ASTEROID POSITIONS BASED ON THE DUSHANBE PART OF THE FON PROJECT OBSERVATIONS

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ABSTRACT. Asteroid images identification and creation the positional catalogs based on digitized photographic observations of previous years were continued. Namely, the cooperation between Ukrainian Virtual Observatory (UkrVO) and the Institute of Astrophysics of the Academy of Sciences of Tajikistan make it possible to expand this work by involving numerous additional archives of digitized observations and processing services and thus obtaining new original data about the Universe.

The Dushanbe part of the Northern Sky Survey (FON project) is represented by about 1570 photographic plates obtained in 1985-1992 on the Zeiss-400 astrograph at the Hissar Astronomical Observatory of the Institute of Astrophysics of the Academy of Sciences of Tajikistan. At present, their digitization and further scan processing continue until the final product is obtained in the form of a catalog of equatorial coordinates and stellar magnitudes for all registered objects on the plates. The equatorial coordinates α, δ of all objects on the plates were obtained in the Tycho-2 reference system at the epoch of exposure of each plate. Photometry of stars for the plates was carried out based on the principles implemented in the processing of the plates of the FON project using photoelectric measurements of stars to construct the characteristic curves of the plates. Photographic B-magnitudes of objects were calibrated with photoelectric standards.

In parallel with solving the main task of the project to create a catalog of stars and galaxies, we analyzed the results of processing the plates to search for images of asteroids and comets and create a catalog of their coordinates and values.

About 300 positions of asteroids and comets were obtained with visual magnitudes from 7 to 16.5. All positions of the asteroids were compared with the ephemeris. A preliminary analysis of the O-C differences and their comparison with similar results obtained from the digitized observations of the Kyiv and Kitab parts of the FON project are conducted.

Keywords: data archives, digitized observations, catalog, asteroid positions.

АНОТАЦІЯ. На основі оцифрованих фотографічних спостережень попередніх років продовжена робота з ідентифікації зображень астероїдів та створення каталогів їхніх положень і зоряних величин.

Кооперація між Українською віртуальною обсерваторією і Інститутом астрофізики Академії наук Таджикистану дають можливість розширити цю роботу, додаючи нові архіви оцифрованих спостережень і сервіси їх обробки, отримуючи, таким чином, нові оригінальні дані про Всесвіт.

Спостереження третьої частини Фотографічного огляду північного неба (ФОН) в Душанбе представлені приблизно 1570 фотопластинками, отриманими в 1985-1992 рр. на астрографі Zeiss-400 в Гісарській астрономічній обсерваторії Інституту астрофізики Академії наук Таджикистану. Тривають оцифрування фотонегативів та подальша обробка сканів, поки за даними всіх спостережень буде отримано каталог екваторіальних координат та зоряних величин для всіх зареєстрованих об'єктів на пластинках. Екваторіальні координати α, δ усіх об'єктів отримані в системі опорного каталогу Tycho-2 на епоху експонування кожної пластинки. Фотометрія зір проводилась на основі принципів, реалізованих при обробці спостережень проекту ФОН з використанням фотоелектричних вимірювань зір для побудови характеристичних кривих для кожної пластинки. Фотографічні B-величини об'єктів відкалібровані за фотоелектричними стандартами.

Паралельно з вирішенням основного завдання проекту зі створення каталогу зір і галактик ми проаналізували результати обробки пластинок з метою пошуку зображень астероїдів і комет та створення каталогу їх положень і B-величин.

Загалом було ідентифіковано близько 300 положень астероїдів і комет з візуальними зоряними величинами від 7 до 16,5. Всі положення астероїдів були порівняні з ефемеридними. Виконано попередній аналіз різниць O-C та їх порівняння з аналогічними результатами, одержаними з цифрованих спостережень Київської та Кітабської частин проекту ФОН.

Ключові слова: архіви даних, оцифровані спостереження, каталог, положення астероїдів.

