Comparison of Hipparcos Proper-Motion System to the FK5

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Abstract. We present an intensive analysis of the FK5 proper-motion system via the two large astrographic catalogs, the PPM and ACRS catalogs, compared with the Hipparcos proper motions. Regional, magnitude, and color-dependent systematic errors in the PPM and ACRS proper motions are found, and exhibit similar tendencies for both catalogs. The term of the global rotation between the FK5 and Hipparcos proper-motion systems cannot be explained by the constant of the FK5 precessional correction, which is given by the VLBI and LLR observations. Comparing the Hipparcos proper motions with those of the SPM 2.0 Catalog, which provides absolute proper motions of objects measured directly relative to external galaxies, we found neither strong systematic nor large regional errors between the two systems.

1. Introduction

The capability of the accurate wide-angle measurements over the whole sky of the Hipparcos mission, has ensured that the Hipparcos system of stellar positions and proper motions is characterized by a high degree of internal consistency. Positions and proper motions in the Hipparcos Catalogue define a reference frame which is likely to be accurate, on a global scale, to about 0.1 mas at the epoch J1991.25 and 0.1 mas yr^{-1}. Therefore, it is not doubtful that the system can be considered to be free of regional errors. The system was constructed on the ICRS. The uncertainty of the Hipparcos system at the catalog epoch was estimated to be as accurate as 0.6 mas for the orientation and 0.25 mas yr^{-1} for the rotation with respect to the ICRS (Kovalevsky *et al.*, 1997).

We will concentrate the present work on proper-motion analyses of the FK5 system via the two large astrometric catalogs, the PPM Star Catalogue, compiled by Röser & Bastian (1989) and Bastian & Röser (1993) and the Astrographic Catalog Reference Stars (ACRS), compiled by Corbin & Urban (1991). Both catalogs are on the FK5 coordinate system. Another catalog, the SPM Catalog 2.0, used for the discussion, provides absolute proper motions of objects measured directly relative to external galaxies (Platais *et al.*, 1998a).

2. Regional, Magnitude, and Color-Dependent Differences

Due to the internal consistency, precise measurements of proper motions, and the high density of stars, the Hipparcos Catalogue is most appropriate to evaluate the regional differences of proper motions of stars contained in other astrometric catalogs. The vector diagrams of Figure 1 show distributions of regional errors of proper motions in the PPM and ACRS catalogs, where the top panel is given for the PPM in the sense PPM−Hipparcos, while the bottom panel exhibits the distribution for the ACRS in the sense ACRS−Hipparcos. The regional differences exhibit a similar distribution over the whole sky, and show similar systematics. But quantitatively, they are obviously inconsistent for the same individual region, even if both catalogs were aligned to the same FK5 system. This is probably due to the localized errors of proper motions existing in the PPM and ACRS catalogs, and to different accuracies of the alignments to the FK5 system.

Using 9,386 single stars common to the SPM 2.0 and Hipparcos catalogs, we have carried out the same analysis for the SPM 2.0 proper-motion system, and found neither strong systematics nor large regional errors. The typical regional error in proper motions is 0.6 mas yr^{-1} for $\Delta\mu_\alpha^*$ and 0.8 mas yr^{-1} for $\Delta\mu_\delta$.

Analyzing the magnitude and color-dependent differences in proper motions between the PPM and Hipparcos, and between the ACRS and Hipparcos, the systematic differences varied with the magnitude (V_T magnitude) and with the color index ($B-V$). These are shown in Figure 2. We found clear systematic differences of proper motions depended both on magnitudes and colors. The PPM and ACRS catalogs are similar in their color and magnitude equations with respect to the Hipparcos proper-motion system.

3. Global Rotation

By means of an overall pattern comparison of the FK5 proper-motion system with Hipparcos via the PPM and ACRS proper-motion data, we have determined the vectors of the global rotation between the PPM and Hipparcos, and between the ACRS and Hipparcos proper-motion system (Zhu & Yang, 1999). A recent work by Mignard & Frœschlè gave the global rotation between the FK5 and Hipparcos, and between the PPM and Hipparcos proper-motion systems (Mignard & Frœschlè, 2000).

