DOI: http://dx.doi.org/10.18524/1810-4215.2016.29.85128

OBTAINING POSITIONS OF ASTEROIDS FROM DIGITIZED PROCESSING OF PHOTOGRAPHIC OBSERVATIONS IN BALDONE OBSERVATORY (CODE 069)

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ABSTRACT. 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. The processing results can be used for a broad search for images of small bodies of the Solar system and determination of their coordinates. From the observations of earlier epoch, we can extract information about the locations of these bodies well before discovering them. Modern approach to processing early photographic observations with new technologies can be an effective instrument for rediscovery of asteroids and correction their orbits. We analyzed the results of digital processing of observations of clusters in UBVR bands which were made on the 1.2-m Schmidt telescope of the Observatory of Institute of Astronomy of University of Latvia in Baldone (code 069). As a result 87 images of minor planets from 9.8 to 17.1 stellar magnitude and 2 images of comets were identified on 152 plates for 1967-1996. The catalogue of positions and stellar magnitudes of the searching asteroids was compiled. Among them 12 observations of asteroids are the earliest of the world's known observations of these asteroids. All positions of asteroids were compared with the ephemeris JPL DE431. Analysis was carried out.

Keywords: photographic archive – asteroids – catalogs – astrometric positions

1. Introduction

Baldone Observatory of Institute of Astronomy of Latvian University has the photographic collection more than 22000 plates obtained using 1.2 m Schmidt telescope (Eglitis et al., 2016d). The observational period started in 1966 and lasted for 39 years. The area of the sky, covered by a single plate is approximately 19 square degree and contains from 10 000 to 50 000 images of different celestial objects. The plate scale is of 72 "/mm. The observations were carried out with various filters and emulsions of astroplates. Combining emulsion ORWO ZU1 (ZU2 or ZU21 or Kodak 103aO or IIaO) with UG1 filter realizes U photometric band. Combining emulsion ORWO ZU2 (ZU21) with GG13 filter realizes B photometric band. Combining emulsion A600 with ZS17 filter or emulsion ORWO ZP1 with filter RG1 realizes V or R photometric band respectively. As a result, photographic observational archive of Baldone observatory has about 700 U-plates, 5000 B-plates, 4500 V-plates and more than 10000 R-plates.

2. Results

From 2013 year the regular digitization and processing of photographic astroplates started in Baldone observatory. The plates were digitized using Epson Expression 10000XL and 11000XL commercial scanners with the resolution 1200 dpi (or 2400 dpi). For processing all images were transformed to the FITS format through GIMP (www.gimp.org) software packages and ImageMagic (www.imagemagick.org). 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).

Approbations of this software are the catalogs of stars coordinates and U-magnitudes and Pluto's positions received from observations in Baldone (Eglitis et al., 2016a; 2016c). The equatorial coordinates α, δ and stellar magnitudes of all objects on the plates were obtained in the reference system of Tycho-2 at the epoch of exposition of each plate. Photographic U_{ph}-magnitudes of objects were calibrated with photoelectric U_{pe}-magnitudes.

The processing results of 152 observations of clusters and Pluto in UBVR bands in 1967-1996 were used for broad search for images of small bodies of the Solar system. As a result, 57 asteroids and 2 comets (31P/Schwassmann-Wachmann 2, C/1969 T1 (Tago-Sato-Kosaka)) were identified on these plates. From them 87 positions of asteroids and 2 positions of comets were received. These objects cover magnitude range from 9.8 to 17.1. All of them have orbit types: Main Belts, Hungarias and Mars-crosser.

Table 1 shows the number of asteroid's positions on all used plates with U, B, V, R filters. Figure 1 shows the distribution of all searching asteroids for all used plates and U-, B-, V-, R- plate's individual contribution in searching. More faint asteroids were identified only on astroplates with V, R filters.

For 33 U-plates the rms-error of coordinates of reduction to reference system is 0.10 arcsec for both coordinates. The rms-error of U-magnitude of calibration with photoelectric U_{pe}-magnitudes is 0.19. For single B, V, R-plates the accuracy values are presented in (Eglitis et al., 2016b). For several astroplates the digitizing six times in a row and further processing were performed to determine the accuracy of measurements of coordinates and magnitudes. According data analysis, the rms-error of measurements of coordinates increases to 0.25 arcsec with increasing asteroid's magnitude from 13 to 16 (Eglitis et al., 2016b).

Table 1.Astroplates used from Baldone astroplate archive.