1. Introduction

At the end of the 20th century, six observatories took part in the implementation of the Photographic Survey of the Northern Sky (FON project): the Main Astronomical Observatory of Ukraine (Kyiv, Goloseevo), the Zvenigorod Observatory of Russia, the Hissar Observatory of Tajikistan, the Abastumani Observatory of Georgia, the Zelenchuk Observatory of Russia and the Kitab Observatory of Uzbekistan (Pakuliak et al., 2016; Andruk et al., 2017b).

The Kyiv and Kitab parts of the project have been successfully completed. The processing of the digitized observations resulted in a few catalogs of coordinates and B-magnitudes for more than 19 million stars and galaxies from the FON-Kyiv part (Andruk et al., 2016) and more than 13 million stars and galaxies from the FON-Kitab part (Yuldoshev et al., 2017; 2019). Besides, based on these data, two catalogs for more than 5,000 positions and B-magnitudes of asteroids were compiled (Shatokhina et al., 2018a; 2018b). These catalogs are placed on the website of UkrVO (http://gua.db.ukr-vo.org/starcatalogs.php) and in Strasbourg astronomical Data Center (http://cdsweb.u-strasbg.fr).

The digitizing of astroplates has been performed using Epson™ and Microtek™ commercial scanners with 16-bit gray levels and a resolution of 1200 dpi. Images of all objects registered on plates were processed using the advanced software complex for CCD images processing MIDAS/ROMAFOT in the LINUX environment. Additional software modules developed and implemented in the Main Astronomical Observatory of the NAS of Ukraine and Research Institute "Mykolaiv Astronomical Observatory" provide both the digitized images processing and the final product as a catalog of positions and stellar magnitudes of all registered objects (Andruk et al., 2015; Protsyuk et al., 2016b; 2019b).

The equatorial coordinates α, δ, and stellar B-magnitudes of all objects on the plates were obtained in the reference system of Tycho-2 at the epoch of the exposition of each plate. The photometry of stars was made on the principles implemented in processing the plates of the FON project (Andruk et al., 2017a) using photoelectric measurements of stars to construct the characteristic curves of each plate (Relke et al., 2015). Photographic B-magnitudes of objects were calibrated with photoelectric standards.

Based on these developed methods (Andruk et al., 2016; Pakuliak et al., 2020; Protsyuk et al., 2019a), we currently prepared similar catalogs for the third part of the FON project in cooperation with the Hissar Astronomical Observatory of the Institute of Astrophysics of the Academy of Sciences of the Republic of Tajikistan. Observations were obtained in 1985–1992 with the Zeiss-400 astrograph (Marsden's code 190, D/F=400/2000 mm) at the Hissar Astronomical Observatory near Dushanbe. The plate collection includes about 1570 negatives covering the northern hemisphere from –8° to + 90°. Plate digitization began in 2017 after the commercial Microtek ScanMaker 1000XL Plus scanner was provided. The first results of this work were published in articles by Mullo-Abdolov et al. (2017, 2018); Rahimi et al. (2018); Yizhakevych et al. (2018).

2. Main results

The results of processing the digitized plates contain coordinates and magnitudes not only for stars, but also for all objects that were fixed on these plates during exposure.

These data were used for a global search for small bodies of the Solar System on these plates (Ivanov et al., 2013; Protsyuk et al., 2015; 2016a; 2017; Shatokhina et al., 2017; 2019).

The asteroid identifications were performed according to the coordinates and stellar magnitudes of asteroids. The diameter and maximum intensity of the central pixel of the asteroid images are also taken into account. Ephemeris support for asteroid identifications and further precise comparison of results was made using the online Internet resources (https://ssd.jpl.nasa.gov/sbfind, https://ssd.jpl.nasa.gov/horizons).

After such identifications and analysis, the 302 asteroid positions and magnitudes from the processing results of digitized plates of the two zones of the FON-Dushanbe project were compiled into a preliminary catalog. The positions of asteroids that were fixed on photographic plates in the immediate vicinity of stars according to the Gaia DR2 catalog data were excluded from compiled catalog. We considered them to be ambiguous identifications of asteroid or star images.

