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The XPM Catalogue as a realization of the extragalactic reference system in optical and near infrared ranges of wavelengths

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ABSTRACT
The final version of the XPM catalogue contains about 314 million stellar positions and absolute proper motions and covers the whole celestial sphere without gaps in the magnitude range 10^m < B < 22^m. The analysis of stellar positions and proper motions of the XPM catalogue is presented. The coordinate axes, defined by the XPM catalogue, were shown to have an ambiguity of rotation relative to the LQAC quasars and ICRF2 sources less than 0.2 mas/yr. It is concluded that the XPM catalogue is the independent realization of the ICRS in the optical and near infrared wavelengths in the sense of obtaining of proper motions. The absolute proper motions of XPM stars were compared with the similar data from the HCRF modern catalogues. The proper motions of stars in these catalogues were shown to have the appreciable random and systematic errors.

Key words: Astrometry, catalogues, reference system.

1 INTRODUCTION

In this paper we present the complete study, the XPM catalogue of stellar absolute proper motions. It has been sent to the Centre de Donnes astronomiques de Strasbourg and will soon be available to users. The brief description of the catalogue's format is presented in this paper.

It is well known that the existing catalogues of stellar absolute proper motions cover the celestial sphere only partially. The southern hemisphere has particularly poor coverage: there is just one catalogue of the absolute proper motions for the zone to the south of -45 degrees in declination, which covers only about 720 square degrees near the southern pole. At the same time, the catalogues of the stellar absolute proper motions are very important for astrometry since they potentially provide, in a quite wide range of stellar magnitudes, a coordinate system that does not rotate relative to extragalactic objects, with no need to use any intermediate systems. If a catalogue of stellar absolute proper motion covers the whole celestial sphere, then the global quasi-inertial coordinate system is produced, which is fixed at J2000.0 by the kinematic method.

On the other hand, the data of these catalogues are very important in stellar astronomy, namely in studying the kinematics of the Galaxy, for example within the Ogorodnikov-Milne model (Milne 1935; Ogorodnikov 1932). Since the mass determinations of radial velocities are not numerous as yet, the proper motions are just one extensive source of the data for kinematic studies of the Galaxy. In this case, as was pointed out by du Mont (du Mont 1977), it is important to use the data for both hemispheres because the 3D Ogorodnikov-Milne model gives the most adequate results if only the proper motions of stars more or less evenly distributed over the whole celestial sphere are used.

The conception of using coordinates of galaxies as a zero-point for direct binding of stellar proper motions was proposed by Gerasimovich and Dneprovsky (Dneprovsky & Gerasimovič 1932). They suggested creating of the Catalogue of Faint Stars (KSZ) with the use of extragalactic nebulae to determine the stellar absolute proper motions. We use the term "absolute proper motions" to describe proper motions with the zero-point, which is determined via a reference system defined by positions of galaxies. Such stellar absolute proper motions are free from any influence of precession and can be used to refine it, as well as to study kinematics of various stellar groups in the Galaxy. The idea has been supported by many observatories in the world. As a result, in the subsequent years three most extensive programs of determining stellar absolute proper motions were realized: the Catalogue of Faint Stars (KSZ), the Lick Northern Proper Motion (NPM) the Yale/San Juan Southern Proper

Motion (SPM). Within the framework of the KSZ, a huge work has been fulfilled to combine 20 initial catalogues and to investigate the master catalogue named GPM (Rybka & Yatsenko 1997). This catalogue contains 54463 stars from 8 to 15.5m in 185 regions from +90 to -25 in declination. The mean accuracy of proper motions is 0.008 arcsec/year. A bit later, another catalogue of stellar absolute proper motions was created in Pulkovo - PUL2 (Bobylev, Bronnikova & Shakht 2004).

Principal results of the NPM program were published as two catalogues, - NPM1 and NPM2. The NPM1 catalogue is described by (Klemola et al. 1987, 1994). It contains 148940 stars in 899 fields in the magnitude range $8^m < \mathrm{B} < 18^m$. The average number of galaxies in a field is 80. The NPM2 catalogue contains 232062 stars in 347 fields near the galactic equator (Hanson et al. 2004). These fields practically do not contain galaxies, therefore the NPM2 stellar positions and proper motions are obtained in the HCRF frame (Perriman et al. 1997).

The SPM program is the extension of the NPM into the southern hemisphere. Principal results of the SPM program are published as 3 catalogues: SPM2 (Platais et al. 1998), SPM3 (Girard et al. 2004), SPM4 (van Altena et al. 2009). The SPM2 catalogue contains about 287000 stars. The SPM3 catalogue is the extension of the HCRF frame to fainter objects. It contains positions, proper motions and photographic B and V magnitudes for about 10.7 millions stars. The SPM4 catalogue contains positions, proper motions and B, V magnitudes for 103319647 stars and galaxies from southern pole to -20 degrees in declination. It should be noted that although the authors of the SPM4 call the obtained proper motions as absolute ones, they are, in fact, relative. This is due to the fact that they are not based on the extragalactic objects directly, but are linked to the zero-point specified by the HCRF frame. The random errors of the proper motions of the aforementioned catalogues depend on stellar magnitude and vary from 2 to 10 mas/yr, whereas the accuracy of the absolute calibration is 1 to 5 mas/yr.

