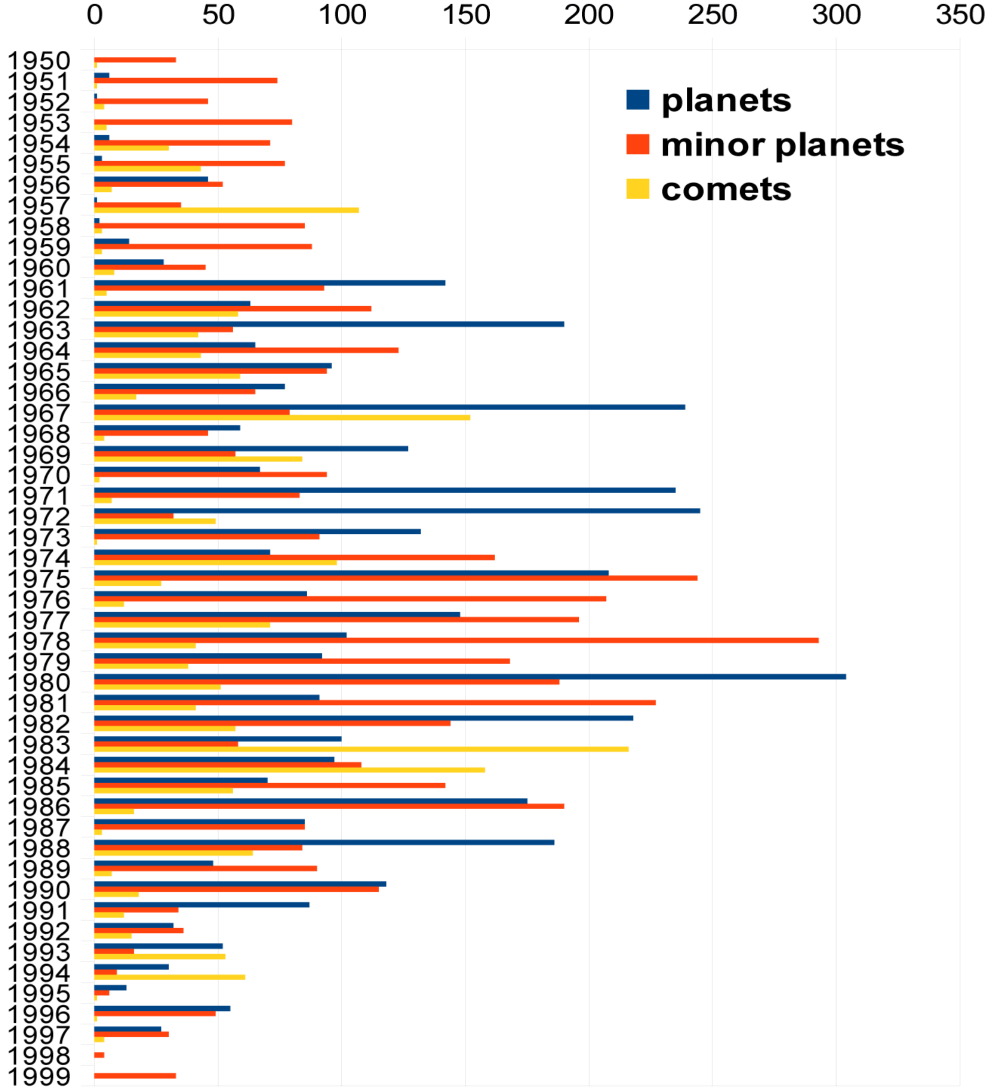
Number of SS Bodies observations in the collection of MAO NASU



