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# PHOTOGRAPHIC OBSERVATIONS OF SOLAR SYSTEM BODIES AT THE MAIN ASTRONOMICAL OBSERVATORY OF NAS OF UKRAINE: FINAL RESULTS

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**ABSTRACT.** Astrometric photographic observations of Solar system bodies in the frame of different programs were made at MAO NAN of Ukraine during 1950-2005. 9245 plates with the images of planets and their natural satellite, Moon, minor planets, comets and artificial satellites were obtained and processed in the late 20th century. At the beginning of the 21st century, the UkrVO Joint Digital Archive (JDA) was created, which is accessible at the MAO NAS resources (<http://gua.db.ukr-vo.org/archivespecial.php>).

To digitize the plate archive for the JDA database, flat-bed scanners were used and the software was specially developed on the basis of the LINUX/MIDAS/ROMAFOT software for the processing of wide-field images, as well as searching for the images of minor planets and comets on the Northern sky survey program plates. Up to the present time, the photographic plates with images of outer planets and their satellites have been re-processed.

The final result of the long-lasting program of the photographic positional observations of Solar system bodies are summarized and presented in this publication.

**Keywords:** Solar system bodies, Astrometric photographic observations, UkrVO Joint Digital Archive.

## 1. Introduction

The article summarizes the results of re-processing of the old photographic observations of the Solar system bodies (SSB) at MAO NAS of Ukraine. The purpose of the observations was to obtain precise coordinates suitable for refining the SSB orbits and constructing new theories of motion, orientation of fundamental catalogs, studying the structure and evolution of the Solar system. The results, obtained by the team of the astrometry department, were the series of observations of Venus, Uranus, Neptune, Pluto, Mars, Jupiter, Saturn, natural satellites, minor planets, comets and Earth artificial satellites, which were later used for astrometric studies. The results of processing of the astrometric observations were published in different forms and placed in different sources (Onegina & Sereda, 1971; Gavrilov & Kislyuk, 1971; Duma & Kizyun., 1972; Sereda &

Izhakevich, 1978; Gavrilov et al., 1980; Kislyuk et al., 1985, 1990, 1995; Duma et al., 2000; Kizyun, 2004). A part of the observations were published in editions, which are difficult to access now, such as “Manuscripts of VINYTY”. Some observations still remain unpublished. Analysis of the data indicates the expediency of using of old photographic observations (Kiseleva 2007; Emelianov et al., 1999, 2006; Sergeeva et al., 2005). The modern approach to the processing of early photographic observations, which were collected in the UkrVO JDA, with new technologies is an effective tool for the reidentification of the SSB and correction of their orbits.

## 2. Telescopes and astroplates’ quantitative characteristics

The observation of the Solar system bodies was carried out using 11 instruments. The technique and methods of observations of the SSB were various. Table 1 shows the characteristics of the used telescopes: abbreviation for the telescopes and their original name in the JDA, scale of the telescope image ("/mm), location of telescopes and periods of the observations of the SSB on the corresponding telescopes. A list of telescopes, observational archives of the JDA prototype, list of emulsions, object types, observers list can be viewed at <http://gua.db.ukr-vo.org/guides.php> (Pakuliak, 2005, 2014; Pakuliak, Vavilova, 2014; Sergeeva, 2004, 2007, 2010).

The SSB observations were conducted with three “home” telescopes (DLA, DWA, DSA) of the Main Astronomical Observatory and seven expeditionary telescopes at Majdanak and Tashkent Observatory, Quito Astronomical Observatory and Comet Station (Ecuador), Astrophysical Observatories Abastumani and Byurakan (so-called “others” telescopes – Z-600, DAZ, CA, 2CAA, SCHC, 53/Sch and BYU (Kulyk et al., 2013). Figure 1 presents the distribution of the number of plates with the SSB according to the telescopes. As we can see 8802 plates were observed with “home” telescopes for 55 years. During eight years of the expeditions to other observatories 443 plates were received on seven “others” telescopes (see Figure 1, Table 2 and Table 4).

