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USING OF UKRVO DATA AND SOFTWARE FOR NEW REDUCTIONS OF PHOTOGRAPHIC OBSERVATIONS OF SELECTED MINOR PLANETS

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ABSTRACT. The new reductions of available photographic plates of UkrVO digital archive containing images of selected minor planets were conducted. Data processing of these plates were carried out to check the possibility of obtaining the new positions with high accuracy in the system of Tycho2/UCAC4 reference catalogues. Archives of the Research Institute "Nikolaev Astronomical Observatory" (NAO) and Main Astronomical Observatory of National Academy of Science (MAO) were used. We have chosen near 60 plates from these archives. Observational epochs of the plates were in the range from 1974 to 1991. Usually, there were 3 exposures in each plate and each plate was scanned 6 times with 1600 dpi resolution. The full identification was conducted and coordinates of all objects were obtained with usage of different options of astrometric reductions. The inner accuracy of obtained positions is within of 0.03″-0.40″. The comparison of the new topocentric positions of minor planets with Horizons ephemeris was made for calculation (O – C) residuals and their RMS. The matching with MPC data is present.

Keywords: Astrometry – methods: data analysis – virtual observatory tools – minor planets: general

1. Introduction

The photographic plates of UkrVO digital archive to check the possibility of obtaining the new positions of selected minor planets (MP) with high accuracy in the system of Tycho2 (Hog et al., 2000) and UCAC4 (Zacharias et al., 2013) reference catalogues were processed. The UkrVO digital archive contains image of plates from different Ukrainian telescopes (Vavilova et al, 2010, 2011, 2012a, 2012b, 2014a). The first investigation of minor planets with flatbed scanners in Ukraine started in 2013 (Golovnya et al., 2013). Then, we have studied dwarf and big planets (Kazantseva et al., 2015, Protsyuk et al., 2015e) and our methodics was significantly improved. The minor planets investigation is continued in this work.

In our new investigation we used plates only from two telescopes: the Zonal Astrograph of NAO (ZA, D/F = 12/204, 101 "/mm, FoV 5° x 5°, exposure 5-6 minutes) and the Double Wide-angle Astrograph (DWA, D/F = 40/200, 103 "/mm, FoV 8° x 8°, exposure 3-15 minutes) of MAO (Protsyuk et al., 2014a, Vavilova et al, 2014b). Usually, there were 3 exposures in each plate and each plate was scanned 6 times with 1600 dpi resolution with same methodics (Protsyuk et al., 2014b, 2014c). In NAO we used Epson Perfection V750 Pro scanner and in MAO – Epson Expression 10000XL scanner.

2. Input data set

We have chosen asteroid (704) Interamnia (1910 KU, 1952 MW, H = 5.94 mag) as main object for our research. This planet was observed by both telescopes at about the same time. The apparent magnitude of the asteroids was near 11.0-11.5. The data reduction results of the measurement of these plates, made with "Ascorecord" measure machine in 20 century, were submitted in Minor Planet Center (MPC). We have also chosen (389) Industria (ZA, NAO) with magnitude near 12.0 and (1064) Aethusa (DWA, MAO) with magnitude near 13.5 as faint objects (Table 1).

Table 1. Selected minor planets

MP	N plates	Obser-vatory	Epoch of observation	Mean Mag
704	29	NAO	1974.5-1985.8	11.1
704	20	MAO	1977.2-1982.2	11.5
389	4	NAO	1991.1-1991.3	12.0
1064	8	MAO	1979.6-1979.8	13.6

3. Data reduction

Detailed description of all steps of processing of digitized image of astro negatives, which containing preliminary filtering, choosing star shape objects and made reduction to the equatorial coordinates and magnitudes of a reference catalogues, are given in Protsyuk et al. (2014c, 2014d) and Andruk et al. (2014, 2015).

For choosing program for reduction we compare results from Kamasutra (00plate) and Plate Graf (plate_gr) program (Protsyuk et al., 2014d) with same parameters (4 iteration with Tycho2 reference stars up to 12.5^m, excluding the option of spectral class). Inner accuracy for 29 plates of NAO (MPC number 089) with Interamnia, received by two programs, are shown on Figure 1 and for 20

