First results of MAO NASU SS bodies photographic archive digitizing

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Review of archives

MAO NASU glass archive encloses about 1800 photographic plates with planets and their satellites (including near 80 images of Uranus, Pluto and Neptune), about 1700 plates with minor planets and about 900 plates with comets. Plates were made during 1949-1999 using 11 telescopes of different focus, mostly 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). Tables 1 and 2 contain data about the most significant numbers of plates sub-divided by years and objects.

The database with metadata of plates (DB GPA) is available on the computer cluster of MAO (http://gua.db.ukr-vo.org) via open access. The database accumulates archives of four Ukrainian observatories, involving the UkrVO national project. Together with the archive managing system, the database serves as a test area for JDA - Joint Digital Archive - the core of the UkrVO [*2*].

Table 1. The distribution of SS bodies observations in time (most significant numbers)

planets	**year**	**1961**	**1963**	**1967**	**1971**	**1972**	**1975**	**1977**	**1980**	**1982**	**1986**	**1988**	**other**
	num	142	190	239	235	245	208	148	304	218	175	186	1924
minor planets	**year**	**1964**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1986**	**other**
	num	123	162	244	207	196	293	168	188	227	144	190	2487
comets	**year**	**1957**	**1967**	**1969**	**1974**	**1983**	**1984**						**other**
	num	107	152	84	98	216	158						1073

Table 2. The distribution of SS bodies observations vs instrument

instrum (scale,s/mm)	Mars	Jupiter +satel	Saturn +satel	Uranus +satel	Pluto	Venus	Neptune	Comets	Minor planets
DWA (103)	23	120	72	22	26	0	15	565	1056
DLFA(38)	516	270	176	9	3	320	3	105	824
Other	142	36	52	31	0	0	23	256	37

Scanning:

Since 2008, the process of MAO NASU archive plates digitizing and inclusion of plate preview images into DB GPA 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 3 presents the comparative positional and photometric accuracy estimations for selected negatives with star standard fields. Results for DWA plates were more than once discussed [*3,5,6*] so as the next large set of plates are those of DLFA it is necessary to find out the same data for this telescope as regarding to SS bodies. Three plates with images of Uranus satellites Titania and Oberon obtained according the rules established for the SS bodies observational program have been selected for further tests.

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 with 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 process [*3,7*].

Table 3. Positional and photometric accuracy obtained for plates with star standards for two telescopes and Microtek scanner

telescope	color	exposition	scale, s/*mm*	field	σ_{ra} *mas*	σ_{dec}, *mas*	σ_m
DWA	B	18 min	103	8^ox8^o	170	180	0.20
DLFA	B_{ph}	20 min	38	2^ox2^o	60	80	0.13

Results for Microtek

The results are given in Table 4. Fig.1 present the raw (non-corrected for scanner mechanics errors) differences between calculated and catalogue coordinates for Tycho stars vs pixel coordinates and magnitudes. Fig.2 gives the same dependences for star magnitudes complemented with dependences on color and the photometric curves, built from Tycho photometric data (dots) comparative to photoelectric standard stars (circles) .

Table.4. Results of 3 Microtek digitized images processing

№	N_T	σ_α	σ_δ	N_p	$\sigma_{B,m}$	N_T	$\sigma_{B,m}$	**Description of Table 2 columns:**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
356	149	39	87	10	0.13	120	0.27	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)
407	136	53	69	8	0.07	107	0.27	
2693	136	73	76	9	0.24	101	0.29	

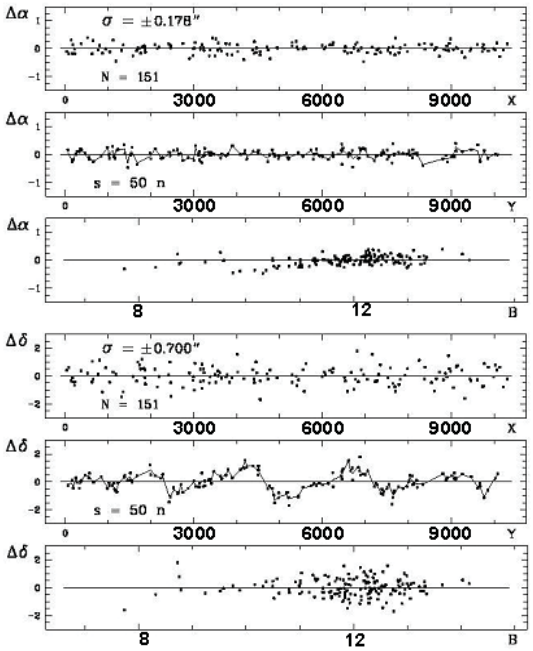

Fig.1. Non-corrected differences between calculated and catalogue coordinates for Tycho stars vs pixel coordinates and magnitudes.

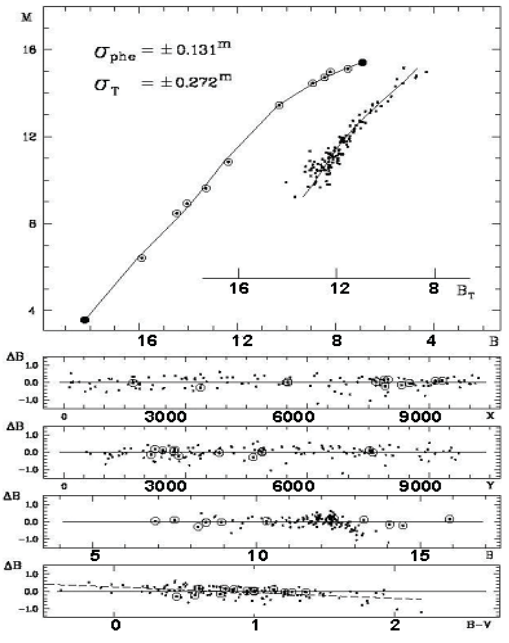

Fig.2. Non-corrected differences between calculated and catalogue magnitude for the Tycho stars vs pixel coordinates, magnitudes and color and photometric curves

The results show that digitized plates of DLFA can provide the positional accuracy of 40-90 mas and photometric accuracy of $0.15^{m.}$

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 plates was selected. The plates obtained in 1979, contain Pluto image and were digitized and processed by the same rules as previous ones.

