

# DIGITAL ARCHIVE OF UKRVO: THE POSITIONAL ACCURACY OF MINOR PLANETS DETERMINATIONS

V. Golovnya, V. Andruk

Main Astronomical Observatory NAS of Ukraine, Kyiv, Ukraine  
*golov@mao.kiev.ua, andruk@mao.kiev.ua*

**ABSTRACT.** Scanning and astrometric processing of two 30x30 cm photographic plates with images of minor planets were conducted. The plates were obtained at the double wide-angle astrograph (DWAA, 400/2000) on the program of photographic sky survey and the program of small planets' observations. The plates were digitized using a flatbed scanner Epson Expression 10000XL. Images were obtained in the gray range of 16 -bits with a resolution of 1200dpi (> 11,000 pix along the one of the axes) and included into the UkrVO Joint Digital Archive (JDA). The plates are related to GUA040C observational archive. Image processing has been carried out in software package LINUS/MIDAS/ROMAFOT. Topocentric equatorial coordinates for the second exposition minor planet images were obtained with a single measurement error  $\pm 0.1''$  and  $\pm 0.3''$  for coordinate and  $\pm 0.2^m$  for magnitudes in the Tycho-2 catalog as reference.

**Key words:** UkrVO, DBGPA V2.0, 4179 Toutatis.

The methods of minor planets search (Sergeev, 2005; Breanne, N.M., 2006; Sergeeva, 2006) and the processing of digitized images of photographic plates has been discussed previously (Andruk, 2005, 2010, 2012; Muminov, M.M., 2013; Vavilova et al., 2010, 2011, 2012a, 2012b). The calculation of the exact topocentric coordinates of the asteroid in the digital images of plates with dimensions of  $8^\circ \times 8^\circ$  was made for the first time (Golovnya et al., 2010).

First we used the 4179 Toutatis asteroids ephemerides which were taken from the Minor Planet Center (<http://cfa-www.harvard.edu/iau/mpc.html>) for time scale 1976-1996. The ephemerides of Toutatis were selected for the moments of the closest approaches when their V-magnitudes were brighter than  $15.5^m$ .

The next step of our work was the searching for asteroids on the plates of JDA using ephemerides which stated below in Table 1 and Database of Golosiyiv plate archive (DBGPA V2.0, <http://www.mao.kiev.ua/ardb/index.php>, <http://194.44.35.19/vo-mao/DB/>). For many approaches there were no periods of astronomical observation. We found the plate number 2088 with possible image of Potentially Hazardous Asteroids

Toutatis and also possible images eight asteroids from Main Asteroid Belt. Fig.1 shows the digital image of GUA040C002088 plate with the marks of potential objects of interest. The plate parameters – center of the plate:  $08^h15^m50^s+16^\circ09'45''$ ; Data 1993 Jan 14; Second  $UT_{start}=22^h44^m23^s$ , duration of exposure  $22^m.5$ .

Table 1. Ephemerides 4179 Toutatis in the moments of the closest approaches with the Earth's orbit.

Date Y M D	R.A.(J2000)DEC h m s deg ' "	M AU	V Mag
19850101	002220 +011237	0.29	15.5
19850119	030005 +162140	0.32	15.2
19881222	001014 -014443	0.12	13.7
19890104	032906 +170837	0.14	13.0
19921208	133250 -250913	0.02	13.1
19921214	095556 +050046	0.04	11.0
19930114	080413 +195414	0.26	13.2

Here: Date – year, month, date; R.A.(J2000)DEC – right ascension and declination of asteroids in  $0^h$  UT; M – orbital intersection distances; V – visible magnitude.

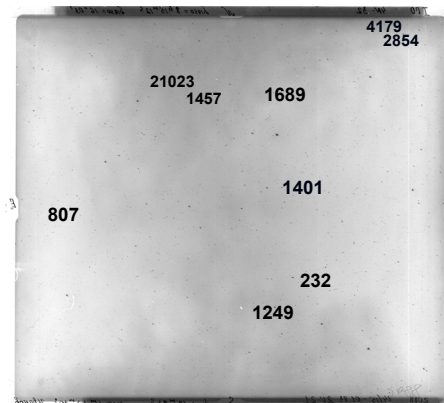


Figure 1: Image of the plate 2088.

Table 2 gives the list of minor planets, potentially appeared on the digital image of the plate. It is added to the list of the number, visible magnitude, right ascension

and declination of asteroids. Coordinates are taken from HORIZONS JPL-ephemerides for the moments of middle of second exposure.

Table 2: List of the asteroids on the plate 2088.

N	V	R.A.(J2000)DEC <sub>JPL</sub>
2854	15.55	08 <sup>h</sup> 02 <sup>m</sup> 18.739 <sup>s</sup> +19°40'22.168"
4179	13.21	080315.448 +195930.590
1401	15.31	080827.771 +154536.553
232	13.31	081044.601 +141210.399
1689	14.66	081224.308 +185610.082
1249	13.66	081317.978 +135038.643
1457	14.40	081612.243 +191847.036
21023	15.45	081950.967 +191703.600
807	14.55	083033.604 +154212.304

On Figure 2 among the stars there is image of 4179 Toutatis with visible magnitude V=13.43.