The final version of the XPM catalogue (Fedorov, Myznikov & Akhmetov 2009, hereafter Paper I) and (Fedorov et al. 2010, hereafter Paper II) contains about 314 million stellar positions and absolute proper motions and covers the whole celestial sphere without gaps in the magnitude range $10^m < \mathrm{B} < 22^m$. The random error of the XPM absolute proper motions depends on stellar magnitude and varies in the range from 3 to 10 mas/yr, whereas the formal error of the absolute calibration is about 0.3 mas/yr in the northern hemisphere, and about 1 mas/yr in the southern one. Positions in the XPM are referred to the HCRF for the 2000 epoch as the stars from the USNO-A2.0 (Monet et al. 1998) and 2MASS (Skrutskie et al. 2006) catalogues are given in this system.

In this paper, we describe only some changes introduced into the final version of the XPM, which have not been described in two previous papers. First of all, the changes are related to investigation and elimination of the specific magnitude equation in the whole range of the XPM magnitudes. Also, we estimate the accuracy of the XPM stellar positions and absolute proper motions via their direct comparison with the data from other catalogues of stars and extragalactic objects. Based on the investigations performed, we conclude that the coordinate axes specified by XPM are non-rotating with respect to distant extragalactic objects to within ±0.20 mas/yr. Therefore, the XPM coordinates and the independently derived absolute proper motions of stars materialize the International Celestial Reference System (Arias et al. 2005) in the optical and near infrared ranges of wavelengths.

2 ORGANIZATION AND FORMAT OF THE XPM CATALOG FILES

The main catalog data are contained within files binned by declination into 0.5-degree wide strips. Within each of these declination strips, the objects are sorted by right ascension. There are 360 such declination strip files, named xpmNNN.txt, where NNN ranges from 000 to 359. Each record contains the data for one object. There is header line. The format of each record is as described in Table 1 and its accompanying explanatory notes.

3 MAGNITUDE EQUATION

The geometrical distortions in the XPM have been investigated in details and eliminated. However, the greatest danger for any catalogue is systematic errors of coordinates caused by the magnitude equation, which result in systematic errors of proper motions. As pointed out by Fedorov (Paper II), the magnitude equation in the XPM has been eliminated in the fainter part with the use of formal proper motions of galaxies and quasars. For the brighter part of the XPM, the magnitude equation has not been eliminated intentionally. The 825 Schmidt plates of the Palomar POSS-I survey and 606 Schmidt plates of the SRC-J and ESO-R surveys were the observational data to compose the USNO-A2.0 catalogue and hence, the XPM catalogue. The routine to correct the USNO-A2.0 coordinates for geometrical distortions was described in our two previous papers. Below, we describe the procedure we used to eliminate the magnitude equation within the whole range of the XPM magnitudes. Solving of this problem is not trivial, since, as has become clear in process of work, the model of the XPM magnitude equation is much more intricate as compared to the use of classical astrographs, for which the principles of Gaussian optics are valid. This complexity is due to specific geometric and photometric distortions of images on the Schmidt plates. It is known a priori that the measured coordinates of objects on the Schmidt plates are shifted from their "geometric" coordinates by a certain quantity that depends on the stellar magnitude. We apply the term "geometric" to the coordinates on the plate, which do not depend on stellar magnitude, but match geometrical positions of the points of the photographic projection defined only by the telescope optical system. Such offset, whatever its origin and dependence on the magnitude and positions on the plate would be, we consider as the magnitude equation. Unfortunately, there are no catalogues of positions and proper motions of faint stars, which would be more or less evenly distributed over the celestial sphere. This is the reason why we could not obtain the magnitude equation for XPM by its comparison with the external data. Although such comparison is

Table 1. Description of file: xpm*.txt. The files are ASCII, free format with tab separator columns.

Format	Units	Label	Description
F.6	deg	RA	Right Ascension (ICRS, epoch 2000.0)
F.6	deg	DEC	Declination (ICRS, epoch 2000.0)
F.2	mas/yr	MuRAp[a]	Proper Motion in RA ($\mu_\alpha cos\delta$)
F.2	mas/yr	MuDEp[a]	Proper Motion in DEC (μ_δ)
F.2	mas/yr	MuRAx[b]	Proper Motion in RA ($\mu_\alpha cos\delta$)
F.2	mas/yr	MuDEx[b]	Proper Motion in DEC (μ_δ)
F.3	mag	Fmag	magnitude from GSC2.3
F.3	mag	Jmag	magnitude from GSC2.3
F.3	mag	Vmag	magnitude from GSC2.3
F.3	mag	Nmag	magnitude from GSC2.3
F.3	mag	jmag	J magnitude from 2MASS
F.3	mag	er jmag	Standard error in J magnitude
F.3	mag	hmag	H magnitude from 2MASS
F.3	mag	er hmag	Standard error in H magnitude
F.3	mag	kmag	Ks magnitude from 2MASS
F.3	mag	er kmag	Standard error in Ks magnitude
I10	—	pts key	Unique source identifier in 2MASS
I3	mag×10	Bmag ua	magnitude from blue plate USNO-A2.0
I3	mag×10	Rmag ua	magnitude from red plate USNO-A2.0
I3	—	field	USNO-A2.0 field number
F.6	year	dT	difference of epochs between 2MASS and USNO-A2.0
bit	—	"good gal"	if flag =0, the proper motion was derived using a quasi-absolute calibration.
bit	—	"gal star"	if flag =1, the extended source was used for absolute calibration

Note.- Upper index denotes:
[a]-the zero-point of the proper motion was derived using the PSC coordinates of extended sources.
[b]-the zero-point of the proper motion was derived using the XSC coordinates of extended sources.

possible for local fields of the sky, extrapolation of the magnitude equation obtained with such a procedure onto the whole sphere is not valid.