First results of MAO NASU SS bodies photographic archive digitization

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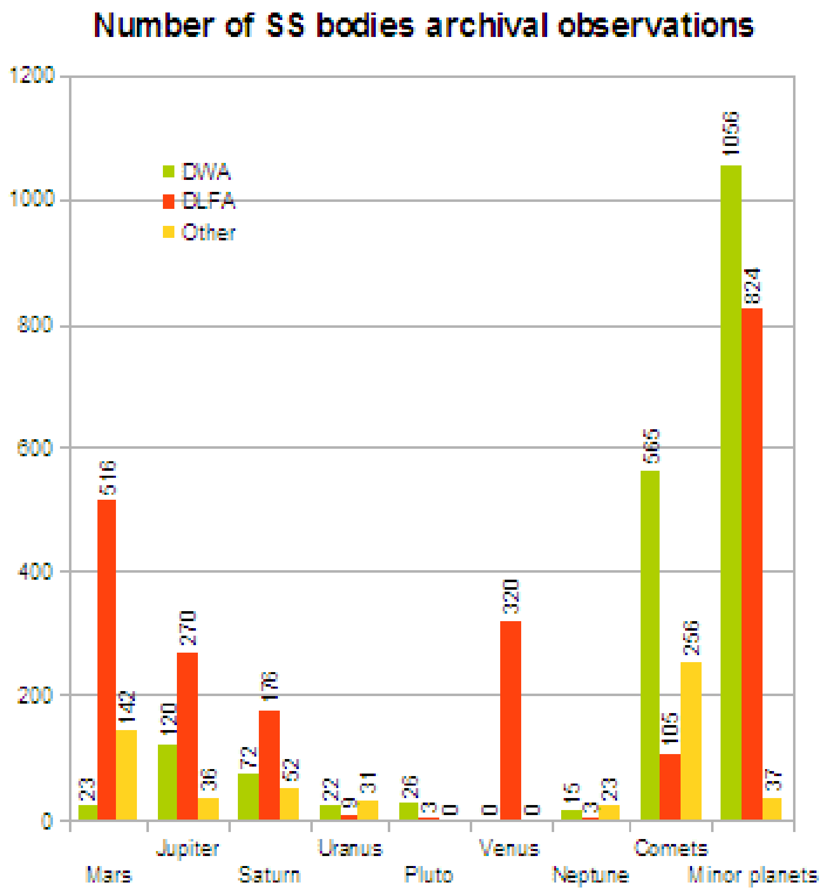
Review of archives

MAO NASU glass archive contains about 1800 photographic plates with the planets and their satellites (including near 80 images of Uranus, Pluto and Neptune), 1700 plates with minor planets and near 900 plates with comets, obtained during 1949-1990 using 11 telescopes of different focus, mostly with the Double Wide-angle Astrograph (F/D=2000/400) and the Double Long-focus Astrograph (F/D=5500/400) of MAO NASU. Observational sites are Kiev (Ukraine), Lviv (Ukraine), Biurakan

(Armenia), Abastumani (Georgia), Mt. Maidanak (Uzbekistan), Quito (Equador).



Database with metadata of plates is allocated on the computational resources of MAO (http://gua.db.ukr-vo.org) [*Vavilova et al. 2011*]. The database accumulates archives of four Ukrainian observatories, involving into the UkrVo national project. Together with the archive managing system the database presents the prototype of JDA - Joint Digital Archive - the core of the UkrVO. The distributions of observations (MAO archives only) in time and for objects and telescopes are given on two bar charts.

Scanning

Since 2008, the process of MAO NASU archive plates digitization and inclusion of plate preview images into GPA database has been under way, using two models of flatbed scanners: Microtek ScanMaker 9800XL TMA and Epson Expression 10000XL. Both digitizers were tested for intrinsic errors and possible accuracy. Table 1 presents the comparative positional and photometric accuracy data for selected negatives with star standard fields for two instruments. Results for DWA plates were more than once discussed

[*Golovnya&Andruk& Yatsenko 2010, Andruk&Pakulaik 2007, Andruk et al.2005*] so as the next large set of plates are of DLFA it is necessary to find out the same data for this telescope in relation to SS bodies. Three plates obtained according the rules established for the Solar System Bodies observational program have been selected for further tests. The plates contain the images of Uranus satellites Titania and Oberon.