The next step of our work was the derivation of minor planet topocentric coordinates.

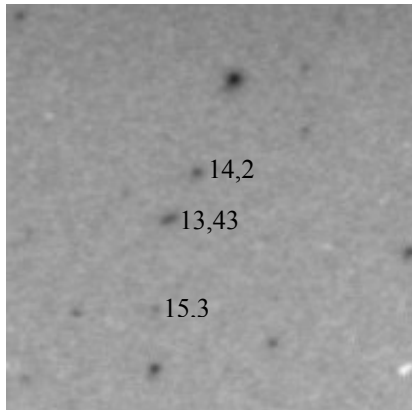


Figure 2: Image of 4179 Toutatis.

Image processing has been carried out in software package LINUS / MIDAS / ROMAFOT. Figure 3 (on the left) shows the trend of systematic differences between measured and catalog coordinates for right ascensions and declinations the correction for the instrumental errors of the scanner (left) and the trend of random differences between the measured values and catalog coordinates of stars after the correction for instrumental errors of the scanner (right). Differences in arcsec on 1a), 1b), 1d) and 1e) panels are given vs pixel coordinate axes of images X,Y and on 1c) and 1f) panels vs B-magnitudes of TYCHO-2. The rms unit errors  $\Delta\alpha$ ,  $\Delta\delta$  decrease from  $\sigma = 0,306''$  to  $\sigma = 0,104''$  and from  $\sigma = 1,928''$  to  $\sigma = 0,113''$  correspondingly after the scanner errors removing. N on 1a) - reference stars of TYCHO-2. The top ticks on 1a), 1e) panels fix the positions of minor planets on the plate; numbers are given according the MP column in Table 3.

We compare the calculated topocentric coordinates of minor planets with the coordinates, given by the theory DE-0431LE-0431 (Giorgini J., HORIZONS Web-Interface <http://ssd.jpl.nasa.gov/horizons.cgi>), to receive the appropriate residuals  $(O-C)_\alpha$  and  $(O-C)_\delta$ .

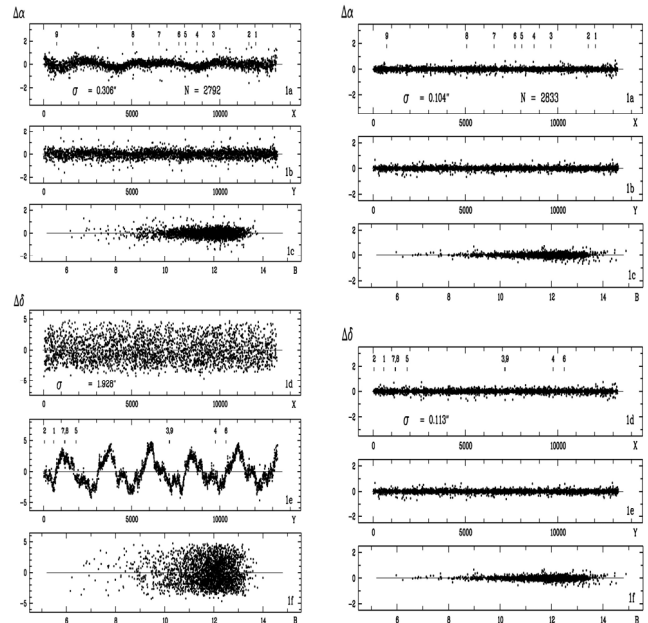


Figure 3: The trend of systematic differences between the measured values and catalog coordinates of stars before the correction for the instrumental errors of the scanner (left) and the trend of random differences between the measured values and catalog coordinates of stars after the correction for instrumental errors of the scanner (right).

Table 3 gives the calculated photographic magnitudes in TYCHO-2 photometric system with the above said residuals  $(O-C)_\alpha$  and  $(O-C)_\delta$ . Minor planets 2854 and 21023 were not fixed on the plates images.

Table 3: Calculated B-magnitudes and residuals  $(O-C)_\alpha$  and  $(O-C)_\delta$ .

Name	MP	Mph	$(O-C)_\alpha$ , $(O-C)_\delta$ .
2854 Rawson	1	-	-
4179 Toutatis	2	13.58	+0.050 <sup>s</sup> +1.150"
1401 Lavonne	3	16.46	+0.064 +0.144
232 Russia	4	13.60	-0.030 +0.374
1689 Floris-Jan	5	14.86	-0.042 +0.629
1249 Rutherfordia	6	13.83	-0.079 +1.306
1457 Ankara	7	14.61	-0.032 +0.868
21023 1989 DK	8	-	-
807 Ceraskia	9	14.95	+0.127 -0.510

The residuals are very different to each other, possibly due to inaccurate ephemerides. To verify this, we have calculated the residuals of some reference stars, given in Table 4. Additionally, the same method was applied to the calculation of coordinates for 2 Pallas – selected minor planet, fixed on the 2471 plate of the same observational archive. The plate parameters - center of the plate: 18h28m13s +19°05'; Data 1986 08 02; First exposure "S"; Second UT<sub>start</sub>=215605, duration of exposure 5<sup>m</sup>.0 (<http://www.mao.kiev.ua/ardb/index.php>).