The curves of discrepancies in coordinates vs pixel coordinates and Tycho star magnitudes are given on Fig.3 (raw, non-corrected) and Fig.4 (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 photometric standards in the desired area and it is almost the same curve than on Fig.2. The final accuracy estimations for different magnitude intervals are shown in Table 5. Table 6 presents the coordinates of all three above mentioned objects and their (O-C). Pluto data are complemented with the results of two DWA plates processing. Table 7 gives the accuracy, obtained earlier from processing of coordinate measurements with iris diaphragm for comparison.

Table 5. Rms errors by intervals of star magnitudes

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

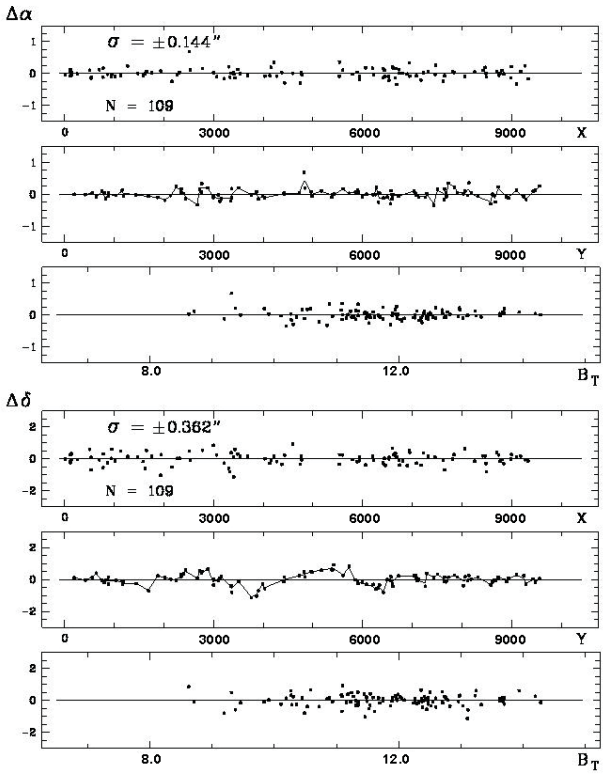

Fig.3. Non-corrected differences between obtained and catalogue coordinates of Tycho stars with respect to pixel coordinates and star magnitudes

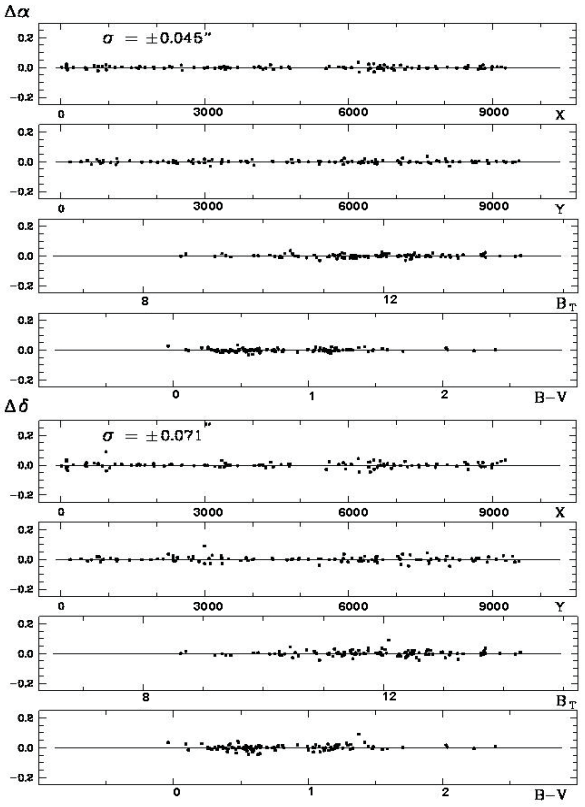

Fig.4. Differences corrected for scanner mechanics errors and optics aberrations with respect to pixel coordinates and star magnitudes

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 7, 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 basis of digitized images of plates with SS bodies.

Table 6. Observed geocentric coordinates and their 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	σ_δ	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	σ_δ	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 (instr)	Date, UT	σ_α	σ_δ	N (TYCHO)	RA, ICRF/J2000.0	DEC, ICRF/J2000.0	(O-C)α	(O-C)δ
5937 DLFA	1979 2 21.067770	.045	.071	109	13 37 33.608	+08 40 57.86	-.19	-.27
1717 DWA	1980 4 15.969857	.29	.28	38	13 42 20.460	+08 25 06.76	-.06	.14
1727 DWA	1980 4 17.904472	.21	.23	36	13 42 08.693	+08 26 09.57	-.11	.01

Table 7. 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 basis 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 includes 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 digitizing of those archives has just started [*1*].

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 closer to planet in relation to their identification or separation from the planet halo on the stage of proper processing algorithm construction in the MIDAS-ROMAFOT software. And the problem of precise photometry exists so far as photometric standards are mostly absent in desired areas.

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