Table 1. Positional and photometric accuracy obtained for plates with star standards for two instruments and Microtek scanner

telescope	**color**	**exposition**	**scale,** *s /mm*	**field**	σ_{ra} *mas*	σ_{dec}, *mas*	σ_m
DWA	B	18 min	103	$8^o x 8^o$	170	180	0.20
DLFA	B_{ph}	20 min	38	$2^o x 2^o$	60	80	0.13

Plates were scanned with Microtek model at 16-bits grey dynamic range, with a resolution of 1200-1600 dpi, and saved in TIFF format. Linear dimensions of images are up to 8 thousand pixels (for plates 24x24 cm). The astrometric and photometric calibration procedures have been done in the LINUX-MIDAS-ROMAFOT environment and Tycho-2 as reference with the image processing procedure specially developed for digitized images of huge linear dimensions on the basis of the image inherent traits [*Andruk& Butenko&Yatsenko 2010,Andruk &Vid'machenko& Ivashchenko 2005*].

Results for Microtek

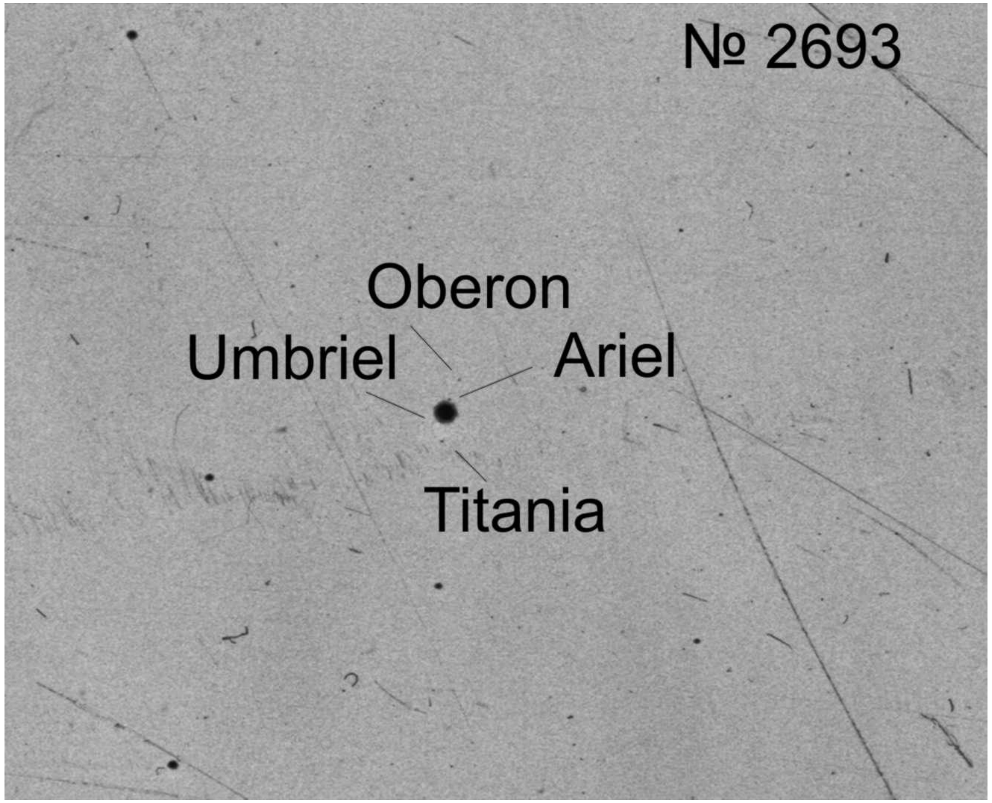


Fig.1. Archival plate with satellites' images

The results are given in Table 2. Fig.2 present the raw non-corrected for scanner mechanics differences between calculated and catalogue coordinates for the Tycho stars vs pixel coordinates and magnitudes. Fig.3 gives the same dependences for star magnitudes supplemented with dependences on color. Fig.4 demonstrates the photometric curves, build from Tycho photometric data comparative to photoelectric standard stars.

