COMPARISONS OF RESULTS FROM HIPPARCOS WITH GROUND-BASED AND RADIO OBSERVATIONS*

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ABSTRACT

In the linkage between the optical and the radio reference frames the radio stars are the important objects. Using the observations of radio stars with the astrolabes at Shanghai Observatory and the Hipparcos results, we study the following terms in this paper: (i) the rotation relations and the systematic differences between the FK5 and Hipparcos catalogues; (ii) the comparisons between the results of the ground-based observations obtained at Shanghai Observatory and that of the Hipparcos and radio results; (iii) the discussion of the observational errors of the ground-based observations.

Keywords: Astrometry, Reference frames, radio stars.

1. INTRODUCTION

Using the radio stars is one method of the linkage between the optical and radio reference frames. From 1980 to 1982 and from 1985 to 1988 respectively with the astrolabe, photoelectric astrolabe and astrograph at Shanghai Observatory, about 100 radio stars have been observed. Among these partial radio stars have been obtained the proper motions through the comparisons between the other catalogues and ours.

For the research of the Earth rotation, the observational results of the Chinese Time and Latitude Services have been transfered into the FK5 system and the new astronomical constants system. These results will be transfered into the Hipparcos system. For this reason the systematic differences between the ground-based catalogues and the Hipparcos catalogue should be estimated.

In addition we have two proposals in the Hipparcos observational programme, it consists the 41 radio stars and about 704 FK5 and 794 GC stars (Xu 1988).

In this paper with the space observational results of 41 radio stars and 704 FK5 stars the comparisons between the observational results of astrolabes of Shanghai Observatory and that of the Hipparcos and radio observations for radio stars were discussed. The systematic differences between the astrolabe catalogues and the Hipparcos catalogue were also estimated.

*Based on data from the ESA Hipparcos astrometry satellite.

2. DATA USED

All of the optical observations which include 22 radio stars were made with the astrolabe and photoelectric astrolabe of Shanghai Observatory (Lu et al. 1996, 1997)

In the Hipparcos Catalogue (ESA 1997) a total of 41 radio stars and 704 FK5 stars were included. These FK5 stars were used by the observational programmes of the Chinese Time and Latitude Services. The declination range is from $-10°$ to $+70°$.

3. COMPARISONS OF THE OBSERVATIONS OF RADIO STARS

The Hipparcos system has been tied into the IERS celestial reference system, therefore the differences between the optical and Hipparcos catalogues should be representative of optical-radio differences. From the catalogues of the FK5 (Fricke et al. 1988) and Hipparcos, the sense (FK5-Hip) of the positions and the proper motions, for 704 FK5 stars include in this study were taken at epoch of J2000.0 respectively. The linkage equations of rigid rotation between two frames can be written as follows:

$$\begin{aligned} \Delta\alpha\cos\delta &= -\omega_x\sin\delta\cos\alpha - \omega_y\sin\delta\sin\alpha + \omega_z\cos\delta \\ \Delta\delta &= \omega_x\sin\alpha - \omega_y\cos\alpha \end{aligned} \quad (1)$$

$$\begin{aligned} \Delta\mu_\alpha\cos\delta &= -\omega_x^{'}\sin\delta\cos\alpha - \omega_y^{'}\sin\delta\sin\alpha + \omega_z^{'}\cos\delta \\ \Delta\mu_\delta &= \omega_x^{'}\sin\alpha - \omega_y^{'}\cos\alpha \end{aligned} \quad (2)$$

in which $\Delta\alpha, \Delta\delta, \Delta\mu_\alpha$ and $\Delta\mu_\delta$ are $(\alpha_{\rm Cat} - \alpha_{\rm Hip})$, $(\delta_{\rm Cat} - \delta_{\rm Hip})$, $(\mu_{\alpha_{\rm Cat}} - \mu_{\alpha_{\rm Hip}})$ and $(\mu_{\delta_{\rm Cat}} - \mu_{\delta_{\rm Hip}})$ respectively, ω_x, ω_y and ω_z represent the orientation

Table 1. Optical-Hipparcos rotational parameters (S refers to sources, N to number of stars).

S	ω_x (mas)	ω_y (mas)	ω_z (mas)	N
SA	5.4 ± 12.2	-40.5 ± 11.8	-37.4 ± 14.2	22
PPM	-18.9 ± 5.7	-34.5 ± 6.5	-3.7 ± 22.2	34

differences of between two frames, $\omega_x^{'}, \omega_y^{'}$ and $\omega_z^{'}$ represent the spin differences between two frames.

