Subsection Virtual observatories are practice of application

COMPILATION OF CATALOG OF STELLAR EQUATORIAL COORDINATES AND B-MAGNITUDES USING UKRVO PLATE DATABASE

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ABSTRACT. To ensure the rational use of informational resources generated by UkrVO in MAO NASU, a catalog of equatorial coordinates (α, δ) and B-magnitudes of stars was created by using plates obtained during observational campaign named FON (ukr., Photographic Sky Survey). 102 plates with field of view of 8° were processed. Digitization of plates with sizes of (30x30) cm or (13000x13000) px was performed by using resolution of 1200 dpi. The catalog contains astrometric data for 1,263,932 stars and galaxies with $B \leq 16.5^m$ at epoch 1984.76. The coordinates and B magnitudes were respectively obtained in the system of TYCHO-2 catalog and photoelectric standards. The internal accuracy of the catalog: for all objects is ±0.26" for coordinates and $\pm 0.17^m$ for magnitudes, and for stars in the range $B = 8^m - 13^m$ is ± 0.13" and $\pm 0.11^m$. Convergence of coordinate with reference TYCHO-2 system is ±0.06" (for 93 925 stars), the convergence with the photoelectric stellar B-magnitudes is $\pm 0.16^m$ (for 4458 stars). Errors relative to the UCAC-4 catalog are ±0.34". We identified 1099005 stars and galaxies.

Key words: virtual observatory tools – astrometry – techniques: photometric – methods: data analysis – catalogs

1. Introduction

At the end of 2013, more than 2000 astro negatives obtained during the program of Northern Sky Photographic Survey (FON) were digitized by using the UkrVO database (Kislyuk, 2000, Vavilova, 2012). Approximately one-third of the plates were digitized by the scanner Microtek ScanMaker 9800XL, others – on the scanner Epson Expression 10000XL (Andruk, 2005, Andruk 2007, Andruk, 2010, Golovnya, 2010). With the help of specially designed software for environment LINUX / MIDAS / ROMAFOT, we obtained rectangular coordinates and the photometric values for all objects and scans (www.eso.org/sci/software/esomidas). Basic software was developed by the Department of astrometry at the MAO of NASU in order to obtain the equatorial coordinates and magnitudes of astronomical objects, and has been successfully applied in practice described in a series of papers (Yatsenko, 2011, Protsyuk, 2014). As shown by subsequent experience of reduction of digitized plates, some astro negatives have to be rescanned and reprocessed. In part of this work, we studied the accuracy of astrometry and photometry.

On the base of 102 scans, we obtained the second version of the catalog of positions and B-values of stars (Yatsenko, 2011). The zone of 8° in declination along the 60° parallel was observed using the principle of quadruple overlap. The plates were exposed by using the Double Wide-angle Astrograph (D/F = 40/200, 103 "/mm) of the MAO of NASU. Most plates for this zone are (30x30) cm in size (8°x8°). All plates were scanned with a resolution of 1200 dpi by using Microtek and Epson scanners, the size of images was up to (13000x13000) px (1px = 2.17"). The second version of the catalog was derived from the processing of single scans without turning the plates on 90°. As the result, an amount of resources to store and process information was reduced twice without compromising the accuracy of the results.

2. Accuracy of scanners

We examined Microtek and Epson scanners to study the astrometric and photometric accuracy. Comparison of errors in the determination of equatorial coordinates for the two scanners gave the following result: astrometric and photometric errors of the Epson scanner is 25% less than of the Microtek scanner. Compiled catalog of Microtek and Epson scanners shows coordinate errors about 10% less than the expected errors and internal errors of convergence. Magnitude errors are a few times less than the expected errors and internal errors of convergence. Developed and applied software allows us to perform high-precision reduction of data to obtain equatorial coordinates and magnitudes.