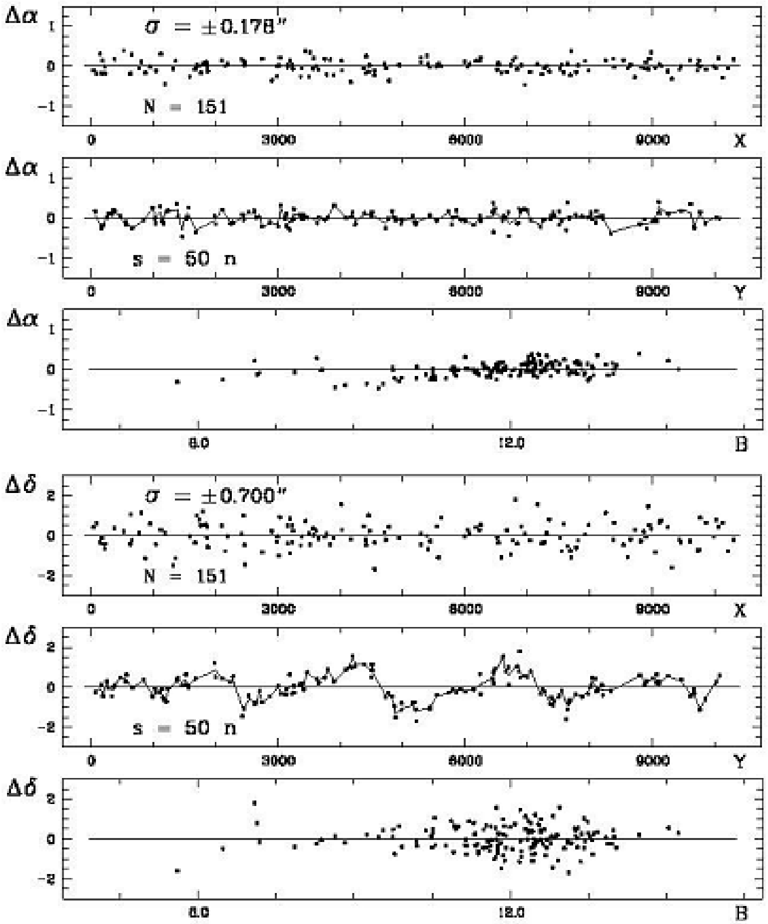


Fig.2. Non-corrected differences between calculated and catalogue coordinates for the Tycho stars vs pixel coordinates and magnitudes.

