Research in Astron. Astrophys. **2011** Vol. **11** No. **9**, 1074–1084
http://www.raa-journal.org *http://www.iop.org/journals/raa*

***R**esearch in*
***A**stronomy and*
***A**strophysics*

Systematic differences in position and proper-motion between the PPMX and UCAC3 catalogs *

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Received 2011 May 10; accepted 2011 May 20

Abstract Considered to be extensions of the Hipparcos reference system, PPMX and UCAC3 are two of the most important astrometric catalogs released in current years. Extensive analyses of these two large catalogs have been made in order to determine the local and overall systematic biases. The regional and magnitude dependent differences in stellar position and proper motion are comparable to random errors and are even larger in the northern hemisphere. The global orientation bias vector ϵ between the two systems is also significant (up to 17 mas), which shows the overall differences of the PPMX and UCAC3 catalogs and their reference systems. On the other hand, the term for the global rotation vector ω is small (tenths of mas per year): it is reasonable to believe that the PPMX and UCAC3 reference frames do not rotate with respect to each other. Because of plate dependent and field-to-field errors in the UCAC3 catalog, we suggest that positions and proper motions of UCAC3 stars in the northern hemisphere $(\delta > -20^{\circ})$ should be used with caution.

Key words: astrometry — catalogs — reference systems

1 INTRODUCTION

The fundamental celestial reference system for astronomical applications is now the International Celestial Reference System (ICRS), as expressed in the IAU resolution B2 of 1997. To establish the ICRS as a practical system, the IAU specified a set of distant radio objects, whose coordinates define the directions of the ICRS axes. This realization of the ICRS, called the International Celestial Reference Frame (ICRF), is a group of highly accurate positions of extragalactic radio objects measured by very long baseline interferometry (Ma et al. 1998). The latest version of the ICRF comprises 295 defining sources, which is called ICRF-2 (Ma et al. 2009). However, for a long time after the establishment of the ICRS, the faintness of the extragalactic sources prevented a precise determination of star positions in the optical bandpass, thus the Hipparcos catalog[1] was adopted as the primary realization of the ICRS at optical wavelengths. The frame bias and spin of the axes defined by the

* Supported by the National Natural Science Foundation of China.
[1] ESA 1997, The Hipparcos and Tycho catalogs (Noordwijk: ESA), ESA SP-1200

Hipparcos catalog were announced within ± 0.6 mas and $\pm 0.25\,\mathrm{mas\,yr^{-1}}$for all three axes, with respect to the ICRF at the Hipparocs mean epoch J1991.25.

The Hipparcos catalog and its revised version (van Leeuwen 2007) contain about 110 000 stars and the stellar density is about 3 per square-degree, which means that the Hipparcos catalog constructs a sparse grid on the celestial sphere. The main task of the astrometric community is to extend the Hipparcos Celestial Reference Frame (HCRF) to higher star densities and fainter limiting magnitudes. The first and most important extension of the HCRF is the Tycho-2 catalog (Høg et al. 2000), based on the mapping observations of the Hipparcos satellite and ground-based astrometric observations. The Tycho-2 catalog contains the 2.5 million brightest stars (99 percent complete to $V = 11.0$) in the sky with star density up to 150 per deg^2. The positional accuracy is about 60 mas for all stars and 7 mas for bright stars $V_{\mathrm{T}} < 9$ mag; the standard error of all the star proper motions is claimed to be 2.5 $\mathrm{mas\,yr^{-1}}$.

Taking Hipparcos or Tycho-2 as a benchmark, several large astrometric and photometric catalogs with much higher star density were produced. The US Naval Observatory B1.0 catalog (USNO B1.0) (Monet et al. 2003) is the latest version of the USNO ultra dense catalog, which publishes positions and three magnitudes for more than 1 billion objects. It results from reductions of thousands of Schmidt plates and calibration by using Tycho-2 stars. The nominal astrometric accuracy is 200 mas. Another example of such a large catalog is the Second Generation Guide Star catalog (GSC2.3) (Lasker et al. 2008), derived from the Digitized Sky Survey (Taff et al. 1990a,b). The GSC2.3 catalog contains more than 945 million entries and is expected to be complete to $R = 20$. Calibrated by the Tycho-2 catalog, the total astrometric standard error is quoted as 300 mas, and the relative astrometric error is lower than 200 mas. In longer wavelengths, the Two Micron All-Sky Survey (2MASS) point source catalog (Skrutskie et al. 2006) was constructed from uniform observations of the entire sky (covering 99.998% of the celestial sphere) in three near-infrared bands J (1.25 μm), H (1.65 μm) and K_{s} (2.16 μm). The 2MASS contains positions and photometric parameters of 470 992 970 sources, but no proper motions. The positions of stars are calibrated to the Tycho-2 catalog and the astrometric accuracy is 70–80 mas in the magnitude range of $9 < K_{\mathrm{s}} < 14$ mag.