3.1 Radial pattern

Fedorov and Myznikov (Fedorov & Myznikov 2006) have pointed out that the images on the Schmidt plates of the Palomar POSS-I survey are distorted not only by a usual, but also by a specific magnitude equation, which can be described by a product of two functions:

$$dr(r, m) = R(r)K(m)$$

where $R(r)$ describes the form of the radial offset and depends on the distance from the plate centre only whereas $K(m)$ depends on the magnitude only. It is obvious that such magnitude equation should be in the proper motions as well, at least for the northern part of the XPM. In order to discover such a dependence in the XPM we investigate the obtained stellar absolute proper motions in the northern and southern fields separately. In this way we investigate the distribution of the stellar proper motions in every field for various magnitudes. An example of such distribution is shown in Fig. 1. For every range of magnitude we obtain two specific terms of the distribution provided different reasons: the constant offset and the radial one.

If the constant offset is eliminated, the residual looks like a radial pattern, with its value close to zero in the centre of the field and up to about of 2.5 degrees from the centre. Such a constant shift is easy to explain. When the proper motions of many stars are averaged, the mean value of peculiar motions is zero, but two other components (the parallactic component and the galactic rotation) will not be zero in averaging, and will cause the constant shift. However, it is reasonable to suggest that the proper motion of a particular star does not relate to the distance of its image from the field of view centre, i.e. it is independent on r. Of course, one can meet the case when a group of stars expands or contracts. But it is unlikely that the centre of this expansion/contraction always coincides with the centre of the plate. Therefore, when the stellar proper motions are averaged in the field, only two components of the proper motions should remain: the mean shift which does not depend on the position on the plate, but depends on the magnitude (the usual magnitude equation), and the radial offset, which depends on both the distance to the plate centre and the magnitude (specific magnitude equation). The inevitable physical deformations of the Schmidt plates can be the probable reason of the radial offset on the USNO-A2.0 plates.

In practice, the mean value of stellar proper motions in the central part of every field ($R< 2.5\ ^\circ$) was determined as a function of coordinates for every sub-range of magnitudes. It is obvious that after elimination of this dependence in each particular field, the residual will represent the radial offset only. To obtain it, we calculated a dependence $dr(r, m) = f(r)\mid_{mag}$ for every field and every sub-range of magnitudes. The radial offset $dr(r, m)$ was found from the formula:

$$dr(r, m) = (\mu_\alpha cos\delta\Delta\alpha + \mu_\delta\Delta\delta)/r,$$

where $\mu_\alpha cos\delta$ and μ_δ are projections of the components of absolute proper motions of the XPM stars onto the direction of the radius for a specific star, and

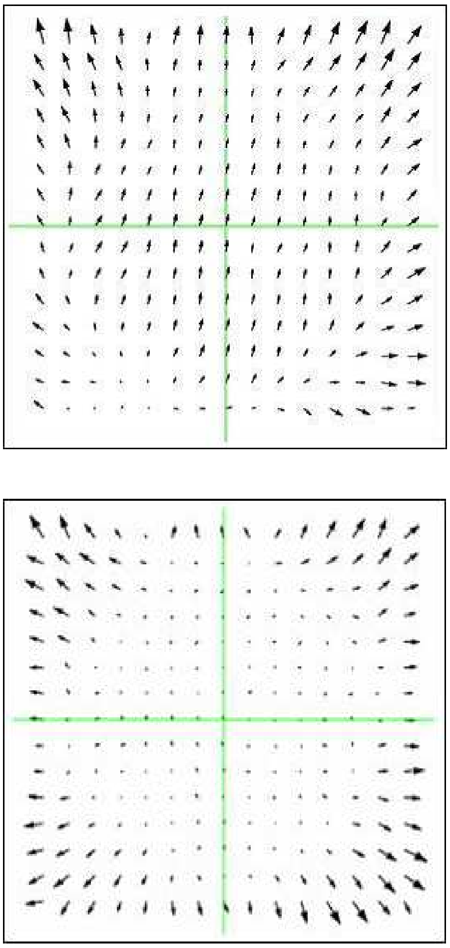

Figure 1. The distribution of the proper motions in a particular field before and after correction for the constant offset.

$r^2 = \Delta\alpha^2 + \Delta\delta^2$.

The functions $f^N(r)$ turned out to be similar for the same sub-ranges of magnitude in different fields of the POSS-I survey. Similar situation is in the southern hemisphere, but the function $f^S(r)$ differs from $f^N(r)$ slightly. The function $f^S(r)$ is seamingly a superposition of the individual functions $f^J(r)$ and $f^J(r)$ from the SRC-J and ESO-R surveys, while its difference from $f^N(r)$ is probably caused by some peculiarities of these surveys.

The final radial pattern $F(r, m)$ was obtained for the northern and southern hemispheres separately as a result of combining the individual radial patterns of 825 fields of the POSS-I survey and 606 fields of the SRC-J and the ESO-R surveys. The obtained dependences $F^N(r, m)$ and $F^S(r, m)$ were used for correction of the initial coordinates of all USNO-A2.0 objects, when the final version of XPM catalogue was being derived.