Table 4:  $(O-C)_\alpha$ ,  $(O-C)_\delta$  for reference and control stars and selected minor planet 2 Pallas.

Stars/minor planet	Mph	$(O-C)_\alpha, (O-C)_\delta$
Tyc 1377-940-1	12.39	$-0.001^s + 0.024^m$
USNOA2 0975-05756822	15.17	$+0.040 + 0.60$
USNOA21050-55623614	14.49	$+0.015 + 0.27$
2 Pallas	10.68	$-0.015 - 0.092$

The calculated coordinates of potentially hazardous asteroid 4179 Toutatis and selected minor planet 2 Pallas coincide with their ephemeris values. Residuals  $(O-C)_\alpha$ ,  $(O-C)_\delta$  can be improved only by elimination of those reference stars, which coordinates have significant errors, especially stars with magnitudes  $B \geq 14^m$ .

The software package LINUS / MIDAS / ROMAFOT permits to build aberration masks of telescope optics on the data of the digital image itself. These masks can give the indirect signs of the correction of plate reduction and scanner errors elimination. Figure 4 shows the example of the above said mask on the data of processed plate.

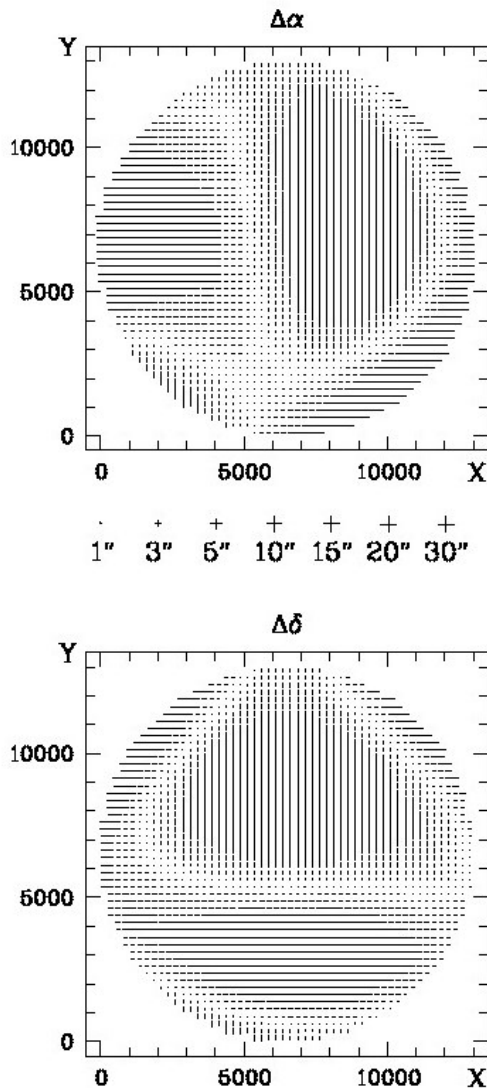


Figure 4: The aberration mask for DWAA optics on the data of 2088 plate processing.

## References

- Andruk V., Ivanov G., Pogoreltsev M., Yatsenko A.: 2005, *Kinematics and Physics of Celestial Bodies*, 21, N5, 396.
- Andruk V.M., Butenko G.Z., Yatsenko A.I.: 2010, *Kinematics and Physics of Celestial Bodies*, 26, N3, 75-81.
- Andruk V.M., Ivanov G.O., Yatsenko A.I. et al.: 2012, *Visnyk "Astronomia" T.Shebchenko National University of Kyiv*, 48, 11-13.
- Breanne N. Morelli *Using Astronomical Databases in the Search for Minor Planets*, City High School, April 5, 2006.
- Golovnya V., Andruk V., Yatsenko A.: 2010, *Journal of Physical Studies*, 14, N2, 2902
- Muminov M.M. et al.: 2013, *Izvestia GAO Pulkovo*, 220, 517-52.
- Sergeev A.V., Sergeeva T.P., Golovnya V.V.: 2005, *Kinematics and Physics of Celestial Bodies Supplement*, N 5, 577.
- Sergeeva T.P., Golovnya V.V., Yizhakevych E.M., et al.: VO: Plate Content Digitization, Archive Mining and Image Sequence Processing, Eds. M.Tsvetkov, V.Golev and others, Sofia, 2006, p.161-166
- Vavilova I.B., Pakuliak L.K., Shlyapnikov A.A. et al.: 2012, *Kinematics and Physics of Celestial Bodies*, 28, 85-102.
- Vavilova I.B., Pakuliak L.K., Protsyuk Yu.I. et al: 2012, *Baltic Astronomy*, 21, 356-365.
- Vavilova I.B., Pakuliak L.K., Protsyuk Yu.I. et al.: 2011, *Kosmichna Nauka i Tekhnologiya*, 17, 74-91.
- Vavilova I.B., Pakuliak L.K., Protsyuk Yu.I.: 2010, *Kosmichna Nauka i Tekhnologiya*, 16, 62-70.