Table 1: List of the telescopes and periods of the observations of Solar System Bodies on the corresponding telescopes

Abbr.	Orig. name of the Instrument	"/mm	Observatory	Periods
DLA	Double Long-Focus Astrograph	38	Main Astron. Obs., Kyiv, Ukraine	1950-1986
DWA	Double Wide-Angle Astrograph	103	Main Astron. Obs., Kyiv, Ukraine	1976-2005
DSA	Double Short Focus Astrograph	295	Main Astron. Obs., Kyiv, Ukraine	1950-1977
Z-600	Zeiss-600	28	Majdanak Obs., Mt. Majdanak, Uzbekistan	1986-1991
DAZ	Wide Angle Astrograph (Kitab)	69.8	Tashkent Ast. Obs. Kitab Station Uzbekistan	1986, 1988
CA	Ast. Photogr. Device AFU-75	281	Ast. Obs. end Comet Station, Quito, Ecuador	1986
2CAA	Two-camera astrograph	206	Astroph. Obs. Abastumani, Kanobili, Georgia	1990
SCHC	Schmidt camera	330	Astroph. Obs. Abastumani, Kanobili, Georgia	1987-1990
53/Sch.	53 cm Schmidt Telescope	113	Byurakan Astroph. Obs., Byurakan, Armenia	1983, 1985
BYU	1 m Schmidt Telescope	97	Byurakan Astroph. Obs., Byurakan, Armenia	1983

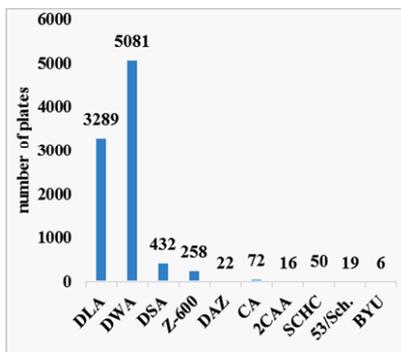


Figure 1: Distribution of the number of plates with the SSB according to the telescopes.

### 3. Observational programs and observers

Regular observations of the SSB were conducted from 1950 to 2005 under different scientific programs including “Orbit”, “Faint minor planets”, “Selected minor planets”, “Planets and their natural satellites”; “Mars, Phobos and Deimos – 1988”; “Mars – 1990-1993”; “Mars – 1994-1996”; “Comets”, “SOPROG”, “Moon”, “Earth artificial satellites”. Astrometric photographic observations of SSB began in 1950 at the astrographs DLA and DSA. First observers, I.G.Kolchinsky, T.A.Azarnova, A.A.Gorynia, R.I.Chupryna, started from the observations of the faint and selected minor planets and comets.

In Figure 2 the image of comet 2P/ Encke is presented. The comet had brightness of 17.7 magnitude and was observed by I.G.Kolchinsky.

The MAO NAS of Ukraine was the center for collecting information on the positions of comet 1P/Halley from around the world (Yatskiv et al., 1986; Major et al., 1987). Comet Halley was observed in the frame of the international program “International Halley Watch” and the Soviet program “SOPROG”.

The plates of the Moon were obtained during the period between 1950 and 1980 with DLA to determinate its accurate position and the absolute orientation of the selenodetic reference frame.

The major planets and their natural satellites were observed since 1951. In the Figure 3 the image of the Venus on the plate 181 DLA is presented.

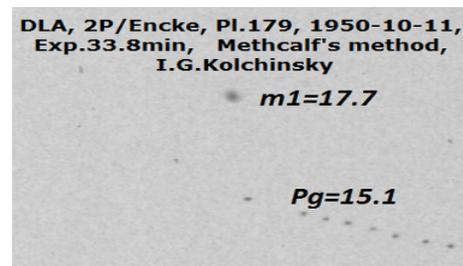


Figure 2: Comet Encke on the plate 179 DLA

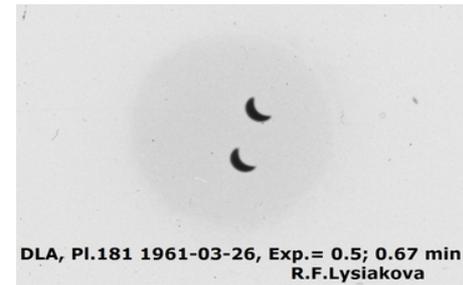


Figure 3: Venus on the plate 181 DLA

Table 2: Distribution of the number of plates according to the observation programs and the telescopes