In practical narrow-angle astrometric observations with photographic or CCD plates, Tycho-2 usually serves as a reference catalog, which provides positions and proper motions of standard stars. Because Hipparcos and Tycho-2 catalogs only have bright stars and low star density, some catalogs with higher star density and deeper limiting magnitude are necessary to serve as reference catalogs for fainter star observations. Those dense catalogs should also provide celestial grids that are consistent with the ICRF. In recent years, the observational UCAC3 (Zacharias et al. 2010) and compiled PPMX (Röser et al. 2008) are typical catalogs that contain on the order of $10^7 \sim 10^8$ stars and are regarded as extensions of the HCRF to about 16th magnitude.

Because of their important role in the extension of the celestial reference frame and studies in Galactic kinematics, dynamics and structure, we continue the overall comparison between the UCAC3 catalog and PPMX catalog, including regional and global differences in stellar positions and proper motions, and thus the reference frames they use. In Section 2 we review the properties of the two astrometric catalogs PPMX and UCAC3 and the cross-identification between them. Sections 3 and 4 show regional position and proper-motion comparisons, respectively and the global orientation and rotation between the two systems are presented in Section 5. In Section 6 there are some concluding remarks about PPMX and UCAC3 position and proper-motion systems.

2 PPMX AND UCAC3 CATALOG DATA AND CROSS IDENTIFICATION

2.1 UCAC3 Catalog

The third US Naval Observatory (USNO) CCD Astrograph Catalog, UCAC3 (Zacharias et al. 2010) was released at the 2009 IAU General Assembly in Brazil, which is an all-sky catalog containing, over 100 million stars mainly in the magnitude range $R = 8 \sim 16$ mag. It is based on observations with the USNO 8-inch Twin Astrograph telescope from 1998 to 2004, starting at the Cerro Tololo Inter-American Observatory (CTIO) and then at the Naval Observatory Flagstaff Station (NOFS). The positional precision at the mean observation epoch (mostly 1980–2002) is about $15 - 100$ mas in each coordinate, depending on magnitude, while the errors in proper motions range from $1 - 10\,\mathrm{mas\,yr^{-1}}$ depending on magnitude and observing history. The early epoch data for UCAC proper motions come from over 140 ground- and space-based catalogs, as well as Schmidt plate data from the Southern Proper Motion (SPM) program and the SuperCOSMOS project. The proper motions of stars in the northern hemisphere did not take the NPM data into consideration and will be improved in the next generation UCAC4.

Compared to its previous release of UCAC2 (Zacharias et al. 2004), the UCAC3 catalog has the following advantages in terms of astrometry:

- The sky coverage was complete in the northern hemisphere but UCAC2 was only complete from $\delta = -90°$ to $+40°$.
- Double stars, mainly in the $2''$–$10''$ separation, are resolved properly to the limit of the data.
- The pixel data were re-reduced with better modeling and a completely new method.
- The limiting magnitude is deeper and the number of stars is double that in UCAC3.
- New source catalogs are put into the reduction process in order to improve UCAC3 proper motions.
- The problematic or suspect entries are specified more explicitly to avoid misunderstandings.

The positions of UCAC3 stars were adjusted by the Tycho-2 catalog (Høg et al. 2000) so that UCAC3 positions are in the Hipparcos system, which is the optical implementation of the ICRS. In other words, UCAC3 can be regarded as an extension of the HCRF to a much higher star density and fainter magnitude. Entries in the UCAC3 catalog with reliable astrometric and photometric parameters can be used as reference stars to provide a standard grid for narrow-angle observations. For details of UCAC3 properties and its comparison with UCAC2 and other catalogs, readers are referred to the release paper of UCAC3 (Zacharias et al. 2010).

2.2 PPMX Catalog

For studies of Galactic structure, kinematics and dynamics, Röser et al. (2008) built the PPM-Extended catalog (PPMX) with the ICRS system, which aims to provide the best proper motions at present. The PPMX catalog is complete down to a well-defined limiting magnitude R_J which was introduced by Piskunov et al. (2008). With the star-list determined, stars in various catalogs (over a time span of one century) are cross-identified and reduced to the ICRS by the Tycho-2 catalog. The reduction method is different from UCAC3: PPMX adopted a rigorous weighted least-square (LSQ) adjustment to derive the mean positions and proper motions of stars. The final catalog contains astrometric and photometric information on 18 088 919 stars and is made up of three parts.

- The survey part flagged 'S,' is complete to $R_J = 12.8$ and comprised of 5 620 114 stars. The precision of proper motion in this part is typically 2 $\mathrm{mas\,yr^{-1}}$.
- The high-precision part flagged 'H' includes 874 934 stars whose earlier epoch data are from the Astrographic catalog (AC) (Urban et al. 2001), therefore the accuracy of proper motion is high (better than 3 $\mathrm{mas\,yr^{-1}}$).
- The other part flagged 'O' which contains all remaining entries.

