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THE INVESTIGATION OF THE FON3 CATALOGUE DATA USING WIELEN METHOD

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ABSTRACT. The method described by Wielen is very efficient provided the data under comparison are independent quantities. In this case, dispersion of position or magnitude differences is equal to the sum of their dispersions, because the index of correlation between the data is set zero. Using three or more independent catalogues, it is easy to estimate the external accuracy of each of them. For the cross-identification of objects, 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 position and magnitude exceeding three standard deviations being rejected. The following catalogues have been used for comparison with the FON3: XPM, PPMXL and UCAC4 in the Northern hemisphere. The dispersions of positions or magnitudes are calculated with the use of about 18 million common stars from these catalogues. The results presented in this work is consistent with analysis of the random errors of positions and magnitude that had been described by authors of FON3 catalog.

Keywords: Astrometry, astrometry-catalog, data analysis

1. Introduction

This paper presents some results of investigation of the FON3 catalogue of star positions and B-magnitudes in Northern Sky Survey (from –4° to +90°). The FON3 catalog has been created under the motto of the rational use of resources accumulated in UkrVO JDA (Joint Digital Archive) in MAO NASU. The total amount of processed plates is 2260. Digitizing of astronegatives has been carried out with the help of Microtek ScanMaker 9800XL TMA and Epson Expression 10000XL scanners, with the scanning mode — 1200 dpi, the linear size of the plates — 30´30 cm or 13000´13000 pix. The catalog contains 19 451 751 stars and galaxies with B 16.5m for the epoch of 1988.1 (Andruk V.M. et al., 2010). The author of the FON3 catalog present internal accuracy for all objects is $\sigma_{\alpha\delta}$ = 0.23" and σ_B = 0.14 mag. For stars in the range of B = 7^m - 14^m errors are $\sigma_{\alpha\delta}$ = 0.10" and σ_B = 0.07mag. Convergence between the calculated and reference positions is $\sigma_{\alpha\delta}$ = 0.06", and the convergence with photoelectric stellar B-magnitudes is σ_B = 0.15mag. (Andruk V. et al., 2016).

Using three or more independent catalogues, it is easy to estimate the external accuracy of each of them. For this purpose data from XPM, PPMXL and UCAC4 in the Northern hemisphere are used.

2. Estimation of external accuracy of the star positions and photometry by use of three independent data sets

The method used for estimation of external accuracy of the star positions was described by Wielen in 1995 (Wielen R. 1995). It is very robust under condition of the independence of the compared data. In such case the dispersion of the differences of positions or photometry is equal to the sum of their dispersions because their correlation coefficient is zero. With three or more independent catalogues it is easy to estimate the external accuracy of each of them:

$$\sigma_1 = \sqrt{\frac{D_{12} + D_{13} - D_{23}}{2}}$$

$$\sigma_2 = \sqrt{\frac{D_{12} + D_{23} - D_{13}}{2}}$$

$$\sigma_3 = \sqrt{\frac{D_{13} + D_{23} - D_{12}}{2}}$$

where D_{12}, D_{13} and D_{23} are the dispersions of the differences of positions or magnitudes for three compared catalogues.

Before the calculation of the dispersions one should test that the correct values are obtained. The possible source of the incorrectness is the assumption that the means of the initial values are zero in the case when the catalogues with systematic errors have some non-zero means. If this non-zero mean is independent on magnitude or varies with it smoothly, then the dispersion of the differences of the positions or proper motions can be calculated. Otherwise, when the systematic differences change fast or disrupted the method does not work. Therefore it is important to determine the behavior of the systematic differences. Fortunately, in most cases the systematic differences of positions or photometry are some smooth functions of magnitude validating this method. Finally, in our case the dispersions are calculated for every small range of magnitude

with rejection of the stars with individual difference larger than 3 standard deviations.

The following catalogues have been used for the comparison with the FON3: UCAC4, PPMXL and XPM. It should be noted that the PPMXL and XPM proper motions were obtained with the use of the same schmidt plates. For the UCAC4 no schmidt plates were used. Consequently, the proper motions of the PPMXL and XPM are not independent. However the FON3-UCAC4-XPM and FON3-UCAC4-PPMXL datasets make the comparison possible.