3.2 Regular magnitude equation

In a previous paper we pointed out that the magnitude equation in the fainter part of the XPM magnitude range can be investigated using the formal proper motions of extragalactic objects, such as quasars. Brightness profiles of their images are very close to those of stars, which are usually used to correct for the magnitude equation. Since the proper motions of quasars are zero, any dependence of their formal proper motions on magnitude should be treated as a magnitude equation. Strictly speaking, the magnitude equation obtained in such a way should be used only in the celestial areas which contain these extragalactic objects. Nevertheless, when using the formal proper motions of the ICRF2 sources (Arias et al. 2009) and LQAC quasars (Souchay et al. 2009) of both hemispheres, their dependences on magnitude presented in Fig. 11 and 12 exhibit the absence of any appreciable magnitude equation in both hemispheres. The regular magnitude equation in the brighter part of the magnitude range was investigated with the use of some external data. If the compared proper motions of two catalogues is supposed to have one the same zero-point and to be free of the magnitude equation, then the difference of their proper motions in dependence on magnitude is zero. If this difference is not zero and does not depend on magnitude, then this fact can be interpreted as mutual rotation of the systems.

The proper motions from the Tycho-2 catalogue (Høg et al. 2000) were used to determine the magnitude equation in the brighter part of the XPM magnitude range. After the radial offset has been eliminated, the XPM stars were cross-identified with the Tycho-2 stars and arranged by the magnitudes. The magnitude equation was obtained separately for each of 1431 fields of the XPM catalogue. Each field contains more than 1000 Tycho-2 stars on the average. If the magnitude equations in the Tycho-2 and XPM catalogues are absent, then the differences of proper motions do not depend on stellar magnitude and must be constant. In this case dependences of their proper motions on magnitude must be parallel to each other. Any deviation from the parallelism we considered as an indication to the presence of the magnitude equation in the bright part of the XPM. As was expected, the dependences $\Delta\mu_\alpha cos\delta(m)$ and $\Delta\mu_\delta(m)$ appeared to be similar in all fields of the catalogue, since the regular magnitude equation of the XPM catalogue distorts the proper motions in different parts of the sky on the average identically. Since we have shown earlier (PaperII) that the magnitude equation is absent for magnitudes $>15^m$ in the XPM catalogue, we demand that the dependence of proper motions of the XPM stars on magnitude be parallel from this point to that of the Tycho-2 stars. This procedure has made it possible to eliminate the magnitude equation in each field of the XPM catalogue.

4 ACCURACY AND PRECISION OF THE XPM ABSOLUTE PROPER MOTIONS.

In this study we estimate the accuracy of stellar positions and proper motions of the XPM catalogue by a direct comparison with the similar data from other modern catalogues of stars and extragalactic objects.

4.1 Comparison of the XPM proper motions with those of other catalogues.

Of all the catalogues containing absolute proper motions, we use KSZ, Pul2, NPM1 and SPM2. These programs are

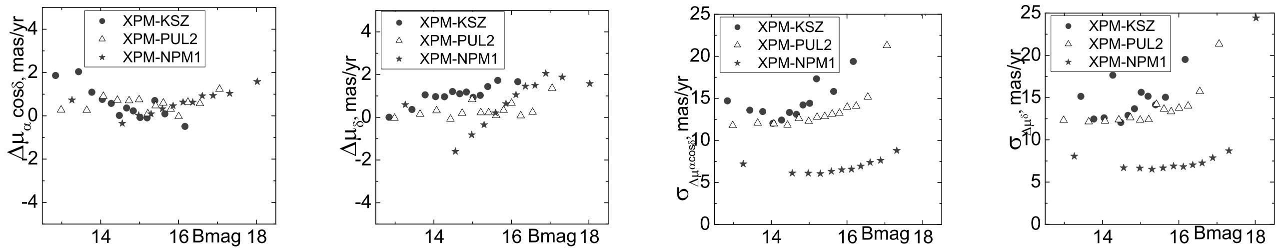

Figure 2. The systematic differences of absolute proper motions (XPM-KSZ, black dots), (XPM-PUL2, asterisks) and (XPM-NPM1, open triangles) and their standard deviations, depending on the magnitude B of GSC2.3.

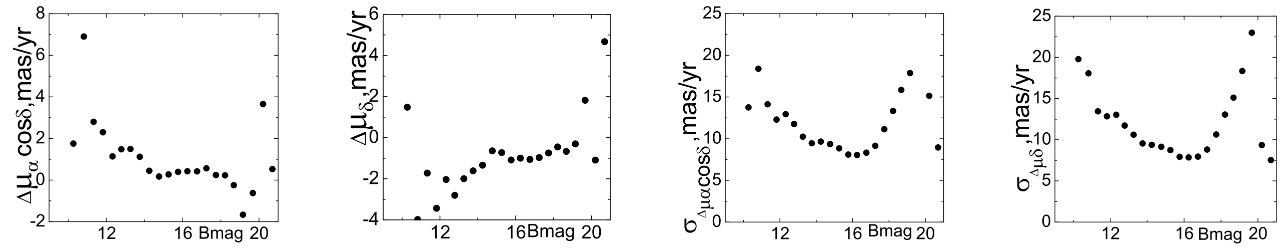

Figure 3. The systematic differences of absolute proper motions (XPM-SPM2), and their standard deviations, depending on the magnitude B of GSC2.3

the most extensive, with their results used for realization of the ICRS in the optical wavelengths (excluding Pul2). There are some more catalogues of proper motions, which are parts of the abovementioned programs, but their proper motions were obtained in the HCRF frame, and this system is expanded to the fainter magnitudes. These are NPM2, Pul3 (Khrutskaya, Khovritchev & Bronnikova 2004), SPM3 and SPM4 catalogues. The NPM2 catalogue covers the area near the galactic equator, while the SPM3 covers the same part of the sky as the SPM2 catalogue. In the overlapping areas, the SPM3 contains about 10 million objects common with XPM, and the NPM2 contains about 232 thousand such objects. The SPM4 catalogue covers the sky areas from -90 to -20 degrees and contains about 100 million stars common with the XPM. Also, we compare the XPM proper motions with those of UCAC2 (Zacharias et al. 2004), UCAC3 (Zacharias et al. 2010), and PPMXL (Roeser et al. 2010) catalogues, which reproduce the HCRF system in the faint end of the magnitude range. The results of these comparisons are shown in Fig. 2, 3, 4, 5, 6 and 7 representing the systematic differences of proper motions in the sense XPM minus catalogue, as well as their standard deviations as functions of stellar magnitude.