Using Equations (1) and (2) for the 704 FK5 stars the rotational parameters and the spin differences both FK5 and Hipparcos are given without weight as follows respectively:

$$\begin{aligned} \omega_x &= -31.3 \pm 0.3 \text{ mas} & \omega_x^{'} &= -0.3 \pm 0.1 \text{ mas/yr} \\ \omega_y &= -8.8 \pm 0.3 \text{ mas} & \omega_y^{'} &= 0.6 \pm 0.1 \text{ mas/yr} \\ \omega_z &= 12.3 \pm 4.6 \text{ mas} & \omega_z^{'} &= 0.6 \pm 0.1 \text{ mas/yr} \end{aligned} \quad (3)$$

In the paper of Lu et al. (1996, 1997) the positions and proper motions of 22 radio stars are in the FK5 system, in which the positions are the J2000.0 equatorial system and the observational epoch, the proper motions are the epoch of J2000.0. The mean observational epoch is 1982. With these proper motions, the positions of 22 radio stars were transfered to epoch of 1991.25. Then using Equations (1) the rotational parameters between Shanghai astrolabes and Hipparcos were taken. The results (SA) are given in Table 1. For the comparison, in 41 radio stars taken from the Hipparcos catalogue, 34 radio stars which are also given in the PPM catalogue (Röser et al. 1988) were selected. Using Equations (1) the similar results (PPM) are also shown in Table 1.

If these results considered of independent each other, then a mean value for each rotation can be estimated by averaging two values in Table 1. The resulting mean rotations are:

$$\begin{aligned} \omega_x &= -6.8 \text{ mas} \\ \omega_y &= -37.5 \text{ mas} \\ \omega_z &= -20.5 \text{ mas} \end{aligned} \quad (4)$$

In 22 radio stars there are 8 stars which have the radio observations (Morrison et al. 1990). The mean epoch is 1984. With the proper motions, the optical positions of these 8 radio stars observed by Shanghai astrolabes were transformed to epoch of 1984. Using Equations (1) the rotational parameters between Shanghai astrolabes and radio are:

$$\begin{aligned} \omega_x &= -13.9 \pm 12.4 \text{ mas} \\ \omega_y &= -7.4 \pm 11.5 \text{ mas} \\ \omega_z &= -27.8 \pm 15.1 \text{ mas} \end{aligned} \quad (5)$$

From the comparisons between the values of (4) and (5) and that of (3) on left hand, there are slightly different for ω_z. The non-uniform distribution of stars, only few radio stars in this study and the residual effect of the systematic errors of catalogues are possibly the reasons.

4. COMPARISONS BETWEEN THE GROUND-BASED AND HIPPARCOS CATALOGUES

After the rotational effect were elimated in the positions of 704 FK5 stars, the sense (FK5-Hip) can be obtained again. With the analysis method (Bien et al. 1987) the systematicc differences (FK5-Hip) were calculated. In Figure 1(a) and (b) the $\Delta\alpha_\delta \cos\delta$ and $\Delta\delta_\delta$ of (FK5-Hip) for 704 FK5 stars are given. The results show that the external consistency of FK5 are about $\sigma_{\Delta\alpha\cos\delta}$=0.067 arcsec, $\sigma_{\Delta\delta}$=0.078 arcsec, and there are also a small magnitude effect in right ascension of the FK5. These coincide with the estimation of Stone (1994).

In the paper of Lu et al. (1993) the systematic differences (Cat-FK5) have been calculated for the Chinese General Photoelectric Astrolabe Catalogue (GCA), the photoelectric astrolabe catalogue of Yunnan Observatory (YUA) and the Carlsburg meridian Catalogue (CAMC5). With the relation:

$$(\text{Cat} - \text{FK5}) + (\text{FK5} - \text{Hip}) = (\text{Cat} - \text{Hip})$$

the systematic differences (Cat-Hip) can be taken. In Figure 2(a) and (b) the $\Delta\alpha_\delta \cos\delta$ and $\Delta\delta_\delta$ are given for the above 3 catalogues respectively. In the $\Delta\alpha_\delta \cos\delta$ and $\Delta\delta_\delta$ it consists the systematic differences of FK5 and the observational errors since the systematic differences in the Hipparcos catalogue can be negligible. From the comparisons between Figures 1 and 2 it shows that the systematic differences (Cat-Hip) coincide fundamentally with that of the FK5. And there are the warps with amplitudes of 0.09 arcsec in some range of the FK5 which coincide with the estimations of previous investigations (Lindegren et al. 1992, Stone 1994, Turon et al. 1992)

5. CONCLUSIONS

Due to the non-uniform distribution of stars, the observational errors and the residual effect of the systematic differences of catalogues, it will influence possibly the linkage both frames by using only few radio stars.