Generally, the vector $\omega = (\omega_x, \omega_y, \omega_z)$ of the global rotation between two proper-motion systems can be expressed by

$$\begin{pmatrix} \Delta\mu_\alpha^* \\ \Delta\mu_\delta \end{pmatrix} = \begin{pmatrix} -\sin\delta\cos\alpha & -\sin\delta\sin\alpha & \cos\delta \\ \sin\alpha & -\cos\alpha & 0 \end{pmatrix} \begin{pmatrix} \omega_x \\ \omega_y \\ \omega_z \end{pmatrix}, \qquad (1)$$

where the components ($\Delta\mu_\alpha^*$, $\Delta\mu_\delta$) of the proper-motion difference are written in the sense of considered catalog minus Hipparcos Catalogue.

Selecting 9,386 single stars common to Hipparcos and SPM 2.0 catalogs, a least-squares solution gives the components of the rotational vector which are listed in Table 1, where the second column is the rotation between FK5 and Hipparcos proper-motion systems taken from Mignard & Frœschlè. The third

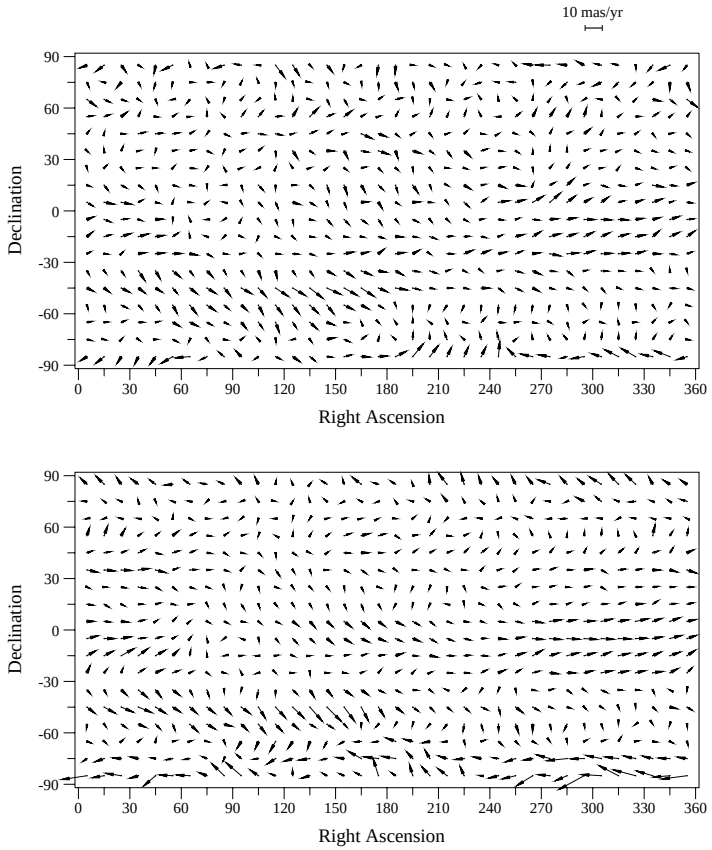

Figure 1. Regional differences of proper motions between PPM and Hipparcos catalogs in the sense PPM−Hipparcos (above), and between ACRS and Hipparcos in the sense ACRS−Hipparcos (below).