PPMX provided precise material to study the Milky Way and is also an important extension of the HCRF.

More recently, Roeser et al. (2010) constructed the PPMXL catalog by combining USNO-B1.0 and 2MASS. PPMXL is also a compiled catalog which contains ICRS positions and proper motions of about 900 million objects and it is the largest collection of ICRS proper motions at present. In the reduction of PPMXL, the PPMX catalog was used as the representation of the ICRS, which means that PPMXL and PPMX are from the same reference system. Considering that PPMX is more fundamental than PPMXL and has a similar order of magnitude in terms of star numbers as UCAC3, we compare UCAC3 with PPMX rather than PPMXL.

2.3 Cross-identification Between Catalogs

In order to make an intensive comparison between the PPMX and the UCAC3 catalogs, cross-identification is necessary and crucial for further analysis. At first, false entries, double and multiple stars and problematic entries are excluded from both catalogs. As the next step, a match radius of $0.3''$ was adopted using the software TOPCAT (available at website: *http://www.star.bris.ac.uk/ mbt/topcat/*) for position coincidence at the epoch of J2000.0. We adopted a radius of $0.3''$ as a criterion because the high positional accuracy of both catalogs is typically better than 200 mas and such a small radius helped us to effectively reject reduplicated pairs. PPMX and UCAC3 have common photometric parameters J, H and $K_{\rm s}$ copied from the 2MASS catalog: they were used as a secondary criterion in the catalog match.

As a result, the cross-identified data have 14 460 602 ($\sim 80\%$ in PPMX) single, well observed and reliable records. Among the matched stars, 5 302 365 stars are in the PPMX survey or high-precision part; they have relatively accurate proper motions. According to the analysis of Roeser et al. (2010), the UCAC3 data north of $\delta = -20°$ may be problematic due to plate-dependent distortions; the comparison is split up between the northern $(\delta > -20°)$ and southern $(\delta < -20°)$ hemispheres. There are 8 743 192 and 5 717 410 stars in the north and south, respectively.

Figure 1 describes the standard error of right ascension in the UCAC3 catalog at J2000.0 as a function of right ascension and declination. The pattern for declination error is quite similar to Figure 1. We can see in the right panel that the standard error is different on the left and right sides of $\delta = -20°$ and the distribution of position errors is also not uniform in the left panel as a function of right ascension.

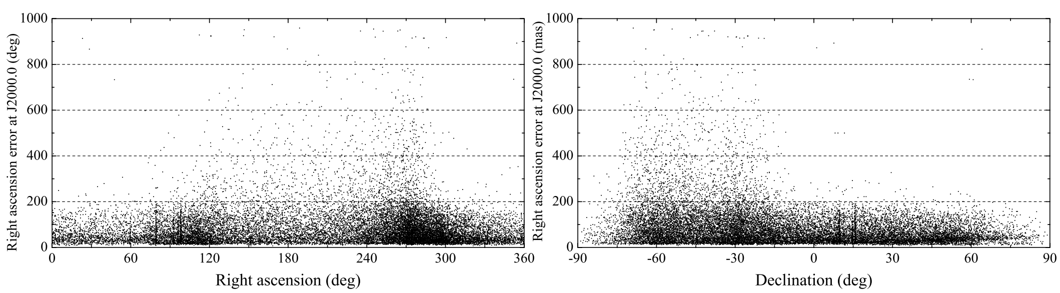

Fig. 1 J2000.0 standard error in right ascension of the UCAC3 catalog.

3 POSITIONAL COMPARISON BETWEEN PPMX AND UCAC3

The PPMX and UCAC3 catalogs are compared at a common epoch based on the cross-identified catalog. Figures 2 and 3 illustrate the [PPMX-UCAC3] position difference as a function of right ascension. The deviation of the two catalogs in the direction of right ascension is almost randomly distributed and the right ascensions in PPMX seem a little larger (approximately 3 mas in the south and 8 mas in the north) than those in UCAC3. The differences are not significant compared to their position errors, although in the plots each dot represents the mean difference in right ascension or declination over 500 stars along the abscissa, eliminating some stars with large residuals.