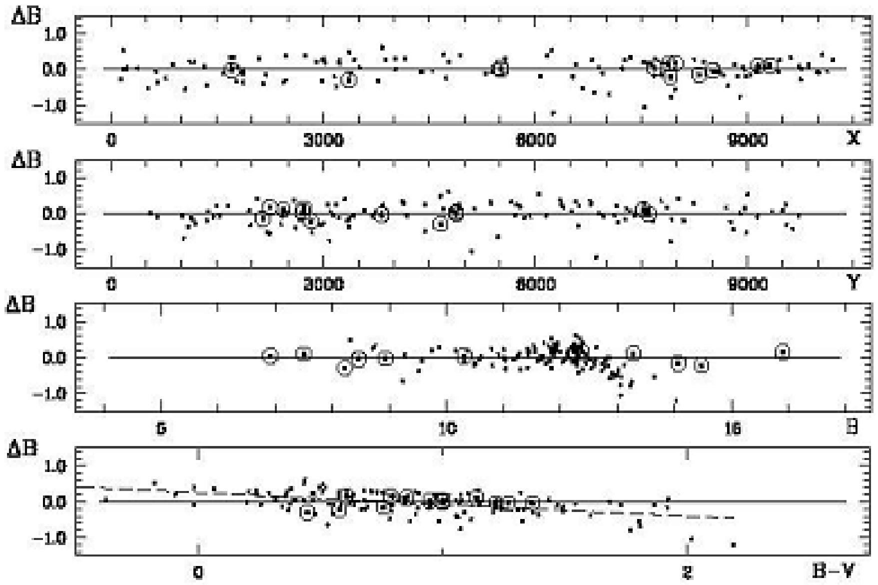
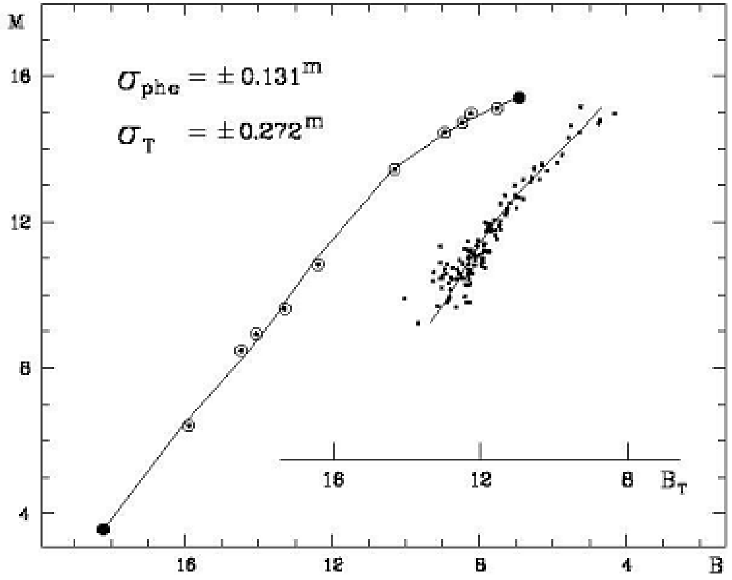


Fig.3. Non-corrected differences between calculated and catalogue magnitude for the Tycho stars vs pixel coordinates, magnitudes and color

Fig.4. Photometric curves, restored over Tycho photometric data (dots), and photoelectric standard stars (circles).



Description of Table 2 columns:
1 - original number of plate;
2 - number of reference stars;
3,4 - positional accuracy of reference stars , mas
5 - number of photoelectric standard stars
6 - photometric accuracy (Johnson B)
7 - number of Tycho stars for curve restoration
8 - photometric accuracy (Tycho photometric system)
9 - numbers of satellites (3 - Titania, 4 -Oberon)
10, 11 - (O-C) values for satellites, mas

Table.2. Results of processing 3 plates digitized with Microtek scanner

№	N_T	σ_α	σ_δ	N_p	σ_B	N_T	σ_B	n_s	Δ_α	Δ_δ
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
356	149	39	87	10	0.13^m	120	0.27^m	3 4	-190 +20	+90 -80
407	136	53	69	8	0.07	107	0.27	3 4	+600 +470	-600 -100
2693	136	73	76	9	0.24	101	0.29	3 4	+60 +360	+770 +740

The results show that digitized plates of DLFA can provide the positional accuracy of 40-90 mas and photometric accuracy of $0.13^{m.}$

Results for Epson Expression

In order to display the aptitude of Epson Expression model for positional detections of SS bodies on digital plates the DLFA plate was selected. The plate obtained in 1979, contain Pluto image and was digitized and processed by the same rules as previous ones (Fig.5).

The curves of discrepancies in coordinates vs pixel coordinates and Tycho star magnitudes are given on Fig.6 (raw, non-corrected) and Fig.7 (after corrections for scanner mechanics errors and telescope optics aberrations). Photometric dependence was built from Tycho photometric data only because there is no any photoelectric photometry standards in desired area and it is almost totally identical the Fig.4. The final accuracy estimations for different magnitude intervals are shown in Table 3. Table 4 presents the coordinates of all three objects, mentioned in the presentation , their (O-C) and Table 5 gives the accuracy, obtained earlier from processing of coordinates measurements with iris diaphragm for comparison.