4.2 Estimation of external accuracy of positions and proper motions from three independent data sets.

The method described by Wielen (Wielen 1995) is very efficient provided the data under comparison are independent quantities. In this case, dispersion of positions or proper motions differences is equal to the sum of their dispersions, because the index of correlation between the data sets is zero. With 3 or more independent catalogues, it is easy to estimate the external accuracy of each of them:

$$\sigma_1 = \sqrt{0.5(D_{12} + D_{13} - D_{23})}$$

$$\sigma_2 = \sqrt{0.5(D_{12} + D_{23} - D_{13})}$$

$$\sigma_3 = \sqrt{0.5(D_{13} + D_{23} - D_{12})},$$

where D_{12}, D_{13} and D_{23} are dispersions of the differences of positions or proper motions for 2 catalogues under consideration. Before proceeding to calculation of the dispersions, we need to ascertain that the correct values will be obtained. The assumption that the initial random quantities are centered, i.e. the mean value of each of them is zero, may be a possible source of incorrectness. In general, the mean value is non-zero because of systematic errors in the catalogues. If this non-zero mean is constant or varies with magnitude smoothly, then the dispersion of the differences can be calculated. In the case, when the systematic differences vary fast or have breaks, the method does not work. Therefore, it is important to determine behaviors of the systematic differences. Fortunately, the systematic differences of proper motions are smooth functions of magnitude, as was shown in Fig. 4, 5.

For the cross-identification of objects in both catalogues, we have used the search window with a 0.5-arcsec radius. Final dispersions were calculated for every sub-range of magnitudes, for the stars with individual differences of proper motion exceeding 3 standard deviations being rejected. The following catalogues have been used for comparison with the XPM: PPMXL and UCAC3 in the northern and the southern hemisphere. It should be noted that the UCAC3 proper motions were obtained with the use of the same yellow plates as for the SPM4 catalogue, while the

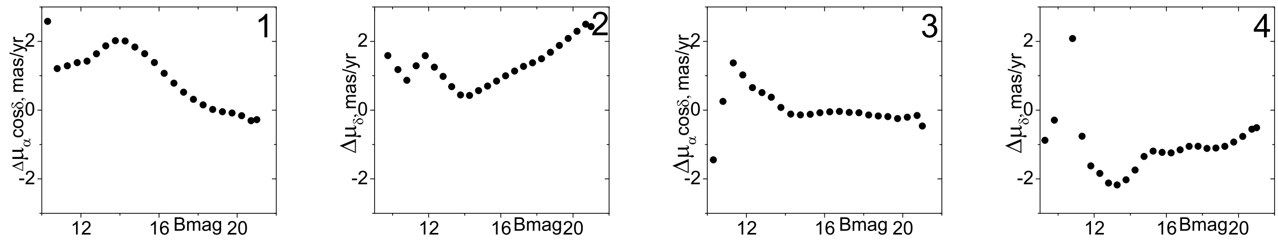

Figure 4. The systematic diferences of proper motions (XPM-PPMXL), depending on the magnitude B of GSC2.3. 1, 2 - Northern hemisphere, 3, 4 - Southern hemisphere.

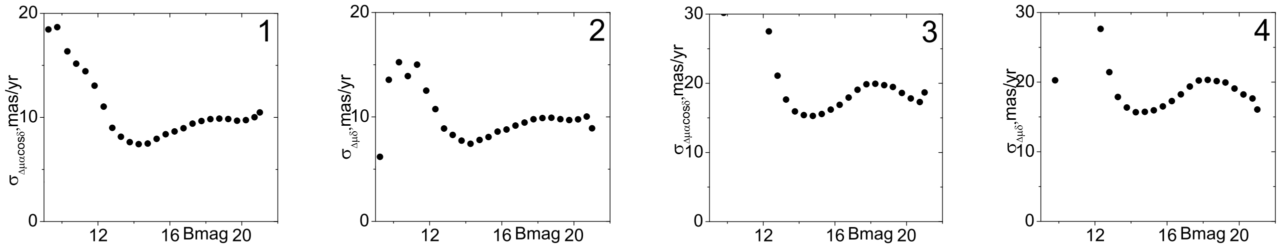

Figure 5. The standard deviations of the systematic differences of proper motions (XPM-PPMXL), depending on the magnitude B of GSC2.3. 1, 2 - Northern hemisphere, 3, 4 - Southern hemisphere.