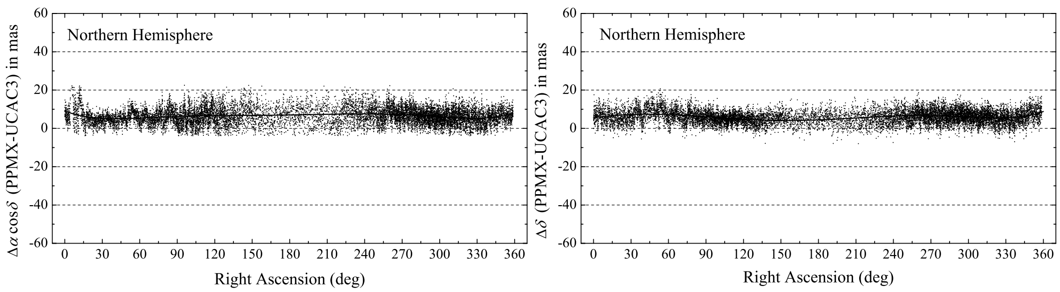

Fig. 2 Position difference [PPMX-UCAC3] at epoch J2000.0 as a function of right ascension for stars in the northern hemisphere $\delta > -20°$. Each dot represents the mean calculated over 500 stars.

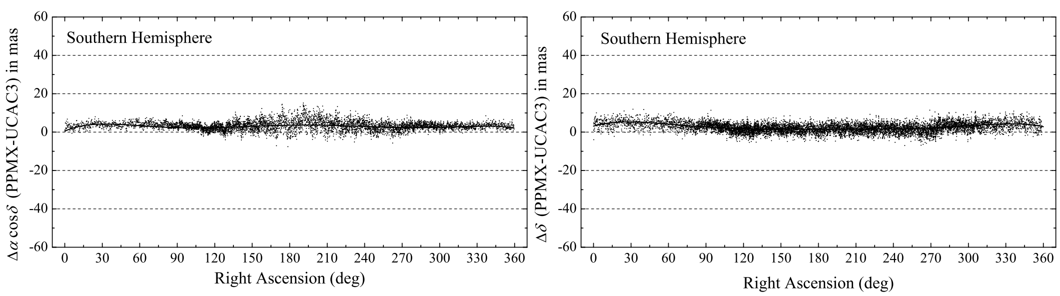

Fig. 3 Position difference [PPMX-UCAC3] at epoch J2000.0 as a function of right ascension for stars in the southern hemisphere $\delta < -20°$. Each dot represents the mean calculated over 500 stars.

The position difference as a function of declination is shown in Figure 4, where the left panel demonstrates the variation for the $\Delta\alpha\cos\delta$ component and the right panel is for the $\Delta\delta$ component. This plot clearly shows strong declination-dependent systematics, especially for the northern hemisphere and the $\Delta\alpha\cos\delta$ component. We cannot make sure which catalog should be responsible for the large systematic difference, however, from the release paper of UCAC3 (Zacharias et al. 2010) and the comparison between UCAC3 and its earlier release UCAC2, we can infer that those systematics may come from UCAC3.

The saw-tooth pattern is visible in both the right ascension and declination directions in the northern hemisphere. These were likely introduced by the SuperCOSMOS (Hambly et al. 2001) Schmidt plate data which were applied to generate the UCAC3 proper motions. The periods of this saw-tooth pattern are close to the SuperCOSMOS $5°$ fields of view which are based on the POSS (Palomar Observatory Schmidt Survey) plates. It is surprising to see a more remarkable dispersion in $\Delta\alpha\cos\delta$ than in $\Delta\delta$: the amplitude in right ascension difference is up to 180 mas at $\delta > 60°$, but the declination difference is much smaller (about 60 mas). The largest discrepancy occurs in the area where plates overlap due to the marginal effect of plate observations that produce distortions in stellar positions (plate-to-plate errors). On the other hand, star positions from the PPMX catalog, derived by rigorous weighted least-square analysis based on individual observational accuracy, suffer a much smaller effect from Schmidt plate observations.

Figures 5 and 6 are the systematic difference [PPMX-UCAC3] referring to the 2MASS magnitude J, where the scale of the y-axes of the northern and southern panels are different. The variation

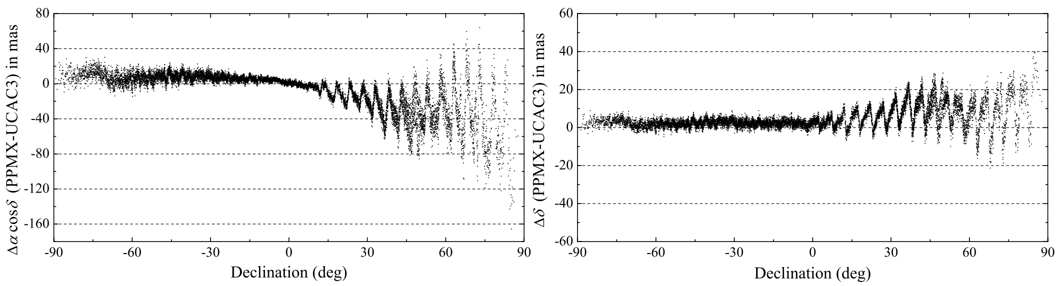

Fig. 4 Position difference [PPMX-UCAC3] at J2000.0 as a function of declination for the whole celestial sphere. Note that the vertical coordinates of the left and right panels are for different scales. Each dot represents the mean calculated over 500 stars.

