FUTURE CONTROL OF THE HIPPARCOS FRAME USING MERLIN

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ABSTRACT

MERLIN radio positions of 21 radio stars are used to link the Hipparcos reference frame to the International Celestial Reference Frame. The accuracy of the link at the epoch 1995.7 using these radio stars is 1.7 milliarcseconds. Further observations are planned to check the accuracy of the link in the future.

Key words: space astrometry; Hipparcos; reference frames.

1. INTRODUCTION

The equatorial cartesian axes of the Hipparcos Catalogue have been fixed relative to those of the International Celestial Reference Frame (ICRF) with an accuracy of ± 0.6 milliarcseconds (mas) at the epoch 1991.25 and with a constraint of $\pm 0.25\,\mathrm{mas\,yr^{-1}}$ on their rotation. The maintenance of the Hipparcos frame will depend on periodic checks of its alignment to the ICRF. One of the most effective ways of doing this will be by comparison of the radio positions of stars with their optical positions in the Hipparcos Catalogue.

We describe here the observational campaign to measure the radio positions of radio stars in the Hipparcos Catalogue using the UK radio telescope MERLIN, and discuss its potential for controlling the Hipparcos frame relative to the International Celestial Reference Frame (ICRF).

2. MERLIN

MERLIN is a real-time radio-linked radio interferometer array with a maximum baseline of 217 km, giving a resolution of ~40 mas at 5 GHz. The positions of weak radio sources (few mJy) are obtained by using sources in the ICRF as phase calibrators. Observations are made at 4993 MHz with a bandwidth of 15 MHz. Typically, the star-calibrator separation is 5° and the cycle time is 5-10 min.

3. TARGET RADIO STARS

Ideally, the target stars for determining the Hipparcos-ICRF link should be compact (ie <2 mas), radio bright (ie >2 mJy) and preferably not in the VLBI programme, so that the MERLIN observations can provide an independent link. The obvious candidates are chromospherically active stars, such as RS CVn and BY Dra stars. The radio emission from these stars is non-thermal and caused by increased magnetic fields, often due to the presence of a close companion. The radio emission is usually variable, showing flares and sometimes related to the orbital period of the binary system.

A list of likely targets was drawn up and the first observations were made in 1992. Since the radio emission is known to flare on timescales of days to weeks, a survey of approximately 25 suitable targets was carried out by observing each one (and its ICRF calibrator) for ~3 hours spread over three widely spaced hour angles. These data were analysed immediately, and those stars detected over a threshold of 1.5 mJy were followed up by further observations. These follow-up observations were made in a piecemeal fashion over a period of about two weeks in order to make use of survey observations and to fit around scheduled observations.

4. HIPPARCOS-ICRF LINK

By the end of 1995, when the link of Hipparcos to the ICRF was finalised, MERLIN had carried out 16 measurements of the positions of 13 radio stars. Of these, 11 stars were actually used in the link. The Hipparcos proper motions and parallaxes were used to reduce the MERLIN geocentric positions of date to the barycentre and mean epoch of Hipparcos (1991.25). The Hipparcos and MERLIN positions were subtracted and the usual observational equations (unweighted) (see, for example, Lindegren & Kovalevsky (1995)) for the position vector of the ICRF from the Hipparcos Catalogue (ϵ) were solved by least-squares:

$$\epsilon' = [\ +1.4 \quad -0.6 \quad +0.5\ ]\,\mathrm{mas} \quad (1994.0)$$

The uncertainty of each component is ± 2.2 mas. This result which is referred to the Earth's equatorial plane can be referred to the galactic plane through the transformation:

$$\varepsilon = G'\epsilon$$

where G is the rotation matrix:

$$G = \begin{bmatrix} -0.055 & +0.494 & -0.868 \\ -0.873 & -0.445 & -0.198 \\ -0.484 & +0.747 & +0.456 \end{bmatrix}$$

The standard error of the solution (ε_1,ε_2) is plotted in Figure 1 as an unfilled circle. The VLBI solution which was used in linking the Hipparcos frame to the ICRF is shown as a black circle.