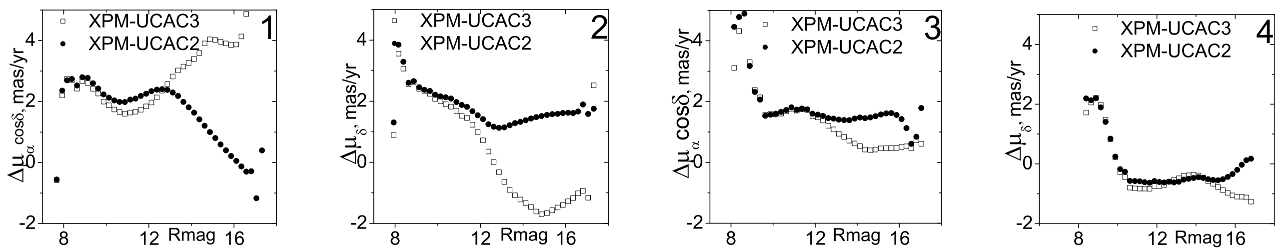

Figure 6. The systematic diferences of proper motions (XPM-UCAC2) and (XPM-UCAC3), depending on the magnitude R of UCAC2. 1, 2 - Northern hemisphere, 3, 4 - Southern hemisphere.

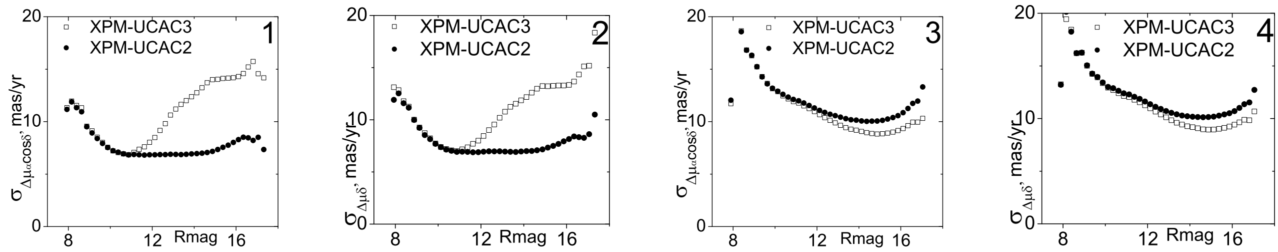

Figure 7. The standard deviations of the systematic differences of proper motions (XPM-UCAC2) and (XPM-UCAC3), depending on the magnitude R of UCAC2. 1, 2 - Northern hemisphere, 3, 4 - Southern hemisphere.

UCAC3 uses the Schmidt plates in addition. Consequently, the proper motions of the UCAC3 are not independent with respect to the SPM4 and to XPM. The situation is still worse with the PPMXL catalogue, where positions and proper motions have been obtained with the use of the Schmidt plates and the 2MASS data. These facts prevents from estimating the external accuracy for each catalogue in both hemispheres. A procedure for the determination of individual dispersions will not give truly external errors. Nevertheless, taking into account that the distortions typical for the Schmidt plates have been eliminated from the XPM data and since no other comparison catalogues of necessary quality exist, we do obtained the estimates of the positions and proper motions accuracy of the catalogues. The results of

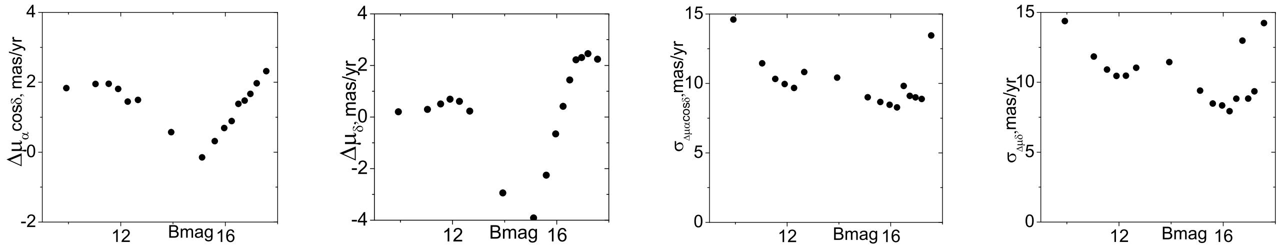

Figure 8. The systematic differences of proper motions (XPM-NPM2) and their standard deviations, depending on the magnitude B of NPM2.

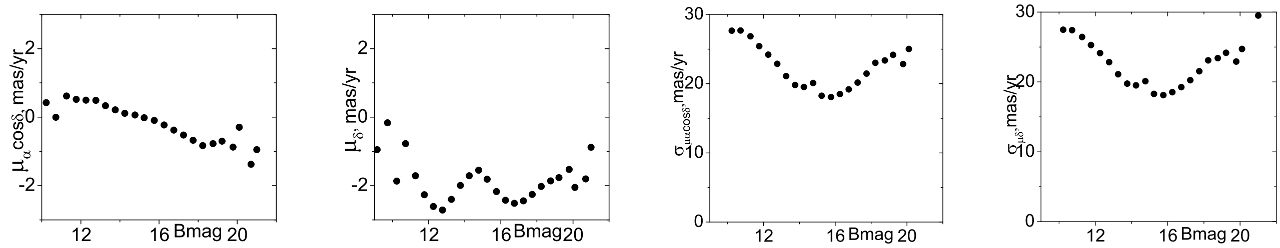

Figure 9. The systematic differences of proper motions (XPM-SPM4) and their standard deviations, depending on the magnitude B of SPM4.

the determination the "random errors" of the proper motion and positions are presented in Fig. 10 for the whole celestial sphere. Unfortunately, from a comparison of Fig. 10 with Fig. 4, 5 it is obvious that the estimates of the positions and proper motions accuracy obtained by this method should be considered as formal.