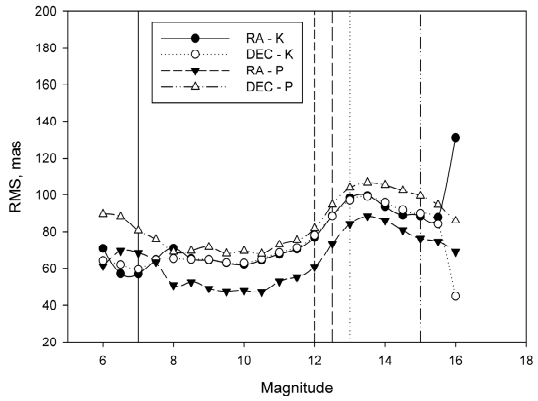

Figure 1: Inner accuracy for 29 plates of NAO received by Kamasutra (K) and Plate Graf (P)

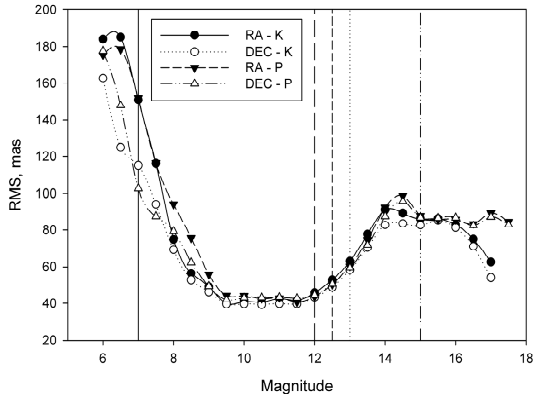

Figure 2: Inner accuracy for 20 plates of MAO received by program Kamasutra (K) and Plate Graf (P)

plates of MAO (MPC number 083) with one are shown on Figure 2.

For further research we chosen Plate Graf program due to the best accuracy results and speed of reduction. For example: time of reduction with one parameter set for 60 input data files of MAO's 4 plates with (389) Industria with usage Kamasutra was 7.5 hours and with usage Plate Graf – only 8 minutes.

In this study we are planning to find the best settings for Plate Graf program, which made all stars identification and astrometric reduction, and to compare obtained results with old one. Main of settings are: changing magnitude limit of reference stars from 12 to 15 with step 0.5^m, choosing reference stars with different options of spectra, using 4 or 5 iteration and receiving mean coordinates from all 6 scans or best 5 scans.

For all plates we obtained totally 384 images in 1600 dpi resolution with several exposures and received 1130 input data files for all exposures. Next, we made near 50 thousands reduction of this 1130 input data files with different settings of Plate Graf program and received near 5 TB data for analysis. This data include, among others, position and instrumental magnitude for chosen asteroids and reference stars.

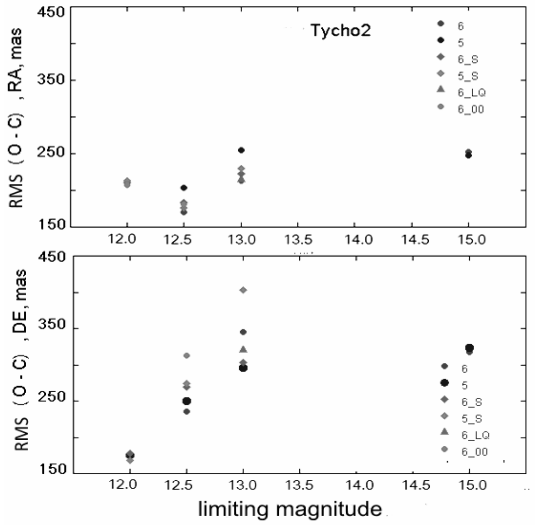

Figure 3: RMS of (O-C) of Interamnia, observed in NAO, for different settings of Plate Graf with Tycho2 reference catalogue

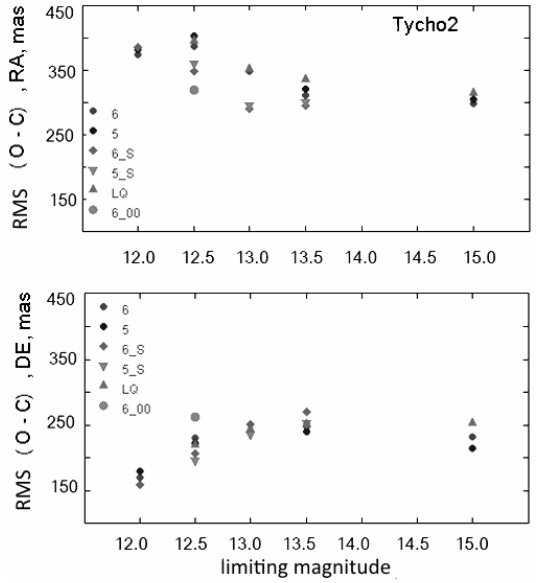

Figure 4: RMS of (O-C) of Interamnia, observed in MAO, for different settings of Plate Graf with Tycho2 reference catalogue

4. Data analysis with different reduction settings

We compare our observed (O) position with calculated JPL ephemeris (C) from on-line service HORIZONS (HORIZONS, 2016). Figure 3,4 shown the RMS of (O-C) for different sets of limiting magnitudes, numbers of iteration and scans quality during processing data in Plate Graf with Tycho2 reference catalogue (RC T2). Figure 5,6 shown results of research for UCAC4 (RC U4) reference catalogue.