3. Catalogs

Catalog UCAC4 is a compiled, all-sky star catalog covering mainly the 8 to 16 magnitude range in a single bandpass between V and R. Positional errors are about 15 to 20 mas for stars in the 10 to 14 mag range. Proper motions have been derived for most of the about 113 million stars utilizing about 140 other star catalogs with significant epoch difference to the UCAC CCD observations. All bright stars not observed with the astrograph have been added to UCAC4 from a set of Hipparcos and Tycho-2 stars. Thus UCAC4 should be complete from the brightest stars to about R=16, with the source of data indicated in flags. UCAC4 also provides a link to the original Hipparcos star number with additional data such as parallax found on a separate data file included in this release (Zacharias N. et al., 2013).

Catalog XPM is a combined data from the Two-Micron All Sky Survey (2MASS) and USNO-A2.0 catalogues in order to derive the absolute proper motions of about 300 million stars distributed all over the sky excluding a small region near the Galactic Centre, in the magnitude range 12<B<19mag. The proper motions were derived from the 2MASS Point Sources and USNO-A2.0 catalogue positions with a mean epoch difference of about 45 years for the Northern hemisphere and about 17 years for the Southern one (Fedorov P. et al., 2009). The zero-point of the absolute proper motion frame (the 'absolute calibration') was specified with the use of about 1.45 million galaxies from 2MASS. Most of the systematic zonal errors inherent in the USNO-A2.0 catalogue were eliminated before the calculation of proper motions. The final version of the XPM catalogue contains about 314 million stellar positions and absolute proper motions. The mean formal error of absolute calibration is less than 1mas/year (Fedorov P. et al., 2010).

PPMXL catalog contains about 900 million objects, some 410 million with 2MASS photometry, and is the largest collection of ICRS proper motions at present. The resulting typical individual mean errors of the proper motions range from 4 mas/year to more than 10 mas/year depending on observational history. The mean errors of positions at epoch 2000.0 are 80 to 120 mas, if 2MASS astrometry could be used, 150 to 300 mas else (Roeeser S. et al., 2010).

4. Astronomical Database

To provide a quick and a simple access to modern astronomical catalogs that contain data of millions or billions celestial objects including stars, galaxies, quasars and others the database has been developed. Modern astrometric catalogs obtained in last 20 years, are collected in this database using PostgreSQL server. The database contains about 30 catalogs with data more 1.5 Tb (Vavilova I.B. et al., 2012).

The main mission of creating the astronomical database is collect astronomical catalogs to provide a quick and a simple access to large dataset both for usual programs (TOPCAT, OriginLab, Microsoft Excel and others) and for a user's special programs.

To facilitate access to astronomical data from modern catalogs a web interface written in PHP programming language has been created. This web interface allows to select data containing in a small region of the celestial sphere *http://astrodata.univer.kharkov.ua/astrometry/db*.

The database allows the user to carry out data selection from the large astronomical catalogues by using: a network server, a internet browser, special scripts and programs. For cross-identification of objects and to calculate systematic errors and random accuracy of the star positions and photometry by use the database based on Wielen method the special program in C++ programming language has been developed.

5. Cross-identification of objects

In this paper star magnitudes of these catalogues are not used for cross-identification because of a significant difference in their band-pass and significant random and systematic errors of photometry. The cross-identification was carried out using only coordinates of objects. It should be noted that such cross-identification is usually named positional association and is not necessarily an exact identification.

To realize this method, the proper motions of catalog XPM has been used. In the first step a position of each objects in XPM catalog is calculated to epoch FON3 catalog by means of database.

The second step of cross-identification is a simple cross-match: each object of the catalog FON3 is compared with the object of the catalog XPM (on epoch FON3). If an angular distance is less than 0.5 arcsec it is common object. This procedure makes it possible to obtain lists of pairs of stars from both catalogs. The position difference between FON3 and XPM produced mainly only by the difference between random and systematic errors of both catalogues.