4.3 Estimation of the accuracy of XPM proper motions with use of extragalactic objects

Extragalactic objects (distant galaxies and quasars) enable direct testing of the XPM proper motions for random and systematic errors. About 12.5 thousand quasars from LQAC and near 1000 ICRF2 sources were identified among the XPM objects. We have identified about 102 thousand LQAC quasars among the PPMXL objects and 890 objects among the UCAC3 objects as well. Since they are all very distant point-like objects, we can check the accuracy of the XPM catalogue "absolute calibration" and proper motions of the XPM, PPMXL and UCAC3 faint stars directly. We consider any non-zero mean value of the formal proper motions of extragalactic objects as a residual rotation of the catalogue system. Dispersion of the formal proper motions of extragalactic objects characterizes the random accuracy of proper motions of all point sources in a proper range of magnitudes. The performed tests show that the XPM coordinate axes (at least for the stars fainter than 15^m) have no rotation, with the uncertainty of about ± 0.2 mas/yr, and thus, the XPM catalogue can be considered as an independent realization of the ICRS in the optical and near infrared wavelengths.

5 CONCLUTION

Summarize the work performed, we conclude the following:

1. The catalogue of positions and absolute proper motions of 314 million objects covering the whole celestial sphere without voids had been created.

2. The random errors of absolute proper motions of the XPM stars are slightly different for the northern and southern hemispheres and equal 3-8 mas/yr and 5-10 mas/yr, respectively.

3. On the basis of the investigations performed, we conclude that the coordinate axes defined by the XPM catalogue are non-rotating with respect to distant extragalactic objects (LQAS and ICRF2) to within ± 0.20 mas/yr. This value is a quantitative characteristic of inertia of the XPM system. Thus, the XPM coordinates and independently derived absolute proper motions of stars materialize the International Celestial Reference System in the optical and near infrared wavelengths.

We emphasize that the XPM absolute proper motions obtained with the use of the proposed method, do not depend on systematic position errors of stars and galaxies under comparison, but depend on their random errors only. Therefore the derived system of the XPM proper motions does not depend on the HCRF data, but represents, together with its positions, an independent realization of the ICRS in the optical and near infrared wavelength range. Additionally, it is important to note that the derived system of proper motions is valid both in optical and in near infrared wavelengths, since it is evident that there are no physical reasons for one the same star to have different velocities in different spectral bands.

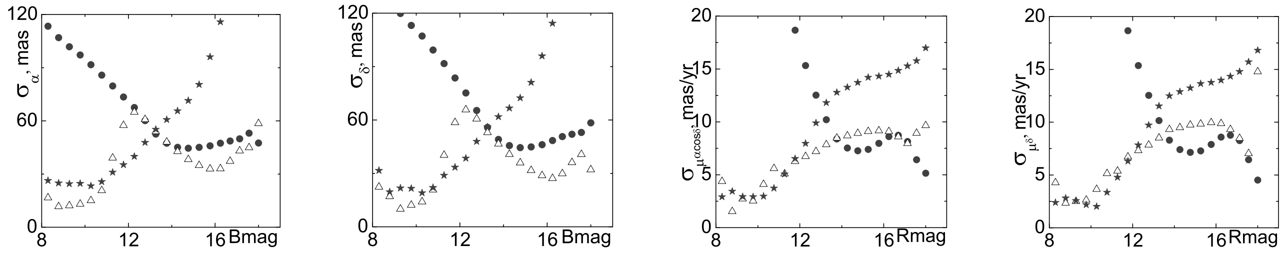

Figure 10. The standard deviations of the positions and proper motions obtained by method of Wielen for XPM (black dots), PPMXL (open triangles) and UCAC3 (asterisks), depending on the magnitude R of UCAC3.