From the results of Figure 1 for 704 stars the warps in the FK5 present mainly in declination.

According to the results of Figure 2 it presents also the intrumental errors of different types. Due to the characters of astrolabes which consist about 4 hours span in right ascension of each observational group, the definition of the observational zenith distance and no curvature influence of the tube, therefore the instrumental errors of astrolabes seem not very large.

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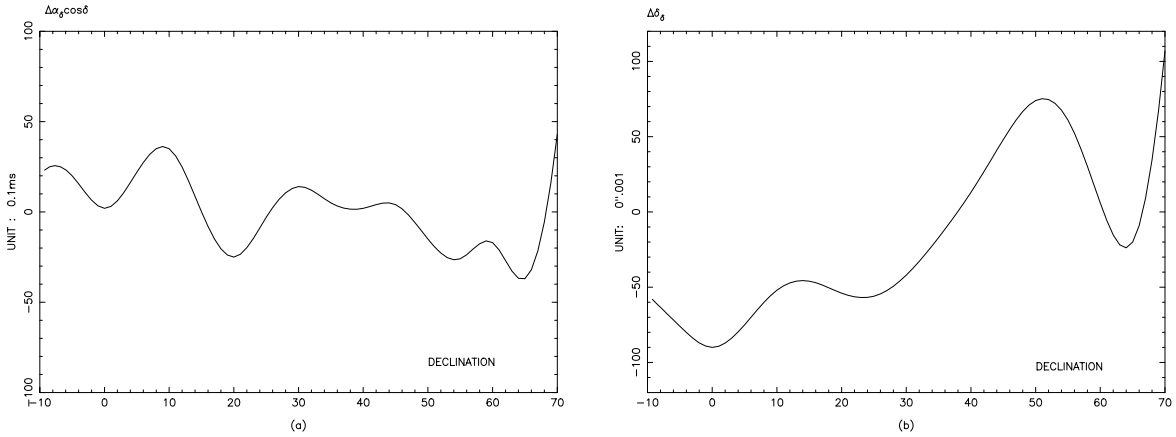

Figure 1. (a) systematic difference $\Delta\alpha_\delta \cos\delta$ and (b) $\Delta\delta_\delta$ in the sense (FK5-Hip).

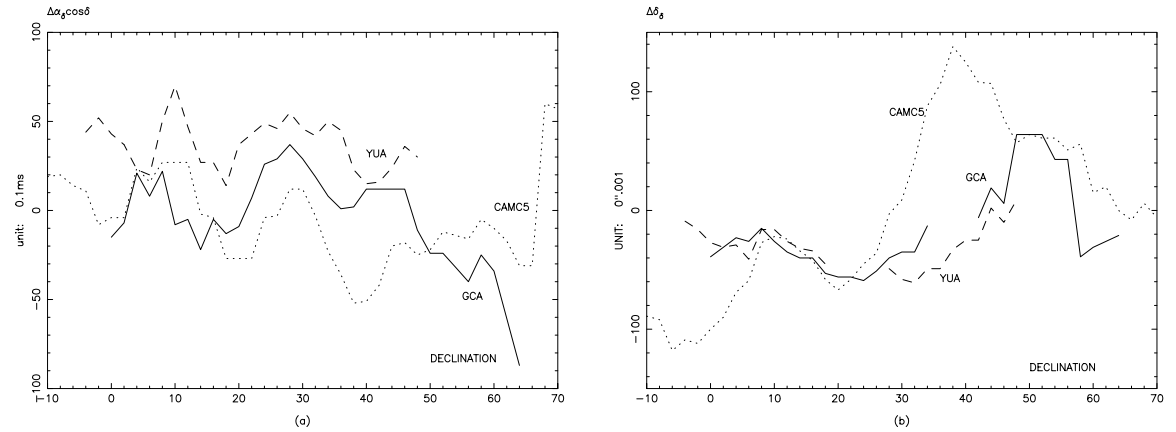

Figure 2. (a) systematic differences $\Delta\alpha_\delta \cos\delta$ and (b) $\Delta\delta_\delta$ in the sense (Cat-Hip).

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