The corresponding procedure has been done for data UCAC4 and PPMXL catalogues. As result the FON3-UCAC4-XPM and FON3-UCAC4-PPMXL datasets about 18 million common stars have been obtained and then inserted to database for analysis.

6. The results of estimate the external accuracy and systematic errors data of catalogs

Below some results of investigations of the FON3, UCAC4, XPM and PPMXL catalogs are presented. For analysis of quality of the positions and photometry of the FON3 stars the different tests have been made.

Comparison of the FON3 data with UCAC4, XPM and PPMXL catalogs are shown in Figs 1 representing the systematic differences of positions in the sense FON3 minus catalogue, as well as their standard deviations as functions of stellar magnitude.

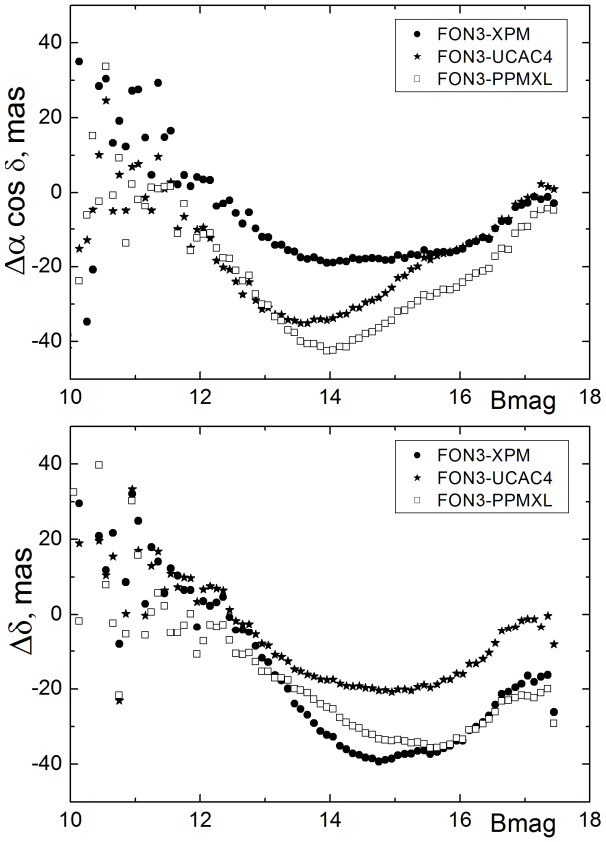

Figure 1: The systematic differences of the position FON3-XPM (black dots), FON3-UCAC4 (asterisks) and FON3-PPMXL (open rectangle) depending on the magnitude B of FON3.

The mean values of systematic differences of positions FON3−XPM, FON3−UCAC4,FON3−PPMXL are less then -40 mas in the both coordinates. As showed in figure 1, the stars position of FON3 catalog are good agreement with XPM and UCAC4 in right ascension and declination correspondingly.

The external accuracy of stars position of FON3 catalogue are as functions of magnitude and equal 150 mas for brightest and up to 250 mas for faintest stars (Figure 2).

These external estimations of positional precision FON3 catalogue are in very good agreement with FON3 internal accuracy at the mean epoch observation.

The figure 3 is presented the systematic differences of star magnitudes in the sense FON3 minus catalogue, as well as their standard deviations as functions of stellar magnitude. The mean values of systematic differences of stellar magnitudes FON3−XPM, FON3−UCAC4, FON3−PPMXL are between -1 up to 2 mag. As showed in figure 3, the stellar magnitudes of FON3 catalogue are good agreement with PPMXL catalogue data. The external accuracy of stellar magnitudes of FON3 catalogue are as functions of magnitude and equal 1 mag for brightest and 0.3 mag for faintest stars from 13 Bmag.

The noted facts should be taking into account in course that to creating catalog FON3 used data only plates of digitized astronegatives but do not used CCD observation.

