DOI: http://dx.doi.org/10.18524/1810-4215.2016.29.85177

SEARCH SMALL BODIES IMAGES IN COLLECTIONS DIGITIZED PHOTOGRAPHIC OBSERVATIONS OF PREVIOUS YEARS

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ABSTRACT. Photographic observations of XX century is an important source of information on small bodies of the Solar system. The observations of chronologically earlier oppositions, photometric evaluation of brightness for long periods of time allow refining the orbits of asteroids and identifying various non-stationaries. Unfortunately international databases were contained a very little observable data for accurate estimates of geometric and kinematic parameters of asteroids.

We analyzed the results of digital processing of 338 photographic plates of Northern Sky Survey (FON) project. Modern approach to processing early observations using new digital technologies provides a sufficiently high accuracy of coordinates and magnitudes for all objects on astroplates. As a result 570 images of asteroids and 4 images of comets from 8-16 magnitudes were detected on these plates. Equatorial coordinates and stellar magnitudes of them were composed to catalog of asteroids. All positions were compared with ephemeris. Analysis of ephemeris calculations with known today about the several hundred small planets with observation data showed some interesting results.

Keywords: photographic archive – asteroids – catalogs – astrometric positions

1. Introduction

A broad searching of small bodies on photographic observations of previous years we planned to carry out on plates from Northern Sky Survey (FON) project. As the first result we used 338 photographic plates of FON project obtained with DWA (Double Wide-angle Astrograph, D/F=40/200, 103"/mm, h=186m) at the Main astronomical observatory in 1982-1994. These plates cover the area on celestial sphere from 0 to 24 hours in right ascention and from -4º to +16º in declination. The digitizing of astroplates has been performed using Microtek ScanMaker 9800XL TMA and Epson Expression 10000XL commercial scanners, with the resolution 1200 dpi. All scans of plates accumulated in Joint Digital Archive of Ukrainian virtual observatory. Standard images were processed using advanced complex LINUX / MIDAS / ROMAPHOT programs. The software was developed and implemented in MAO NASU to process the digitized astronomic negative plates as well as to obtain the final product in the form of a catalogue of positions and stellar magnitudes for all registered objects on the plate. In detail, the process of digitization of images and their further processing and determination of coordinates and magnitudes are described in the series of publications (Andruk et al., 2005; 2007; 2010; 2014; 2015; 2016; Protsyuk et al., 2014a; 2014b). The results of the software testing are described in (Kazantseva et al., 2015; Yizhakevych et.al, 2014; 2015; Protsyuk et al., 2014; Andruk et al., 2013; Eglitis et al., 2016b; 2016c).

Digital processing of photographic plates of star fields allows to determine with high accuracy the coordinates and stellar magnitudes for all registered objects on these plates, such as stars, galaxies, small bodies, artificial satellites and artefacts.

At the first, the processing results of photographic plates of Northern Sky Survey project were used for composing of the catalog of star positions and B-magnitudes for 19451751 stars and galaxies with $B < 16.^{m}5$ (Andruk et al., 2016b).

Secondly, the processing results of these photographic plates had been used for a broad search for images of small bodies of the Solar system and determination of their coordinates. First test results of searching of Solar system bodies using plate archive of photographic observations were obtained earlier and described in (Shatokhina et al., 2005).

2. Results

376 asteroids from Main Belt and 2 comets (65P/Gunn [1982], 4P/Faye [1991]) were identified on plates. From them 570 positions of asteroids and 4 positions of comets were received and composed in total catalog. These objects cover magnitude range from 7.8 to 16.1. The equatorial coordinates α, δ and stellar B-magnitudes of all small bodies on the plates were obtained in the reference system of Tycho-2 at the epoch of exposition of each plate. Photographic B-magnitudes of objects were calibrated with photoelectric standards.

Figure 1 shows the distribution of all searching asteroids for all used plates. More faint asteroids with 15-16 magnitude were identified on the astronegatives with high atmospheric transparency and good observing conditions only.

Almost every astronegative has images from 1 to 10 different asteroids. For example, Figure 2 shows mutual locations of 9 different asteroids from $10.^{m}7$ to $15.^{m}0$ magnitudes on the scan of plate GUA040C000887B.