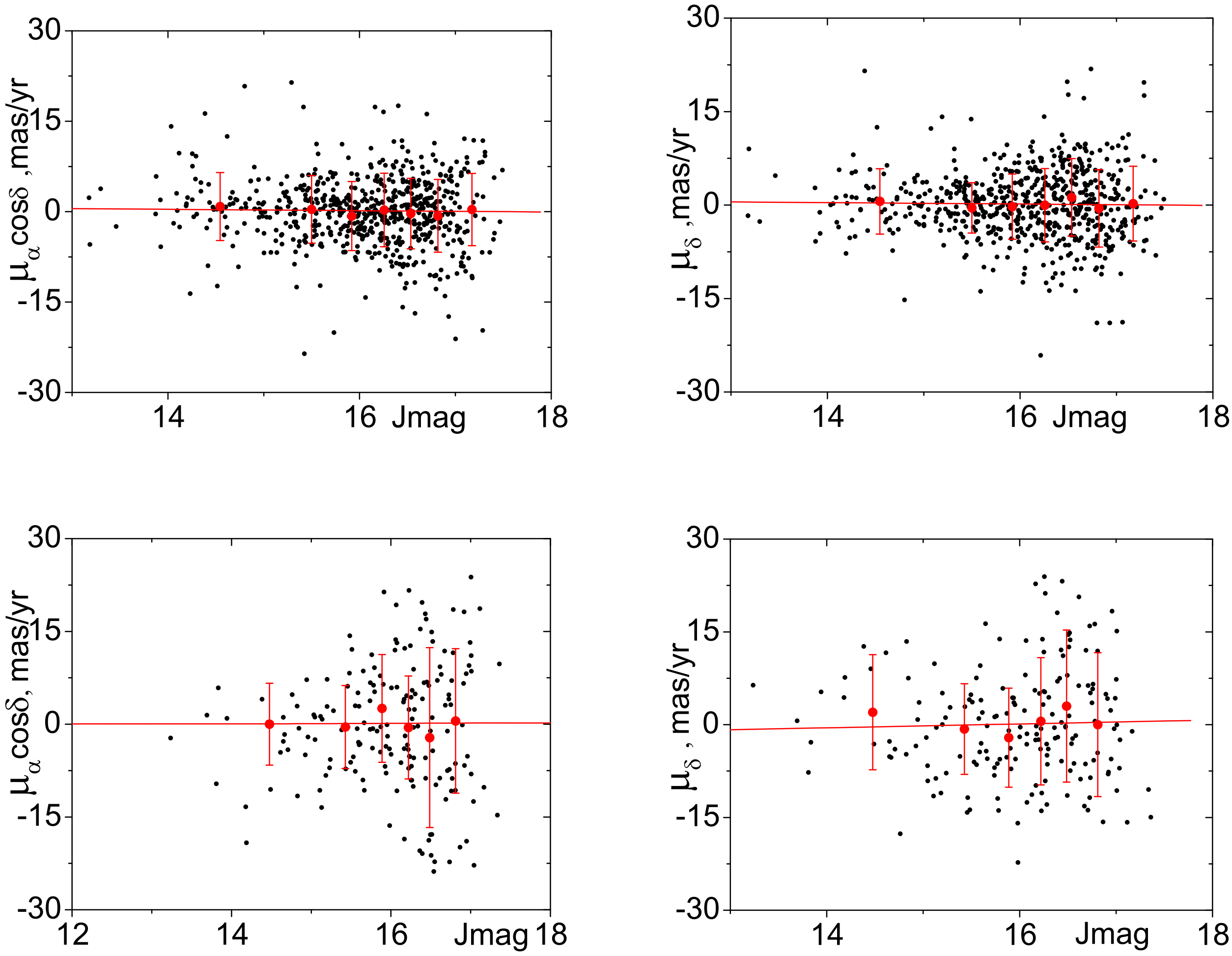

Figure 11. Scatter of individual formal proper motions of optical counterparts of ICRF2 sources from XPM as a function of magnitude J. Top panel - Northern hemisphere, bottom panel - Southern hemisphere.

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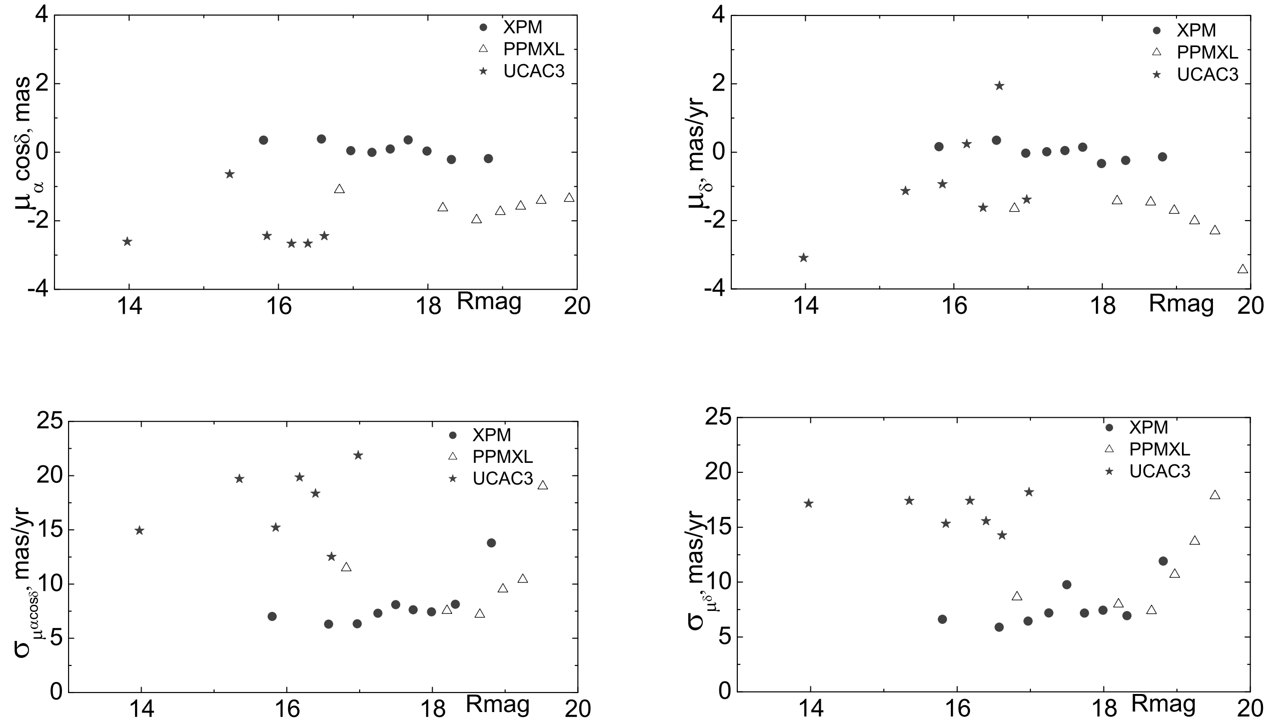

Figure 12. The mean value of the formal proper motions of LQAC quasars from XPM (black dots), UCAC3 (asterisks) and PPMXL (open triangles) and their standard deviations for the whole celestial sphere as a function of magnitude B GSC2.3.

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