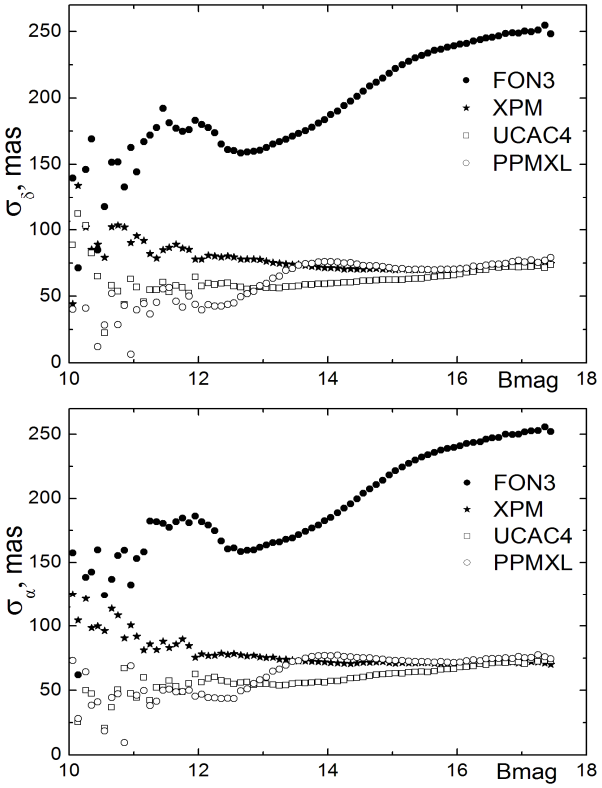

Figure 2: The standard deviations obtained by method Wielen of the position FON3 (black dots), XPM (asterisks), UCAC4 (open rectangle) and PPMXL (open circles) depending on the magnitude B of FON3.

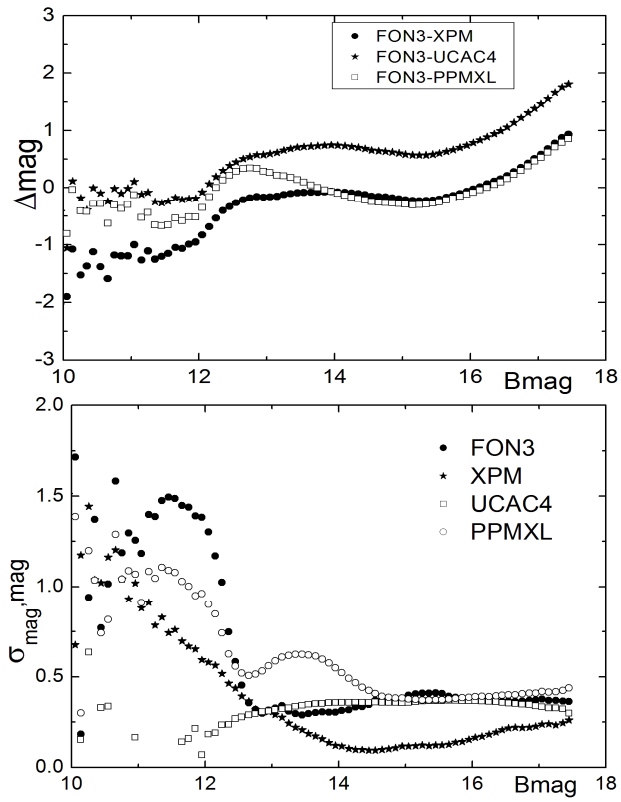

Figure 3: The systematic differences of the stellar magnitude FON3-XPM (black dots), FON3-UCAC4 (asterisks) and FON3-PPMXL (open rectangle) and their standard deviations obtained by method Wielen FON3 (black dots), XPM (asterisks), UCAC4 (open rectangle) and PPMXL (open circles) depending on the magnitude B of FON3 catalogue.

7. Conclusions

To summarize the work performed, we conclude the following.

The positions and photometry of FON3 stars were compared with same data of other modern astrometric catalogues.

The dispersion of positions and stellar magnitudes are calculated with the use of about 18 million common stars from FON3, XPM, UCAC4 and PPMXL catalogues.

The external accuracy of stars position of FON3 catalogue are good agreement with FON3 internal accuracy and equal 150 and 250 mas for brightest and faintest stars correspondingly.

The results that presented in this work are consistent with analysis of the random errors positions and stellar magnitudes that had been described by authors of FON3 catalog.

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