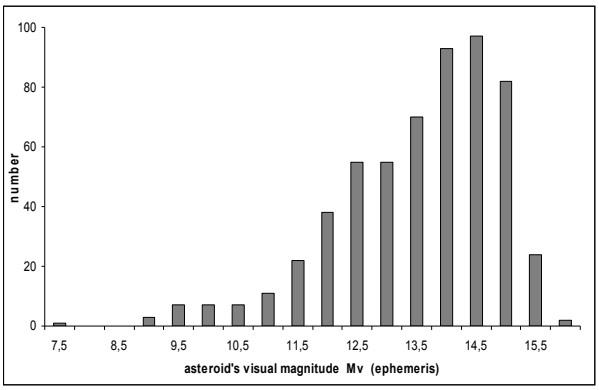

Figure 1: Distribution on magnitudes for 574 searching asteroids

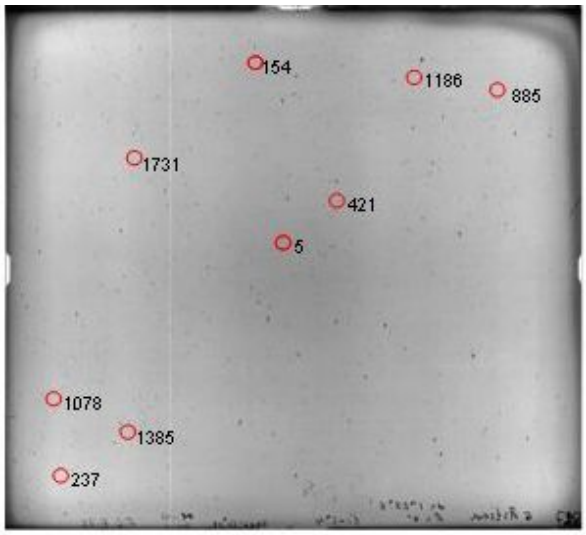

Figure 2: Images of 9 asteroids on scan of the plate GUA040C000887B.

From digital processing of photographic plates of FON project were obtained the mean internal errors equal 0.233 arcsec in both equatorial coordinates and $0.^{m}14$ in B magnitudes for all objects (Andruk et al., 2016b).

The comparison with the JPL DE431 ephemeris (http://ssd.jpl.nasa.gov/horizons) is given. The differences O-C on both coordinates and difference B-Mv (Mv – approximate visual magnitude calculated by ephemeris JPL) are received for all positions of asteroids and comets.

The most of searching asteroids have a single position in composed catalog. But 138 asteroids have a several positions from 2 to 5 during one opposition of asteroid. A range of changes in the differences O-C is 1 arcsec for such asteroids. We analyzed O-C of asteroids on different distances from center of plates. We analyzed O-C of asteroids on different values of asteroid's speed projection too. The significant dependencies O-C were not detected in analysis of these results.

Figure 3 shows changes of observed B magnitudes for 574 searching asteroids and comets. The small trend of B magnitudes observed for faint asteroids with 14-16 magnitudes in comparison with visual magnitudes calculated JPL. As a result, a lower value of color index observed for them. At the same time, the spread of values of B magnitude for faint asteroids increases.

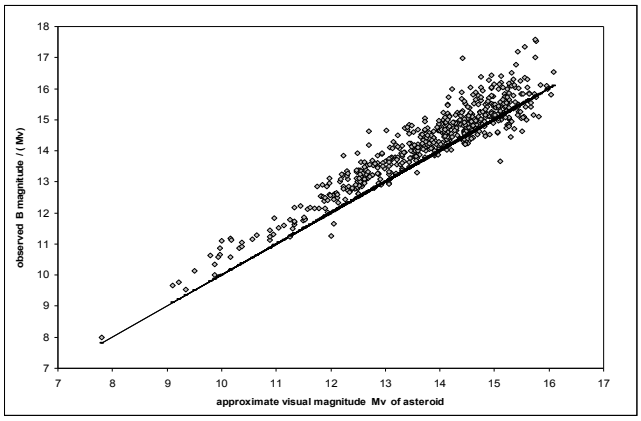

Figure 3: Changes of observed B magnitudes for 574 searching asteroids and comets along Mv asteroid's magnitude axis. (B magnitudes pointed gray color. Mv visual magnitudes pointed black color).

Eight asteroids of the total number in catalog were observed many years before dates of their discovery. For them equatorial coordinates α, δ and stellar magnitudes B and O-C differences in both coordinates, and B-Mv, where B – blue observed magnitudes, Mv -approximate visual asteroid's magnitude calculated by ephemeris JPL, presented in the Table 1. Only 1 position of asteroid (20730) Jorgecarvano in this table have the earliest chronologically observations among all known in the world.

For asteroids (4816) Connelly and (20730) Jorgecarvano the distributions of all known observations in the world are presented on figure 4. Observational data took from Minor Planet Center (http://www.minorplanetcenter.net/db_search). With bold black color pointed our observations