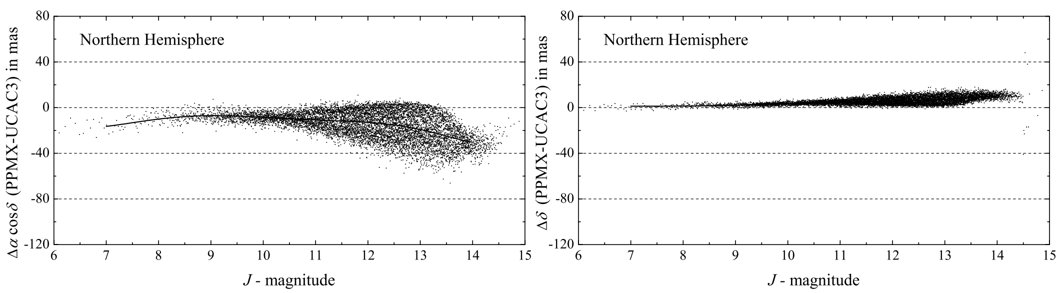

Fig. 5 Position difference [PPMX-UCAC3] at epoch J2000.0 as a function of 2MASS J magnitude for stars in the northern hemisphere $\delta > -20^{\circ}$. Each dot represents the mean calculated over 500 stars.

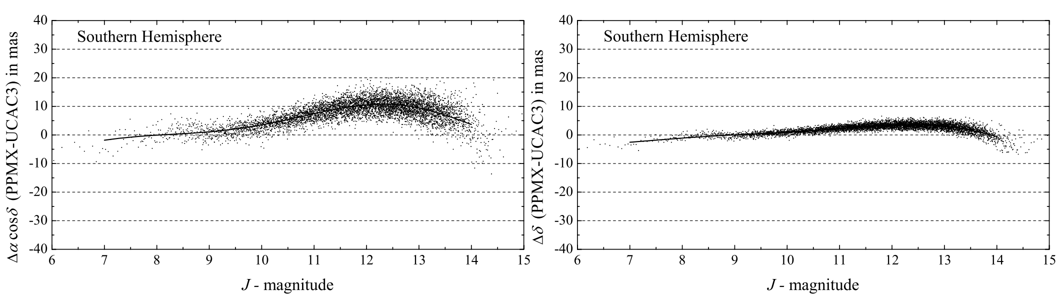

Fig. 6 Position difference [PPMX-UCAC3] at epoch J2000.0 as a function of 2MASS J magnitude for stars in the southern hemisphere $\delta < -20^{\circ}$. Each dot represents the mean calculated over 500 stars.

of position differences as a function of magnitude is significant, especially for the right ascension component. In the northern hemisphere, $\Delta\alpha \cos\delta$ is almost negative but in the southern hemisphere it seems positive. For the declination component, the difference is not pronounced except for the fainter end.

4 SYSTEMATIC DIFFERENCE BETWEEN PPMX AND UCAC3 PROPER-MOTION SYSTEMS

Proper-motion systems of reference star catalogs are crucial and the framework of a reference catalog may be distorted by the systematic and random errors of proper motions.

Based on the well identified catalog that contains common stars in PPMX and UCAC3, we perform a regional comparison between the two catalogs. First we divide the celestial sphere into 36×18 cells so that each one covers $10°$ in right ascension or Galactic longitude and $10°$ in declination or Galactic latitude. Each sub-area contains hundreds of thousands of stars depending on the declination or Galactic latitude zone. Then the mean differences of proper motions of stars in each sub-area $\left(\overline{\Delta\mu_\alpha \cos\delta}, \overline{\Delta\mu_\delta}\right)$ are calculated in the sense of [PPMX-UCAC3]. Stars with large residuals $(> 2.6\sigma)$ of proper motions were removed from the statistical average to ensure the reliability of the comparison.

Figures 7 and 8 are vectorial diagrams that describe the regional distribution of proper motion difference between PPMX and UCAC3 in the equatorial and Galactic coordinate systems respectively. Remarkably large discrepancies in the proper-motion system are found in the northern hemisphere $(\delta > -20°)$ which are mainly pointing to the direction of decreasing declination. The typical magnitude of the vector in the northern sub area is 4–6 $\mathrm{mas\ yr^{-1}}$. In the Galactic coordinate system, the rotations of those vectors are likely to be around the north celestial pole (NCP). In the southern hemisphere $(\delta < -20°)$ the proper-motion system of the two catalogs does not show a significant difference. As mentioned in the previous section, the mismatch in the northern hemisphere may be attributed to the UCAC3 catalog.