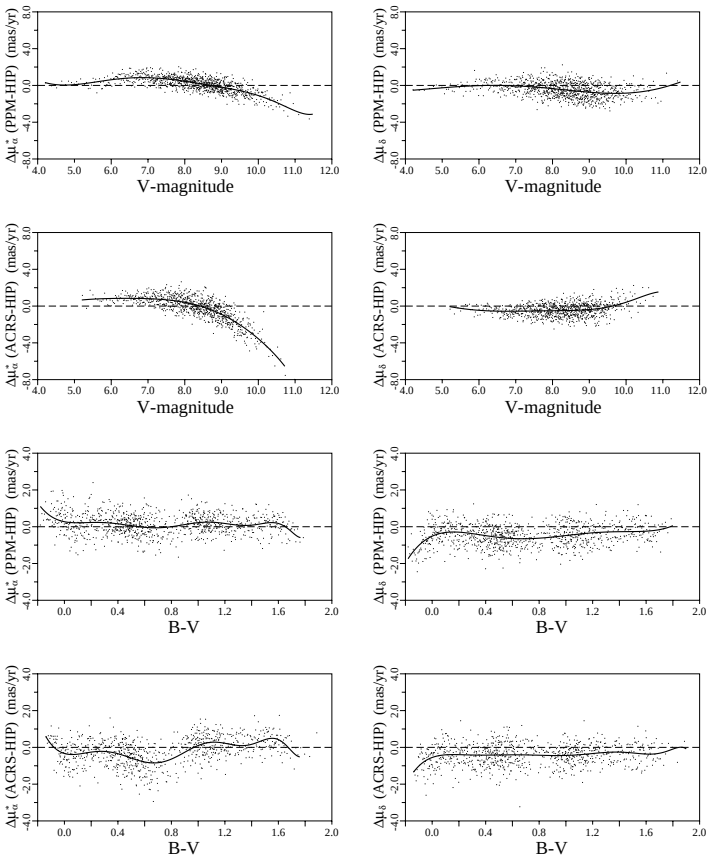

Figure 2. Proper-motion differences between PPM and Hipparcos (PPM−HIP), and between ACRS and Hipparcos (ACRS−HIP), varied with the Hipparcos V_T magnitude or color index.

and fourth columns are our previous results for rotational vectors between PPM and Hipparcos, and between the ACRS and Hipparcos proper-motion systems, respectively (Zhu & Yang, 1999).

Table 1. Global rotation from FK5, PPM, ACRS, and SPM 2.0, relative to the Hipparcos proper-motion system.

	FK5−HIP[a]	PPM−HIP[b]	ACRS−HIP[b]	SPM−HIP
ω_x	-0.30 ± 0.10	-0.67 ± 0.03	-0.42 ± 0.10	-0.10 ± 0.17
ω_y	$+0.60\pm0.10$	$+0.84\pm0.03$	$+0.56\pm0.10$	-0.48 ± 0.14
ω_z	$+0.70\pm0.10$	$+0.18\pm0.03$	-0.08 ± 0.10	$+0.17\pm0.15$

[a]Given by Mignard & Frœschlè (2000)

[b]Taken from Zhu & Yang (1999)

In a global sense, the FK5 proper-motion system should differ from the Hipparcos proper-motion system by the constant of the lunisolar precessional correction and by a correction to the fictitious motion of the equinox. Considering the results of the relative rotations of the FK5, PPM, and ACRS proper-motions systems to Hipparcos listed in Table 1, and taking the precessional correction $\Delta p \approx -3.0 \pm 0.2$ mas yr^{-1} into account, which is independently determined by VLBI and LLR (Charlot *et al.*, 1995, Chapront *et al.*, 1999), we cannot find a consistent explanation directly from the derived values of the rotational vector.

The SPM 2.0 proper-motion system has been constructed on the ICRS reference system with respect to distant extragalactic sources. Thus, the proper-motion system of the SPM 2.0 should coincide with the Hipparcos proper-motion system, if the two systems are exactly aligned to the ICRS system. The solution gives the rotational vector of the SPM 2.0 proper motions related to the Hipparcos proper-motion system. The present result is in a good agreement for all three components with the mean values of the residual spin components derived from the mean-per-field SPM-data solution using the re-calibrated magnitude equation by Platais *et al.* (*cf.* Table 3 in Platais *et al.*, 1998b).

4. Conclusion

On the basis of the Hipparcos data, we have performed analyses on the FK5 proper-motion system via two large astrometric catalogs, and have found that the PPM and ACRS catalogs are similar in their color and magnitude equations with respect to the Hipparcos proper-motion system. The global rotation of proper motions between the PPM and ACRS, and between the ACRS and Hipparcos, show a large offset compared with the correction of the precessional constant determined by VLBI and LLR.

From the proper-motion comparison between the SPM 2.0 and Hipparcos catalogs, we found that the regional differences of the SPM 2.0 proper motions exhibit neither strong systematics nor large regional errors. The typical regional error for the SPM 2.0 proper motions is as small as ±0.8 mas yr^{-1}. The global

rotation related to the Hipparcos frame is slower than 0.25 mas yr^{-1} except for the component along the y-axis.

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