° to the celestial North Pole includes the above 3. New observations are now underway in the framework of a long-term astrometric program to determine the absolute kinematics of radio source components in the S5 complete sample. This program, extended over 5 years, will reach a precision in the determination of the relative separations better than 0.1 mas and consequently in the proper motions of the radio source components.

References

Eckart, A., Witzel, A., Biermann, P., Johnston, K.J., Simon, R., Schalinski, C., Kühr, H. (1986), A&A, 168, 17
Guirado, J.C., Marcaide, J.M., Marcaide, J.M., Elósegui, P., Ratner, M.I., Shapiro, I.I., Eckart, A., Quirrenbach, A., Schalinski, C.J., Witzel, A. (1995), A&A, 293, 613
Guirado, J.C., Marcaide, J.M., Ros, E., Ratner, M.I., Shapiro, I.I., Quirrenbach, A., Witzel, A. (1998), A&A, 336, 385
Lara, L., Marcaide, J.M., Alberdi, A., Guirado, J.C. (1996), A&A, 314, 372
Marcaide, J.M., & Shapiro, I.I. (1983) AJ, 88, 1133
Pérez-Torres, M.A., Marcaide, J.M., Guirado, J.C., Ros, E. (1999), these proceedings
Ros, E., Marcaide, J.M., Guirado, J.C., Ratner, M.I., Shapiro, I.I., Krichbaum, T.P., Witzel, A., Preston, R.A. (1998), A&A, submitted
Ros, E., Marcaide, J.M., Guirado, J.C., Sardón, E., Shapiro, I.I. (1999), in preparation
Sardón, E., Rius, A., Zarraoa, N. (1994), Radio Science, 29, 577