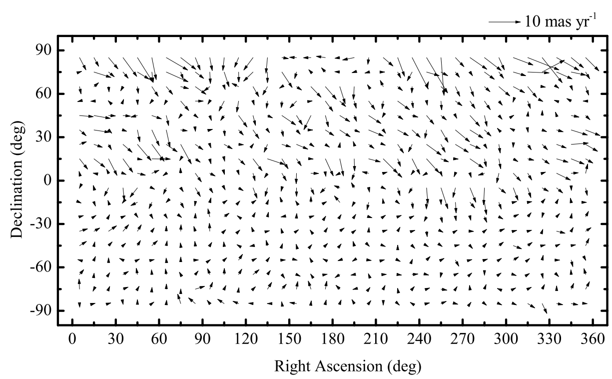

Fig. 7 Regional difference of proper motions between PPMX and UCAC3 in the sense [PPMX-UCAC3] in the equatorial coordinates.

The magnitude-dependent differences between PPMX and UCAC3 proper-motion systems are also more significant in the north than in the south and are pronounced in the fainter magnitude range where the systematic trend is clearly shown (see Figs. 9 and 10). The proper-motion system in the fainter magnitudes is more uncertain than at the bright end. We also analyze the relation of the color-dependent pattern of the systematic differences in proper motions for the PPMX and UCAC3, where the color index $J - K$ is taken from the 2MASS catalog. The 2MASS gives the $J - K$ index of stars normally running from –0.2 mag for early type stars to 1.6 mag for late-type stars. The variations in proper motion difference are displayed in Figures 11 and 12. For the northern hemisphere, the systematics are visible but not that evident compared to regional differences.

From the above analysis, there may be some systematic errors in the northern part of PPMX or UCAC3 and, according to Roeser et al. (2010), UCAC3 should be responsible for the difference.

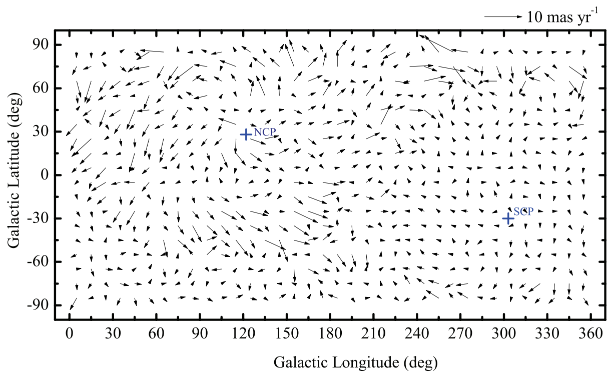

Fig. 8 Regional difference of proper motions between PPMX and UCAC3 in the sense [PPMX-UCAC3] in the Galactic coordinates.

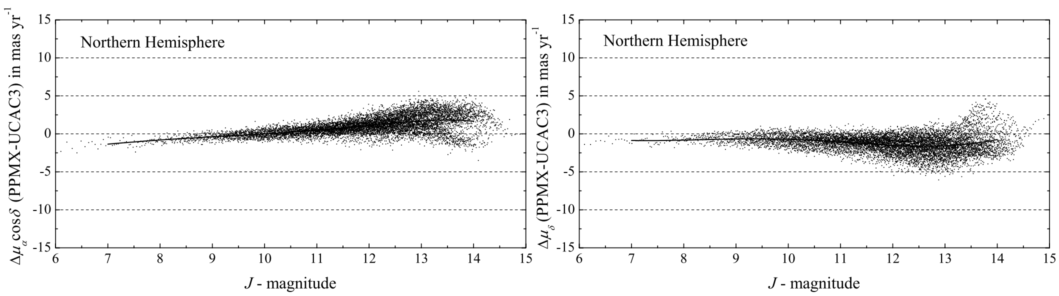

Fig. 9 Proper motion difference [PPMX-UCAC3] as a function of 2MASS J magnitude for stars in the northern hemisphere $\delta > -20°$. Each dot represents the mean calculated over 500 stars.

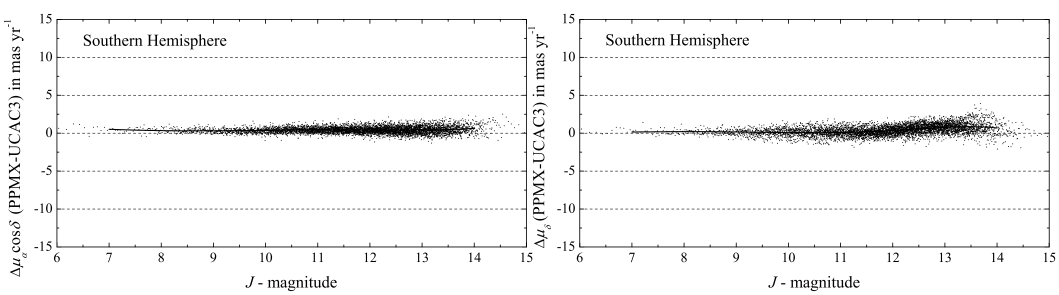

Fig. 10 Proper motion difference [PPMX-UCAC3] as a function of 2MASS J magnitude for stars in the southern hemisphere $\delta < -20°$. Each dot represents the mean calculated over 500 stars.