First results of Pluto plates processing give the rms errors of 10 and 20 mas for RA, DEC respectively, 40 to 60 mas in the TYCHO system and (O-C) in comparison to JPL PLU021.DE405 are of 190(RA) and 270(DEC) mas. It follows from Table 5, that Epson Expression model of scanner gives a little better results in positional accuracy than Microtek one. And from the same table it is obvious that results, derived from digitized plates exceed ones had been obtained earlier with measuring appliances. The last fact opens the reassuring outlook for re-processing the MAO NASU archive data on the ground of digitized images of plates with the SS bodies.

Table 3. Rms errors by intervals of star magnitudes

#	B_{Tycho}	σ_{ra} mas	σ_{dec} mas	N of stars
1	8.66	38	43	2
2	9.51	56	69	6
3	10.48	49	60	15
4	11.52	39	72	36
5	12.5	53	89	35
6	13.46	38	46	13
7	14.24	15	11	2
aver.	11.81	45	71	

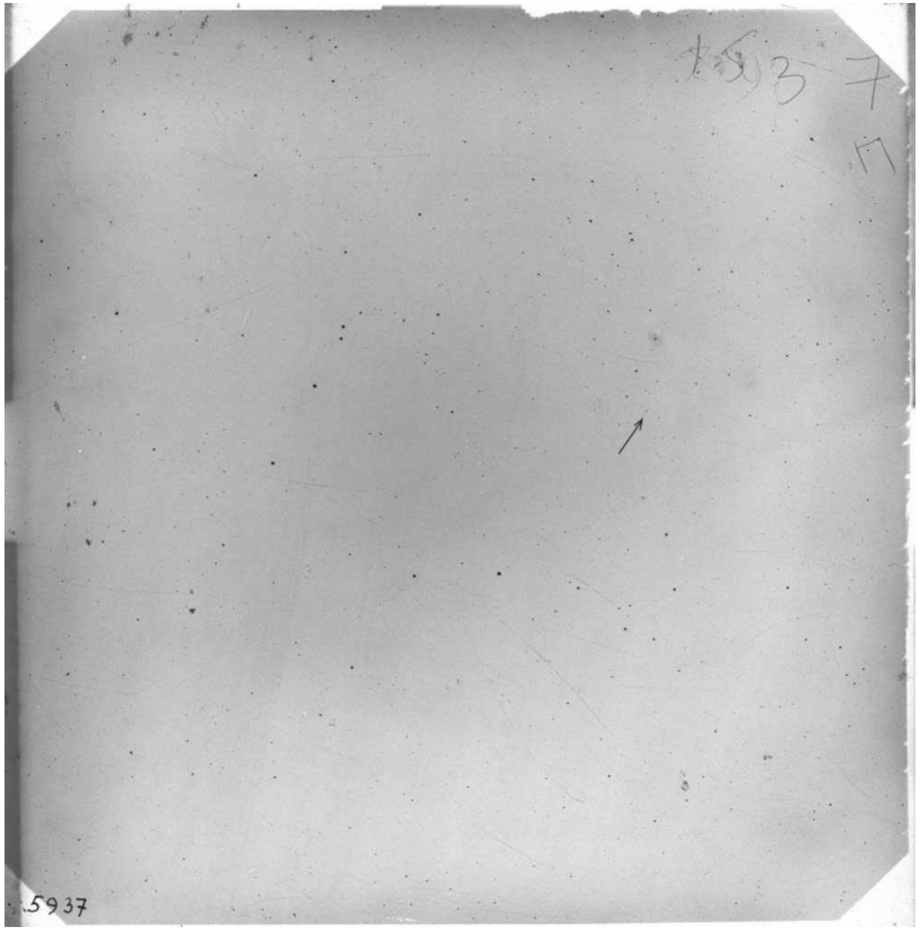


Fig.5. Archive plate GUA040A005937 (1979) with Pluto (arrow)