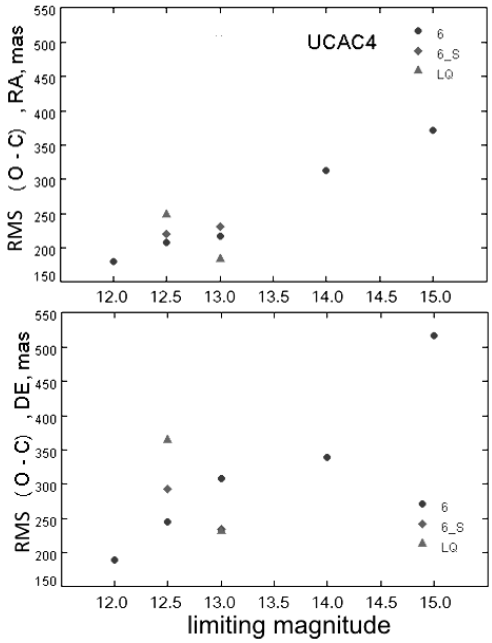

Figure 5: RMS of (O-C) of Interamnia (704), observed in NAO, for different settings of Plate Graf with UCAC4 reference catalogue

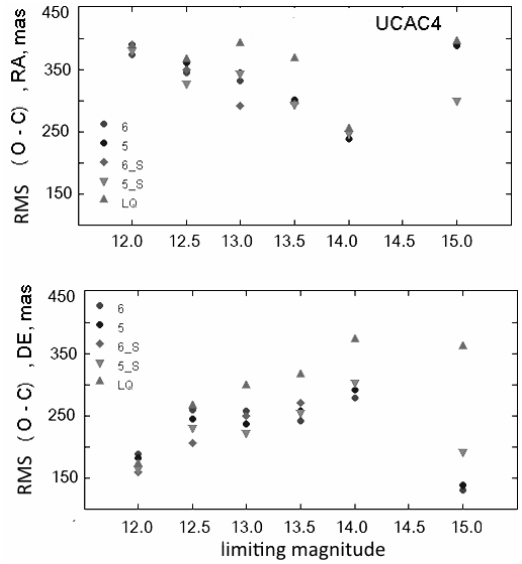

Figure 6: RMS of (O-C) of Interamnia (704), observed in MAO, for different settings of Plate Graf with UCAC4 reference catalogue

As can be seen, that the parameter "limiting magnitude of the reference catalogue" for NAO's observation provide the best results with 12 magnitude and for MAO's – gives the best results in the region of 13^m-14^m. This is due to the fact that the exposure time of the NAO's observation has been smaller on average and diameter of the ZA telescope is less than DWA more than 3 times. Results for most optimal settings are given in Table 2 and in Figure 7.

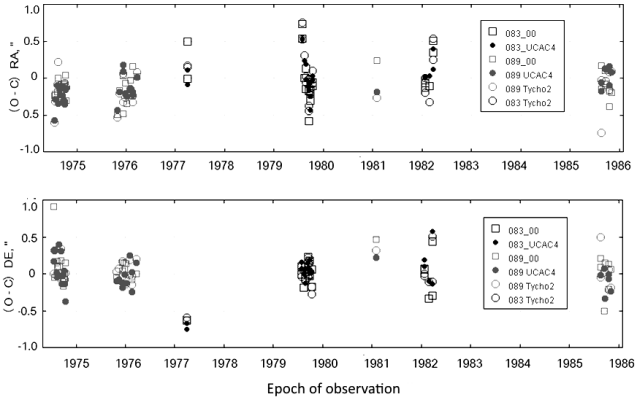

Figure 7: Reduction of Interamnia (704) observations for the selected option with different reference catalogues

Table 2. (O-C) for Interamnia obtained with optimal settings

Obser-vatory	RC	m	$(O-C)_{RA}$, mas	$(O-C)_{DEC}$, mas
NAO	T2	12.0	-186 ±207	45 ±168
NAO	U4	12.0	-149 ±178	-17 ±188
MAO	T2	13.5	31 ±311	-49 ±247
MAO	U4	14.0	40 ±237	-7 ±278

5. Final analysis

For final analysis to compare our new results with old one we have used AstDyS-2 service (AstDyS-2, 2016). In this service we have chosen data from 083 Goloseevo, 084 Pulkovo and 089 Nikolaev observations (Figure 8, 9). Average (O-C) differences for all plates in our investigation and data from AstDyS-2 service are shown in Table 3.