Number of plates	Filter	Period of observations	Total number of positions of asteroids identified on plates	Number of positions of asteroids identified before discovering dates
143	U	1967-1987	45	9
7	B	1969-1996	16	2
1	V	1973	10	7
1	R	1973	16	12
∑=152			87	30

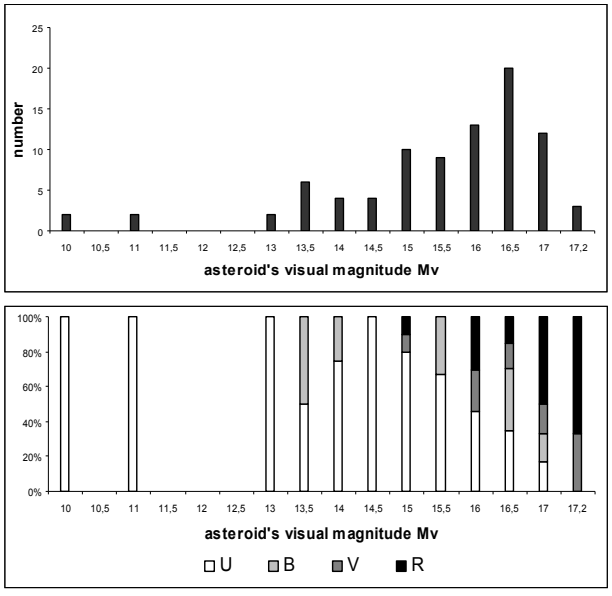

Figure 1: Distribution of all searching asteroids (top figure) and individual contribution U, B, V, R -plates (lower figure)

Full catalog of coordinates α, δ and magnitudes of 87 positions of asteroids is given at http://baldonesobservatorija.lu.lv. The comparison with the JPL DE431 ephemeris (http://ssd.jpl.nasa.gov/horizons) is given. 30 positions of asteroids from total searching quantity were observed many years before their discovering dates. Equatorial coordinates α, δ and stellar magnitudes U (or B, or V, or R) and O-C differences in both coordinates, and U-Mv (B-Mv, V-Mv, Mv-R), where U – ultraviolet, B – blue, V – visual, R – red observed magnitudes, Mv -approximate visual asteroid's magnitude calculated by ephemeris JPL, presented in the Table 2. But 12 positions of asteroids in this table have the earliest chronologically observations among all known in the world. With bold font pointed these observations in this table. For several asteroids (31527, 2356, 2078) the distributions of all known observations in the world are presented on figures 2a,b,c. Observational data took from Minor Planet Center (http://www.minorplanetcenter.net/db_search). With bold black color pointed observation in Baldone.

3. Conclusion

On photographic plates of Baldone Observatory can be detected asteroids with high accuracy up to 16-17 magnitude. Among those may be objects which discovered much later than observed. The presence of the archive of all observations in time scale 1966-2002 will give possibilities to select and process the interesting asteroids, including the bright Kuiper Belt objects. Cooperation with Ukrainian Virtual Observatory gives the opportunity to expand this work, involving numerous additional files of observations and, ultimately, to increase the number of new original positions. From this view Baldone observatory could compete with modern observations. A necessary condition for obtaining high-precision series of observations of asteroids is the presence of a confident moment of observations.

This investigation is supported by FP7 project „Noctural atmosphere".

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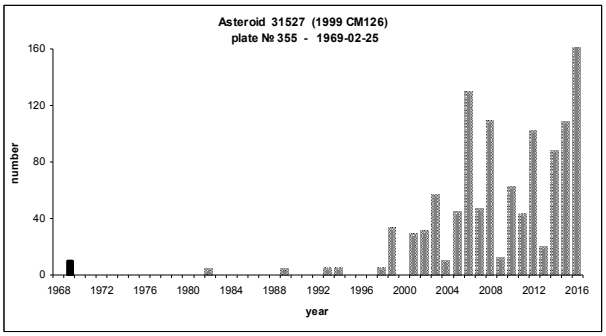

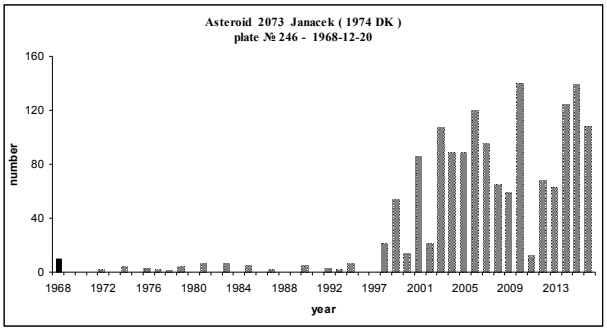

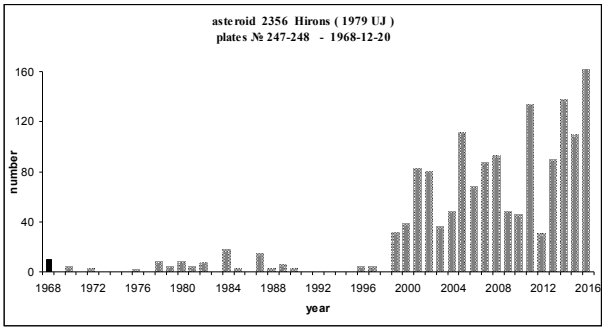

Figure 2a,b,c: Distributions on time scale of all known observations in the world for 31527, 2078, 2356 asteroids. With bold black color pointed observation in Baldone.