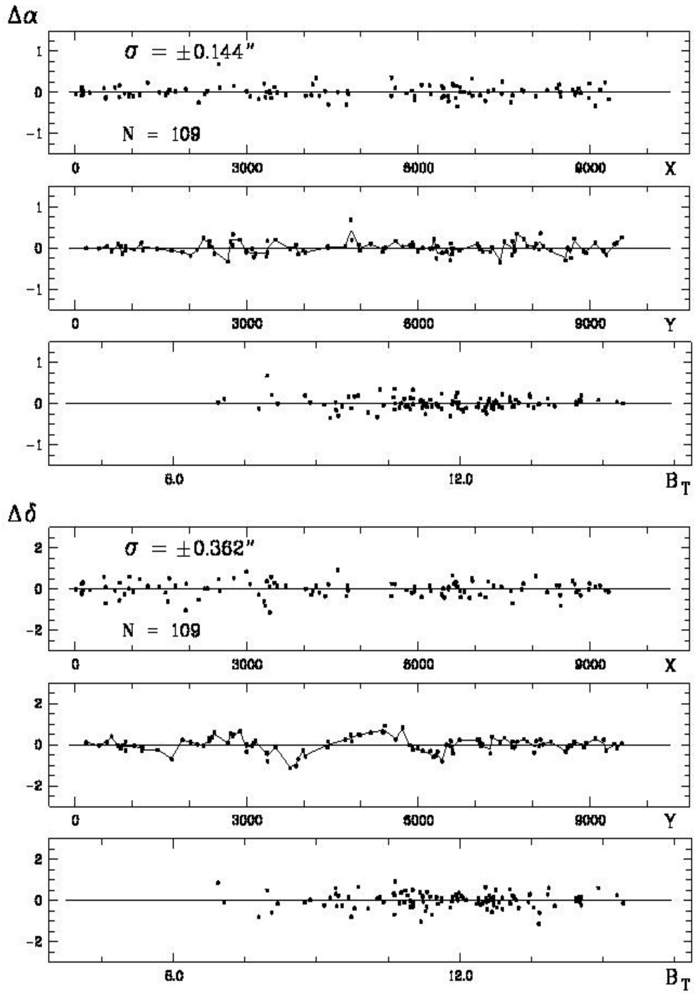


Fig.6. Non-corrected differences between obtained and catalogue coordinates of Tycho stars in dependence on pixel coordinates and star magnitudes