As can be seen, that the new (O–C) differences obtained with ephemeris Horizons (JPL) and with previous "Ascorecord" measurements from AstDyS-2 database coincide within the limits set error. There were no significant accuracy improvement for NAO plates due to high precisions observations and performed reductions to HCRF/ACT reference system. We have obtained a significant improvement of random and systematic errors for MAO plates.

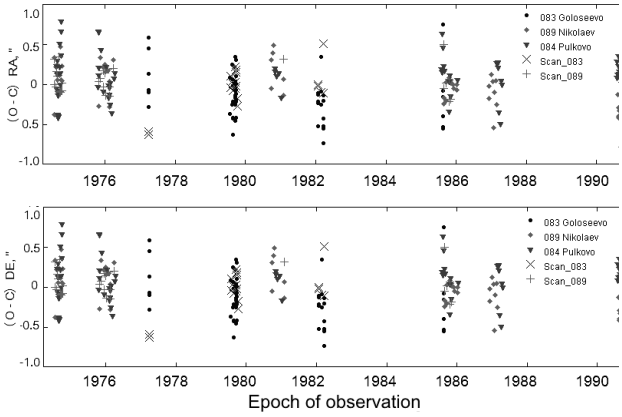

Figure 8: Comparing of new results (prefix scan_) with old one

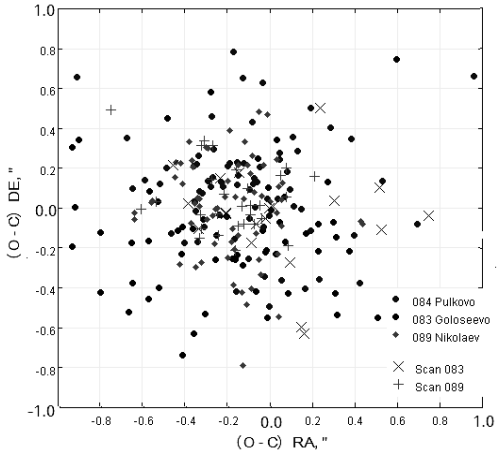

Figure 9: Compare of new results (prefix Scan) with old one

Table 3. Average (O-C) for old and new measurement

Observ. / MP	**NAO (704)**	**MAO (704)**	**NAO (389)**	**MAO (1064)**
N plates	65	55	4	-
Catalogue	ACT GSC	PPM	ACT GSC	-
AstDyS RA,mas	-185 ±206	-220 ±402	-218 ±332	-
AstDyS DEC,mas	-92 ±248	-157 ±296	-140 ±116	-
N plates	29	20	4	11
Catalogue	Tycho2	Tycho2	Tycho2	Tycho2
New scan RA, mas	-186 ±207	40 ±237	60 ±220	-455 ±514
New scan DEC, mas	45 ±168	7 ±278	158 ±227	-143 ±316
N plates	29	20	4	11
Catalogue	UCAC4	UCAC4	UCAC4	UCAC4
New scan RA, mas	-149 ±178	31 ±311	225 ±310	-460 ±368
New scan UCAC4 DEC, mas	-17 ±188	-49 ±247	113 ±243	-139 ±266

6. Conclusion

We chose 64 plates with 180 exposures of 3 minor planets observed in 1970-1990 from the archives of UkrVO.

Obtained 384 plates images with a resolution of 1600 dpi and processed in MIDAS environment to obtain X, Y, h / 2, I. Made identifying for 1130 processed data files.

More than 50 thousand reductions of data with different parameters were performed at total. The volume of reductions data is of about 5 TB.

We obtain the coordinates of minor planets for all variants of reductions.

A comparison of new (O–C) differences obtained with ephemeris Horizons (JPL) and with previous "Ascorecord" measurements from AstDyS-2 database was done.

New results for observations Interamnia in the NAO were shown a repetition of (O–C) system with improving accuracy. For MAO's observations improvement in the (O–C) system and noticeable improvement of accuracy were received.

These results are shown that reprocessing of old photographic plates with asteroid image, even on flatbed scanners, could give good results to reduce systematic errors in the positions of asteroids, associated with the use of old catalogues like PPM, SAO etc. Due to the high labor intensity, of course, this process should be selective. And plates for reprocessing should be chosen considering the quality and availability of plates, last history of the asteroid observations and precision of performed of old astrometric reductions.

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