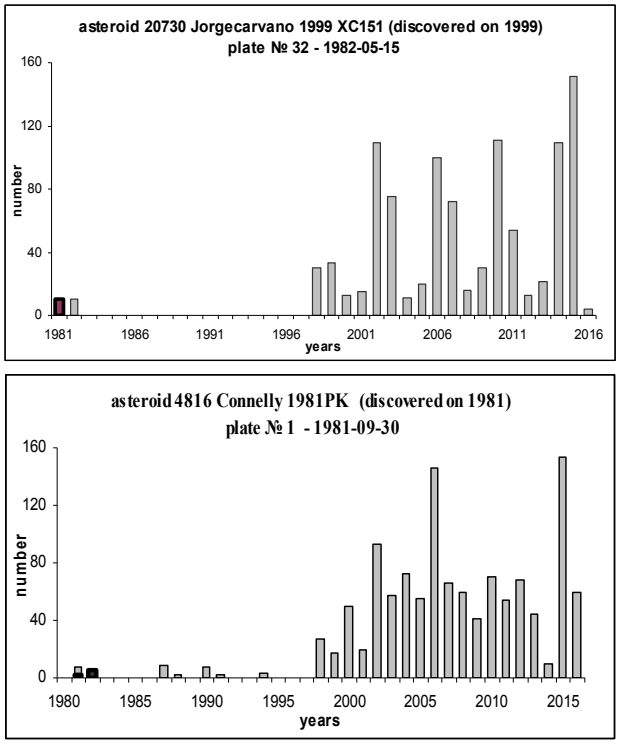

Figure 4: Distributions on time scale of all known observations in the world for 4816, 20730 asteroids.

Table 1 Asteroids observed before their discovering dates.

Object name	RA, J2000.0 h m s	Dec, J2000.0 deg ' "	Magnitude	$(O-C)_{RA}$ arcsec	$(O-C)_{Dec}$ arcsec	B-Mv
Plate 1 UT=1981-09-30.762512						
(4816) Connelly 1981 PK	205232.895	+013454.26	16.31U	.57	-.74	.70
Plate 83 UT=1982-05-15.958641						
(7262) Sofue 1995 BX1	164301.910	-023619.46	15.14	-.59	-1.76	.16
Plate 82 UT=1982-05-15.958641						
(20730) Jorgecarvano 1999 XC151	161716.268	-023720.98	16.99U	.87	.56	1.25
Plate 274 UT=1982-07-14.702812						
(5001) EMP 1987 SB1	165147.325	-010355.78	15.99U	-1.15	-1.46	.02
Plate 1484 UT=1989-07-06.955139						
(13977) Frisch 1992 HJ7	195521.821	+085000.65	15.76B	-.24	.48	.78
Plate 1500 UT=1989-09-20.831430						
(14691) 2000 AK119	213153.404	+051221.23	15.77V	.11	-.80	.11
Plate 1513 UT=1989-10-19.872058						
(4290) Heisei 1989 UK3	005758.001	+154944.45	15.42R	-.60	.50	-.14
Plate 1618 UT=1990-03-01.044557						
(6518) Vernon 1990 FR	134123.217	+150003.62	16.36B	-.13	.77	.81

Similar (parallel) work was presented in Baldone observatory (Eglitis et al., 2016a). The faint asteroids up to 17 magnitudes were identified on the plate in Baldone observatory. Among them are much more interesting asteroids which discovered much later than observed.

Calculations evolution of asteroids with orbits MPC catalog from 2005 to 2016 were made earlier (Kazantsev et al., 2008). Differences semi-major axis of the orbits of asteroids between the catalog value in 2016 and calculated received.

The size and distribution of these values for albedo asteroids indicate the existence in the solar system is some non-gravitational effect. This effect is overwhelming growth of semi-major axis of the orbits of asteroids with small albedo.

Additional confirmation aforementioned effect, in principle, can be measured by the regulations asteroid on the plates of a few decades ago. More important differences in semi-major axis must meet greater values O-C.

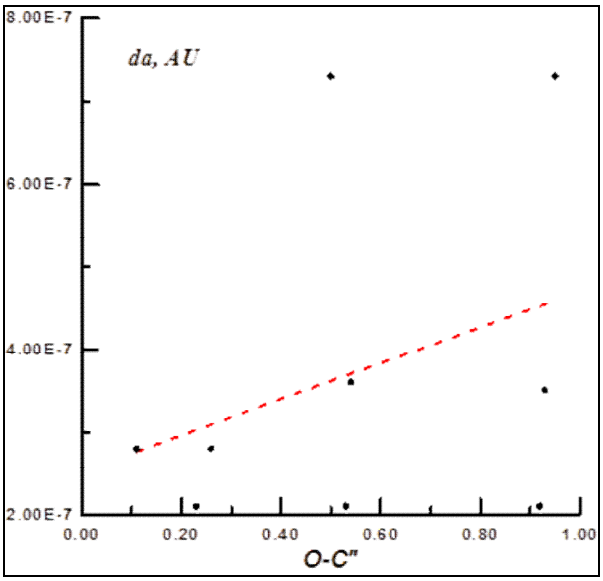

Figure 5: Distribution of values da (O-C) for O-C < 1" and da > 2•10-7 a.o.

3. Conclusion

On photographic plates of Northern Sky Survey project can be detected asteroids with high accuracy up to 16-16.1 magnitude. Among those may be objects which discovered much later than observed. The presence of the archive of all observations at previous years will give possibilities to select and process the interesting asteroids. A necessary condition for obtaining high-precision series of observations of asteroids is the presence of a confident moment of time of observations.

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