3. The results of data processing

Normal scanning means that the Y-axis direction of movement is parallel to the axis of the equatorial coordinates of δ. When the plate is rotated on 90°, it implies that the Y axis is parallel to the axis of α. The

TYCHO-2 catalog was used as the reference system for the identification and correction of systematic errors caused by scanners and optical aberrations of telescopes. Normal scanning gives us the error for the equatorial coordinates about 25% less than for scanning with rotation on 90°. This is an expected result, since the scanning with rotation on 90° suggests that the uneven movement of the CCD line scanner (coordinate Y) coincides with the change in the scale of the plate by α relative to the lower and upper parts of the plate. For greater statistical reliability, the results were separately processed for scans of 23 plates with 4-fold overlap, i.e. we obtained two catalogs for testing on 437946 and 433726 stars for two positions of the plate. The overlap zone is 18h to 24h in α, 56° to 60º in δ. Third catalog was obtained by averaging the data of equatorial coordinates and magnitudes of the first two catalogs for 391852 stars. For the third catalog internal coordinate errors were decreased by about 40-50%, and internal magnitude errors were decreased by several times. All three test catalogs were compared with the TYCHO-2 as reference catalog. Number of common stars for them respectively: 28981, 28830 and 28758. Analysis of the errors gave us the following result: scanning the plates with rotation on 90° leads to an increase of errors by 20% in the determination of equatorial coordinates relative to the reference system of TYCHO-2. To check the error of the external convergence, we also made comparison of the three catalogs with the UCAC4 catalog (Zacharias, 2013). Number of common stars for the three catalogs are 372487, 369744 and 363584 respectively. Note that the external convergence of the coordinate errors for the averaged catalog about 10% less than for the individual catalogs. A separate analysis of the distribution of errors in determining the coordinates gave the following result: value of errors for faint stars is strongly dependent on the diameter (FWHM) of stellar images. The values of errors begin to grow for about 8 pixels in FWHM, which corresponds to $B \approx 12^m$.

The plates obtained during the FON program were exposed for: 16 to 20 minutes and 30 to 60 seconds, long and short exposure respectively. To create a catalog, we must exclude the images with short exposure from data processing at an early stage, prior to the procedure of reduction of rectangular coordinates X, Y in the equatorial coordinates α, δ (Andruk, 2012).

We paid special attention to take into account the magnitude equation (mdtX, mdtY) for calculating tangential coordinates ξ, η. We took into account the magnitude equation for stars brighter than $B \approx 11^m$. Analysis showed us that the magnitude equation is linear for brightness diameters and B-values and have second order for instrumental photometric values.

The combination of characteristic curves for both exposures allowed us to obtain the characteristic curve for the entire range of magnitudes. Photoelectric catalogs (Kornilov, 1991; Mermilliod, 1991) were used as the photometric standards. Stages and principles used to obtain the characteristic curve will be presented later due to the lack of space in this paper. The accuracy of the characteristic curve is $\sigma = 0.115^m$, a contrast ratio of emulsion is $\gamma = -0.763$ (37º).

4. Catalog

The second version of the catalog was created on the basis of data processing after the normal scanning. The first version of the catalog includes 1,108,603 stars and galaxies, and was created in 2011, using the combined data from the two versions of the scan (Yatsenko, 2011). The second version of this catalog contains 1,263,932 stars and galaxies up to $B_{ph} \leq 16.5^m$ (photographic magnitudes in the Johnson system) at epoch 1984.76 ± 0.50. The catalog was obtained after processing of 102 plates, mostly (30x30) cm in size or (13000x13000) px. Total number of objects (stars, galaxies, artifacts, etc.) were more than 7.2 million. Identification and selection of candidates for stars and galaxies for overlapping plates was carried out according to the following criteria: 1) objects should have the same equatorial coordinates ± half of the pixel size in seconds of arc (0.5px ≈ 1.1"); 2) magnitude difference of objects should not exceed ± 2^m. If the candidate met selection criteria for at least two plates, the object is counted in the catalog.

The internal accuracy of the catalog for all objects is ±0.26" for coordinates and $\pm 0.17^m$ for magnitudes. For stars in the range of $B = 8^m - 13^m$ errors are ± 0.13" and ± 0.11^m. For the TYCHO-2 reference stars, astrometric error does not exceed the value of ±0.060".

Also, we made comparison of the equatorial coordinates between our catalog and UCAC-4 catalog. We identified 1099005 common stars and galaxies. Coordinate errors between our catalog and the UCAC4 is $\sigma_{\alpha\delta} = \pm 0.34$".

Photometry error was determined by comparing the magnitudes of our catalog with the photoelectric one of reference catalogs (4457 common stars). Photometry error is equal to $\pm 0.16^m$.

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