We analyzed the quantitative and qualitative characteristics of the catalog data. Figure 1 shows the distribution of all the identified asteroids by year. Figure 2 shows the number of asteroid positions obtained from FON-Dushanbe observations for each visual magnitude interval. Asteroids with a visual magnitude of up to 16.5^m have been identified. In comparison to the results of other parts of FON observations, the asteroids with a maximum visual magnitude of 16^m were identified with FON-Kyiv and 17-17.5^m with FON-Kitab.
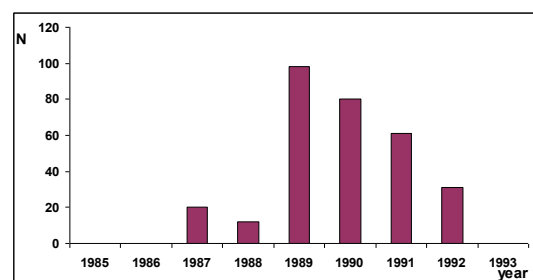

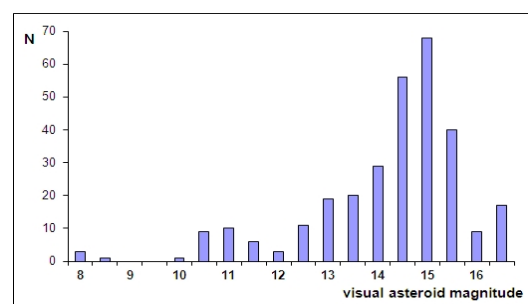Figure 1: Distribution of identified asteroids by years.

Figure 2: Distribution of identified asteroids by visual magnitudes.

All positions of asteroids were compared with the JPL DE431 ephemeris. The O-C differences in both coordinates for all asteroids are presented in Fig.3. Additionally, this figure also shows similar results for all asteroid positions from the FON-Kyiv and FON-Kitab observations. The scatter of O-C values is greater in both coordinates for the FON-Dushanbe observations than for the FON-Kyiv and FON-Kitab observations. A systematic O-C shift is noticeable in the RA coordinate for all asteroid positions from the two FON-Dushanbe zones. To find the reasons for the appearance of systematic O-C shift at the asteroid positions, they were further analyzed.

Firstly, several plates were selected, where many asteroids identified, their O-C differences have large values, and a clear systematic O-C shift was found. For example, on plate No.1108 with identified seven asteroids, the coordinates of all stars were also analyzed. All stars on this plate were identified and O-C differences were calculated (Fig. 4) between the coordinates of the stars determined on the plate and identified in the Gaia catalog. From the analysis of the coordinate differences, both separately for the magnitude intervals, and as a whole, systematic shifts for the coordinates of stars inherent in the positions of asteroids were not found.
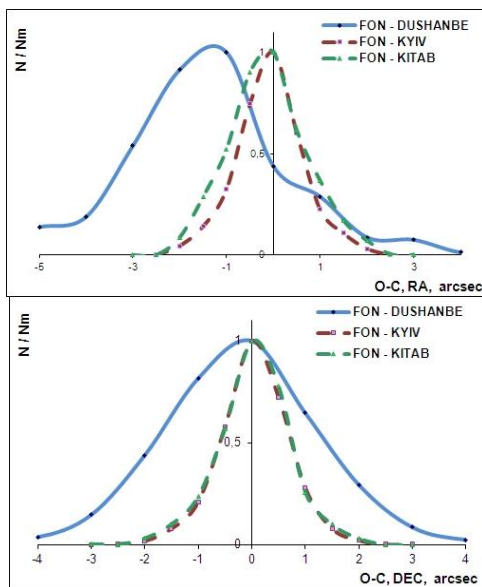

Figure 3: Histograms of distribution of O-C differences on both coordinates for 302 asteroid positions from the FON-Dushanbe observations.
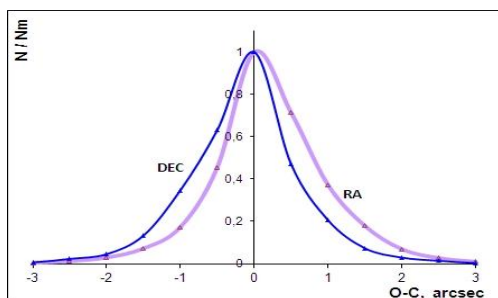