Zacharias & Gaume (2011) have pointed out that there may be some problems in the reduction of UCAC3 proper motions. Thus, UCAC3 should be used with caution as a reference catalog at J2000.0, especially for the stars in the northern hemisphere ($\delta > -20°$).

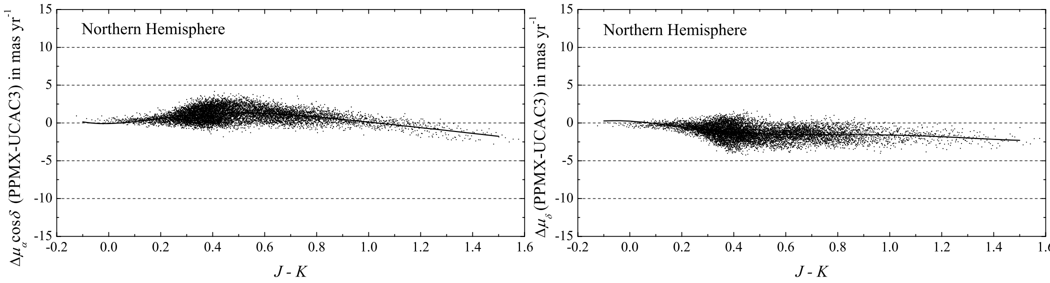

Fig. 11 Proper motion difference [PPMX-UCAC3] as a function of 2MASS $J - K$ color for stars in the northern hemisphere $\delta > -20^\circ$. Each dot represents the mean calculated over 500 stars.

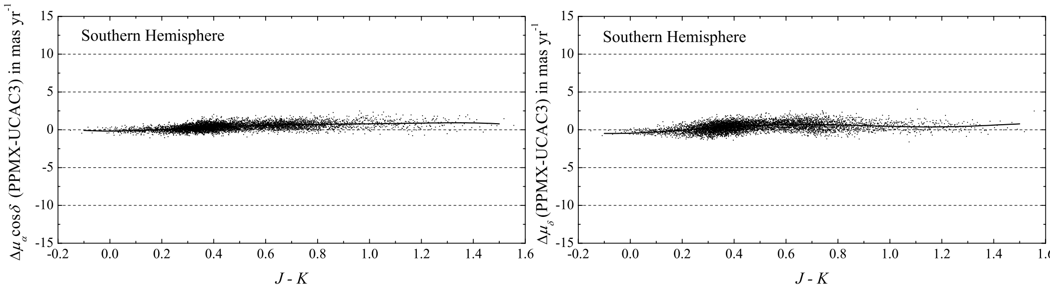

Fig. 12 Proper motion difference [PPMX-UCAC3] as a function of 2MASS $J - K$ color for stars in the southern hemisphere $\delta < -20^\circ$. Each dot represents the mean calculated over 500 stars.

5 GLOBAL ORIENTATION AND ROTATION BIAS

In previous sections we discussed region-, magnitude- and color-dependent differences between PPMX and UCAC3 positions and proper-motion systems. The deviation between the two systems in the northern hemisphere is larger than in the south. In this section we analyze global orientation difference and rotation between PPMX and UCAC3 systems. Both of them are constructed to represent as close as possible the reference system defined by the Hipparcos Catalog. The comparison is performed for each common star in the cross-identified catalog as the positional and proper-motion difference $\Delta\alpha\cos\delta$, $\Delta\delta$, $\Delta\mu_\alpha\cos\delta$ and $\Delta\mu_\delta$ in the sense of [PPMX-UCAC3]. The global orientation bias can be expressed as a vector $\epsilon = (\epsilon_x, \epsilon_y, \epsilon_z)$ and it is related to the position difference of stars in the reference frame by:

$$\begin{aligned}&\Delta\alpha\cos\delta = -\epsilon_x\cos\alpha\sin\delta - \epsilon_y\sin\alpha\sin\delta + \epsilon_z\cos\delta,\\&\Delta\delta = \epsilon_x\sin\alpha - \epsilon_y\cos\alpha.\end{aligned} \tag{1}$$

By the least square fit method, three components of the bias vector can be solved. For comparison purposes, we divide the whole catalog into northern and southern parts at a declination of -20° and the results are presented in Table 1.