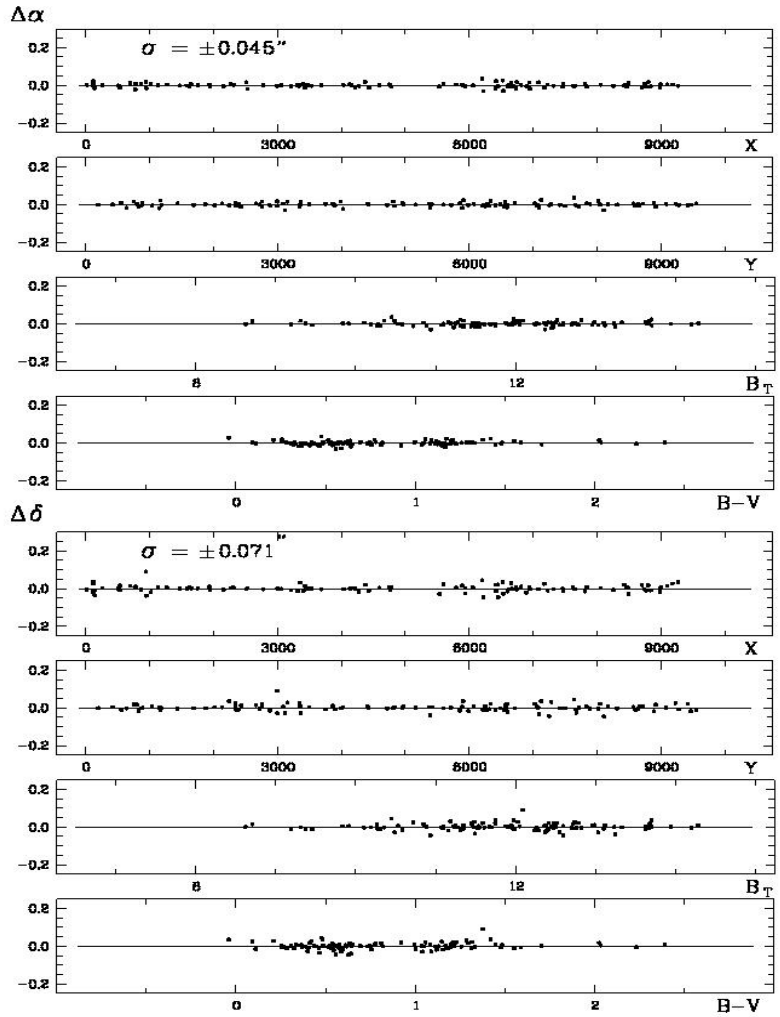


Fig.7. Differences corrected for scanner mechanics errors and optics aberrations in dependence on pixel coordinates and star magnitudes

Table 4. Observed geocentric coordinates and comparison with ephemeris (Horizons On-line Ephemeris System, JPL, sources: URA083.DE405, PLU021.DE405)

U3.Titania (mV=13.5) mV — approximate apparent visual magnitude arcsec

PL	Date, UT	σ α	σδ	N (TYCHO)	RA, ICRF/J2000.0	DEC, ICRF/J2000.0	(O-C)α	(O-C)δ
356	1963 2 24.959422	.039	.087	149	10 23 28.568	+10 54 16.14	-.03	.04
2693	1963 4 18.842792	.073	.076	136	10 16 32.965	+11 32 36.35	.22	.72
407	1963 4 25.914368	.053	.069	136	10 16 08.051	+11 34 50.40	.77	-.64

U4.Oberon (mV=13.7) arcsec

PL	Date, UT	σ α	σδ	N (TYCHO)	RA, ICRF/J2000.0	DEC, ICRF/J2000.0	(O-C)α	(O-C)δ
356	1963 2 24.959422	.039	.087	149	10 23 30.031	+10 55 33.12	.22	-.15
2693	1963 4 18.842792	.073	.076	136	10 16 34.336	+11 33 43.25	.55	.66
407	1963 4 25.914368	.053	.069	136	10 16 07.863	+11 34 31.00	.62	-.14

Pluto (mV=13.8) arcsec

PL	Date, UT	σ α	σδ	N (TYCHO)	RA, ICRF/J2000.0	DEC, ICRF/J2000.0	(O-C)α	(O-C)δ
5937	1979 2 21.067770	.045	.071	109	13 37 33.608	+08 40 57.86	-.19	-.27

Table 5. Data on available accuracy of digitized images in comparison to the accuracy, obtained from measurements with iris diaphragm appliances.

	Microtek, *Epson Expression				Iris Diaphragm appliances			
PL	σ_{ra} mas	σ_{dec} mas	N of stars		σ_{ra} mas	σ_{dec} mas	N of stars	
356	39	87	149	TYCHO	110	120	34	ACT
2693	73	76	136	TYCHO	90	120	15	ACT
407	53	69	136	TYCHO	120	110	27	ACT
5937*	45	71	109	TYCHO	160	200	19	ACT

Prospects

Having regard to the above said precision considerations we can state the task of re-processing the archival data for the plates with SS bodies on the grounds of digitized images. The most interesting plates are plates with satellites of external planets, obtained on earlier epochs in comparison with numerous contemporary CCD observations.

As the MAO NASU archive envelopes archival data of other observatories, such as astronomical observatories of Lviv and Kiev universities (near 30 000 plates from the first half of the XX century), it is possible to involve their resources into the process in the framework of UkrVO collaboration agreement as far as the digitization of those archives has just commenced [*Pakuliak et.al.2012*].

Surely this task should embrace only plates of the best quality to preserve the accuracy deterioration. Some problems arise for plates with satellites fainter or more close to planet in relation to their identification or separation from the planet halo on the stage of construction the proper processing algorithm in the MIDAS-ROMAFOT software. And the problem of precise photometry exists so far as photometric standards are absent in desired areas.

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