Figure 4: Distribution of O-C differences between the coordinates determined from plate No. 1108 (observations of FON-Dushanbe) and identified from the data of the Gaia DR2 catalog for 14103 stars.
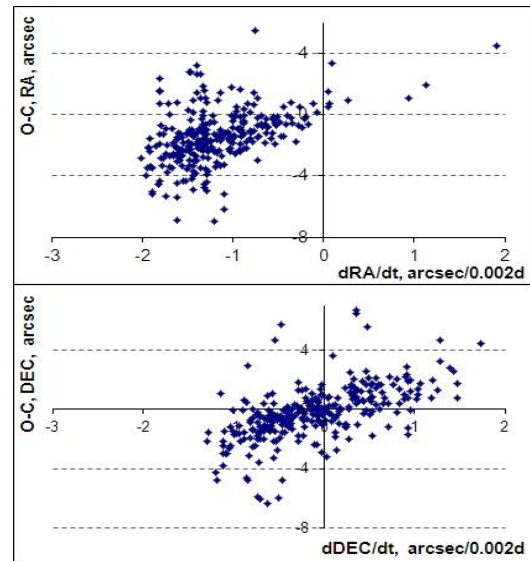

Figure 5: Dependence of the O-C differences on the values of orbital velocities for all asteroid positions.

Secondly, the O-C differences for all asteroid positions were analyzed depending on asteroid orbital velocities near the corresponding observational moments. The results are shown in Fig. 5. A clear correlation of the O-C differences of asteroids with the value of their orbital velocities near the observational moments was found in the right ascension coordinate. For asteroids with a higher orbital velocity, the largest values of the O-C differences and their significant scatter are observed. Therefore, the systematic shift of asteroid O-C differences may be the result of a systemic underestimation of time in the positions of asteroids, as also noted in the article by Yizhakevych et al. (2018). According to the preliminary estimates, its value can reach several minutes. Further analysis of the results is also required using the remaining observations from other FON-Dushanbe zones. As a result, the systematic component of the asteroid positional errors can be analyzed and, if possible, taken into account.

3. Conclusion

According to the results of processing the digitized plates of the third part of the FON project in Dushanbe, more than 300 asteroid positions were obtained.

Precise recording of the time of each exposure on a photographic plate, as is required when observing moving celestial objects, was not a necessary requirement for observing stellar areas in the FON project implementation.

Therefore, using FON observations to determine the precise positions of moving celestial objects may lead to some increase in positional errors for different plates or their groups. However, in most cases, this leads to an increase in the random component of these errors. So, the systematic components of errors should be analyzed and, if possible, taken into account.

We note that the observations of the FON-Kyiv and FON-Kitab parts gave successful results in identifying the positions of asteroids compiling their catalogs and determining their positional accuracy.

The use of new digital technologies for processing observations made it possible to increase the total number of positions of small bodies of the Solar System by searching for images from various digitized archives of observations of previous years as well as to increase their accuracy.

The covering of time intervals with missing data on asteroid positions and their analysis can be useful not only for modern ephemeris calculations but also for studying the evolution of asteroid orbits along time, non-gravitational effects, and others. These missing data can be obtained from the digitized observational archives of the UkrVO (Pakuliak et al., 2013; Vavilova et al., 2016; 2017; 2020), modern processing methods (Savanevych et al., 2015a; 2015b; 2018) and other databases.

The magnitudes of asteroids determined simultaneously with their coordinates can be used to determine the photometric characteristics of asteroids, constructing light curves and phase dependencies.

Note. While the article was being typeset, a previously lost log-book of observations was found. Preliminary analysis of several records showed differences in observational moments. This gives hope for a decrease in the values of the O-C differences for asteroids. The work is continued. The final complete list and positions of asteroids will be received after all observations have been processed.

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