The orientation bias is given at the catalog epoch J2000.0 and the standard error for each component is similar. For results based on all sky, northern and southern stars, the signs of the three bias components are not consistent, which reflects the complexity of the regional difference discussed in the previous sections. The orientation bias has no deep physical meaning but only gives the global

Table 1 Global Orientation between the PPMX and UCAC3 Catalogs

	Whole sky (100 766 420)	Northern (8 743 192)	Southern (5 717 410)
ϵ_x	$+4.55 \pm 0.21$	$+6.82 \pm 0.24$	-0.65 ± 0.24
ϵ_y	-1.03 ± 0.21	$+1.46 \pm 0.24$	-6.29 ± 0.24
ϵ_z	-4.44 ± 0.24	-12.11 ± 0.28	$+15.97 \pm 0.31$

Notes: The above parameters are in units of mas and the numbers in the brackets are the numbers of stars in the corresponding sky areas.

orientation differences between the rigid framework that are manifested by PPMX and UCAC3 in a statistical sense. We cannot infer from the above results that the two catalogs represent different celestial reference systems considering the uncertainties of star positions in each catalog.

For proper-motion systems, the basic relation can also be described by a pure rigid-body rotation

$$\begin{aligned} \Delta\mu_\alpha \cos\delta &= -\omega_x \cos\alpha \sin\delta - \omega_y \sin\alpha \sin\delta + \omega_z \cos\delta, \\ \Delta\mu_\delta &= \omega_x \sin\alpha - \omega_y \cos\alpha, \end{aligned} \tag{2}$$

where ω_x, ω_y and ω_z are three small angular rotation speeds. The PPMX catalog provides stars with high-precision proper motions (flagged 'H') ($\sigma_{\rm pm} < 3\ {\rm mas\,yr^{-1}}$) which are derived from early epoch plate data. With an additional survey part (typical error of proper motion in this part is $2\,{\rm mas\,yr^{-1}}$), we have 5 302 365 high-precision cross-identified stars in the PPMX and UCAC3 catalogs. The global rotation we thus determined from a least square fit for all stars and high-precision proper motions are listed in Table 2. Note that stars with large residuals are excluded. In this table, the solutions are given in units of ${\rm mas\,yr^{-1}}$ with standard errors. The relatively larger rotation between the two systems occurs in the northern hemisphere and the spin is slower if we only take the high-precision part into consideration.

Table 2 Global Rotation between the PPMX and UCAC3 Catalog

	All stars			High precision		
	Whole sky	Northern	Southern	Whole sky	Northern	Southern
ω_x	-0.29 ± 0.06	-0.55 ± 0.07	-0.10 ± 0.07	-0.10 ± 0.06	-0.13 ± 0.07	-0.13 ± 0.07
ω_y	$+0.20 \pm 0.06$	$+0.34 \pm 0.07$	$+0.01 \pm 0.07$	$+0.20 \pm 0.06$	$+0.31 \pm 0.07$	$+0.05 \pm 0.08$
ω_z	-0.50 ± 0.07	-0.98 ± 0.08	$+0.66 \pm 0.09$	-0.58 ± 0.07	-0.77 ± 0.07	-0.14 ± 0.09

Notes: The above parameters are in units of ${\rm mas\,yr^{-1}}$.

The global rotation is related to the inertia and maintenance of a reference system and the precision of proper motion is the most crucial characteristic of a reference catalog. The spin vector between PPMX and UCAC3 is quite small so it is reasonable to believe that they do not mutually rotate. Because both catalogs are calibrated using Tycho-2 stars, they can be regarded as extensions of the Hipparcos catalog.

6 CONCLUDING REMARKS

PPMX and UCAC3 are considered as extensions of the ICRS in the optical wavelength and are practically important in astrometric observations. We have made regional and global comparisons between the PPMX and UCAC3 position and proper-motion systems. Our conclusion includes: (1) The difference between the two catalogs is more significant in the northern hemisphere and the mismatch may be attributed to UCAC3 according to literatures; (2) Systematic differences increase at the fainter magnitudes; (3) In a global sense both PPMX and UCAC3 represent the HCRF with a higher star density, however the northern UCAC3 stars should be used with caution; (4) The relative rotations that are derived from proper-motion system comparisons are very small and we can conclude that the PPMX and UCAC3 systems are globally compatible; (5) From literatures, most responsibility for the discrepancy in the northern hemisphere should be attributed to UCAC3 astrometric reductions and position and proper motions of UCAC3 stars in the northern hemisphere should be treated carefully, especially when they are used as reference stars.

Acknowledgements This work was funded by the National Natural Science Foundation of China (Grant No. 10973009). This research makes use of data products UCAC3 (U.S. Naval Observatory) and we are indebted to Dr. N. Zacharias who sent us the DVD disk containing their up-to-date research achievements.

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