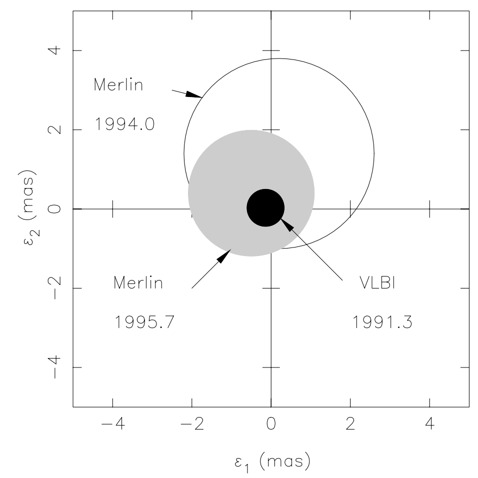

Figure 1. Measurements of the offset in the galactic plane of the origin of the ICRF from that of Hipparcos. The radii of the circles denote one standard error.

Since the link was finalised, MERLIN has carried out more observations, bringing the total number of observations of 21 radio stars to 28. The areal distribution of these radio stars is shown in Figure 2.

Hipparcos frame from the ICRF was made after the rejection of two outliers:

$$\epsilon' = [\ -0.8 \quad 0.0 \quad +1.1\ ]\,\mathrm{mas} \quad (1995.7)$$

The uncertainty of each component is ±1.7 mas. This latest solution (transformed to the galactic plane) is plotted as a gray circle in Figure 1.

The post-fit residuals from this solution are listed in Table 1.

Algol is a triple system, AB–C, where the separation of AB is ∼4 mas and AB–C is ∼95 mas. The Hipparcos position is the centre of mass of the AB–C system. The radio emission comes from AB, so we reduced the MERLIN position to the centre of mass using the orbital elements and mass ratios given by Pan et al. 1993. However, there is evidence from the Hipparcos observations that the line of nodes in Pan et al. is wrong by 180°. The subsequent residuals (see Table 1) for the MERLIN position of Algol in this paper confirm this. With this alteration, we found corrections from AB to the centre of mass of +12.9 and −10.0 mas in right ascension and declination, respectively.

5. DISCUSSION

The final orientation of the Hipparcos Catalogue is very close to the VLBI determination at 1991.3 (Kovalevsky et al. 1997). The latest MERLIN observations support that determination. Only five of the 21 stars are common to the VLBI and MERLIN datasets (LSI +61° 303, Algol, BH CVn, σ^2 CrB, IM Peg); so the two solutions are virtually independent and their close agreement lends confidence to the stability of the link, which could have been distorted by significant offsets between the optical and radio positions in some of the binary systems.

The VLBI solution for the rotation of the Hipparcos frame relative to the ICRF has an uncertainty of ±0.25 mas yr^{-1}. The maintenance of the Hipparcos frame will therefore depend on periodic checks on its alignment to the ICRF. There are four years between the epoch of the VLBI solution (1991.3) and that of the latest MERLIN solution (1995.7). The projected error at epoch 1995.7 of about 1.2 mas (including 0.6 mas at epoch 1991.3) is well within the 1 σ (1.7 mas) limit of MERLIN.

Our aim is to provide a tighter constraint in the future. In the best cases MERLIN may achieve sub-mas accuracy on radio stars. Even for weak radio stars of only a few mJy and separations of several degrees, MERLIN can achieve accuracies of a few mas. Possible enhancements to MERLIN, such as upgrading the Lovell telescope and increasing the bandwidth, along with better corrections for atmospheric phase errors, might allow MERLIN to achieve sub-mas accuracy on many more stars. Pilot observations will identify which radio stars are radio-active.

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Table 1. Post-fit residuals, Hipparcos–MERLIN.