Table 2. Asteroids observed in Baldone before their discovering dates.

Object number name	RA, J2000.0 h m s	Dec, J2000.0 deg ' "	Magnitude	$(O-C)_{RA}$ arcsec	$(O-C)_{Dec}$ arcsec	U-Mv or B-Mv or Mv-R
Plate 26 (UT=1967-04-28.880787)						
2048 Dwornik (1973 QA)	121557.635	+265627.19	16.66 U	-.85	.03	.37
Plate 38 (UT=1967-05-12.878773)						
2048 Dwornik (1973 QA)	121521.343	+270852.92	-	-.55	-.89	-
Plate 246 (UT=1968-12-20.939583)						
2073 Janacek (1974 DK)	055815.208	+234757.40	16.04 U	-.96	.62	.59
2521 Heidi (1979 DK)	061008.994	+254139.11	16.22 U	.53	.13	.97
Plate 247 (UT=1968-12-20.961805)						
2356 Hirons (1979 UJ)	064122.935	+010604.39	16.75 U	.16	-.19	.95
Plate 355 (UT=1969-02-25.103587)						
31527 (1999 CM126)	123431.805	+264334.75	16.16 B	.03	-.58	-.29
Plate 2492 (UT=1973-01-01.869005						
1964 Luyten (2007 P-L)	060210.229	+205211.52	16.94 V	-.57	-.23	1.13
2222 Lermontov (1977 ST1)	055721.505	+232045.48	14.22 V	-.51	-.67	-.59
4095 Ishizuchisan (1987 SG)	060542.953	+215512.14	15.87 V	-.75	.15	-.64
5588 Jennabelle (1990 SW3)	061027.128	+234945.76	16.50 V	.04	-2.00	.03
8260 (1984 SH)	060916.957	+215506.72	18.25 V	-.33	.60	1.27
14221 (1999 WL)	055455.643	+223031.62	16.36 V	.22	.09	-.11
26629 Zahller 2000GZ132	055505.199	+225921.89	16.88 V	.96	-.86	-.23
Plate 2496 (UT=1973-01-01.883241)						
1964 Luyten (2007 P-L)	060209.360	+205211.31	14.68 R	-.64	.17	1.13
2222 Lermontov (1977 ST1)	055720.803	+232046.92	13.56 R	.17	-.17	1.25
4095 Ishizchisan (1987 SG)	060541.979	+215511.04	14.80 R	.04	-.15	1.71
5588 Jennabelle (1990 SW3)	061026.231	+234951.53	14.98 R	-.44	.23	1.50
5877 Toshimaihara (1990 FP)	055150.141	+232721.98	15.25 R	1.03	-.36	1.38
7346 Boulanger (1993 DQ2)	055557.298	+211840.79	15.40 R	.45	.10	1.38
8260 (1984 SH)	060915.903	+215507.20	16.67 R	-.70	-.18	.31
11974 Yasuhidefujita (1994 YF)	060111.237	+214944.57	15.63 R	.32	-.16	1.43
14221 (1999 WL)	055454.716	+223035.14	15.62 R	.56	-.06	.85
16506 (1990 UH1)	060319.833	+245725.71	14.57 R	.54	-.27	1.35
22282 (1985 RA)	061122.090	+233152.17	15.33 R	-.42	.17	1.21
26629 Zahller (2000 GZ132)	055504.277	+225918.46	16.12 R	.37	.23	.99
Plate 3511 (UT=1974-03-12.886782)						
2659 Millis (1981 JX)	060658.341	+222218.86	16.59 B	.38	1.06	-.18
Plate 4318 (UT=1975-05-08.893865)						
6785 (1990 VA7)	102220.190	+311948.67	16.52 U	-1.07	.16	.08
Plate 5912 (UT=1976-12-24.155115)						
3024 Hainan (1981 UW9)	102328.384	+285515.06	17.36 U	.37	.44	.67
Plate 15652 (UT=1987-03-24.954630)						
5914 Kathywhaler (1990 WK)	122048.075	+122110.13	17.13 U	.52	-.41	.70
Plate 15661 (UT=1987-03-25.929259)						
7472 Kumakiri (1992 CU)	123316.961	+131747.44	16.16 U	.35	.09	.28

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