HIC	Name	Alias	Epoch	$\Delta\alpha \cos\delta$ mas	$\Delta\delta$ mas	HIC	Name	Alias	Epoch	$\Delta\alpha \cos\delta$ mas	$\Delta\delta$ mas
9630	XX Tri	HD12545	96.81	−4.3	−9.1	66257	BH CVn	HR5110	92.98	−0.6	−3.1
12469	V615 Cas	LSI+61° 303	93.00	−3.7	+1.0	66257	BH CVn	HR5110	96.81	−6.5	−4.2
14576	β Per	Algol	93.00	−8.5	+5.3	79607	σ^2 CrB		92.94	+1.6	+0.3
16879	V837 Tau	HD22403	95.40	−4.1	−17.4	91009	BY Dra	HD234677	95.35	−3.5	−2.4
16879	V837 Tau	HD22403	95.40	+0.9	−14.9	108644	FF Aqr	SAO145804	95.33	−4.9	−0.3
16879	V837 Tau	HD22403	95.40	+3.3	−7.2	108728	RT Lac	HD209318	96.81	−2.0	−4.0
16879	V837 Tau	HD22403	97.06	+7.7	−3.3	109002	HK Lac	HD209813	96.81	−3.3	+3.9
19431	EI Eri	HD26337	95.32	−10.8	−11.8	112997	IM Peg	HD216489	96.81	−4.4	−0.9
37629	σ Gem	HD62044	96.81	+0.2	−1.3	114939	SZ Psc	HD219113	96.81	+8.2	−5.5
37629	σ Gem	HD62044	97.15	−1.5	−7.8	116584	λ And	HD222107	95.35	−4.5	+5.1
49018	DH Leo	SAO81134	96.81	+3.0	+6.6	117915	II Peg	HD224085	95.32	−3.3	+0.1
53425	DM UMa	SAO15338	95.31	+17.0	+1.4	117915	II Peg	HD224085	95.35	+1.8	−4.2
64293	RS CVn	HD114519	96.81	+0.2	−7.7	117915	II Peg	HD224085	97.15	+2.0	+5.4
65915	FK Com	HD117555	95.31	+6.5	−10.7						
65915	FK Com	HD117555	97.15	+14.7	−11.3						

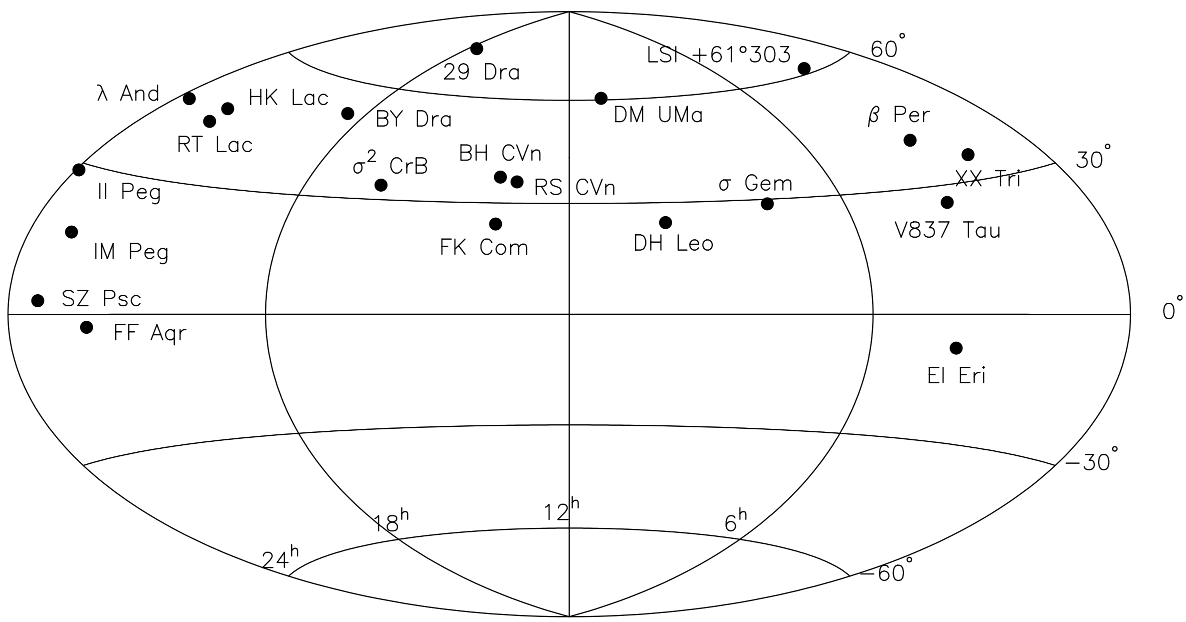

Figure 2. Distribution of link sources.