Object Type / $\Sigma$ No. of plates	DLA	DWA	DSA	Other
Planets and their natural satellite <b>2065</b>	1508	263	17	277
Moon <b>657</b>	649	-	8	-
Minor planets <b>2037</b>	935	1063	39	-
Comets <b>1422</b>	197	693	366	166
Artific. Satellite <b>3064</b>	-	3062	2	-

The distribution of the number of plates with the SSB according to the telescopes and the observation programs is given in the Table 2 and Figure 4.

Table 3 gives the distribution of the number of plates obtained by the different observers in accordance with the observation period at the “home” telescopes. Additionally 47 plates were received by the following observers: 9 – L.L.Novoborskaya, 8 – A.N.Kur'yanova, 8 – D'jakonova, 6 – T.Ye.Majzlina, 6 – Ya.T.Kapko, 5 – L.K.Pakuliak, 5 – A.S.Duma; 31 plates were received one by one and 14 – by unknown observers.

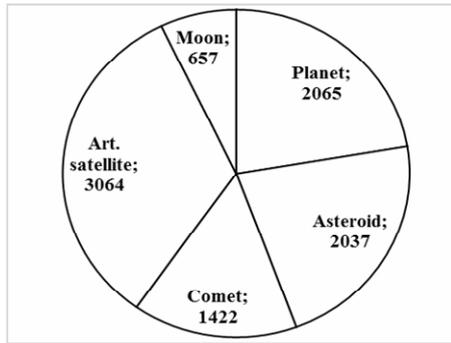


Figure 4: Distribution of the number of plates according to the observation programs.

Table 3: Observers at DLA, DWA, DSA

Observers, instruments (1-DLA, 2-DWA, 3-DSA)	Plates.	Observation period
L.M.Kizyun (Miz') (1+2)	1939	1960-2005
E.M.Sereda (1+2)	1180	1959-1987
I.V.Gavrylov (1)	816	1954-1966
Yu.I.Safronov (2)	646	1978-1991
G.V.Moroz (1+2)	595	1967-1983
A.B.Onegina (1+2)	470	1953-1977
S.P.Major (1+2)	410	1959-1986
Yu.M.Ivashchenko (2)	367	1983-1992
O.M.Yizhakevych (2)	347	1978-1988
Yu.V.Sizonenko (2)	287	1978-1997
R.F.Lysiakova (1)	196	1959-1965
I.M.Demenko (1)	114	1960-1971
I.V.Kulyk (Ledovskaya) (1+2)	114	1982-1988
I.G.Kolchinsky (1)	113	1950-1963
R.I.Chupryna (1+3)	112	1951-1956
G.A.Garazdo-Lesnykh (3)	103	1964-1970
M.R.Bocharova (2)	96	1985-1990
V.K.Rosenbush (Fartushnaya) (2+3)	95	1976-1979
V.I.Stupin (3)	92	1964-1968
V.V.Golovnya (2)	92	1985-1996
S.V.Shatokhina (1+2)	76	1984-1989
Yu.K.Philippov (1)	63	1971-1974
M.L.Divinskij (1)	44	1969-1972
A.V.Bolbochanu (1)	37	1960,1975
I.G.Zhdanova (3)	36	1954
A.E.Rosenbush (3)	33	1974
G.A.Ivanov (1+2)	25	1974-1983
A.A.Gorynia (1)	22	1950-1953
E.A.Herz (1+2)	21	1973-1981
T.A.Azarnova (3)	18	1950,1954
N.V.Kharchenko (1)	17	1982
O.V.Nazarenko (2)	17	1987
G.I.Balan (3)	16	1970
S.V.Kaltygina (2)	16	1984-1986
F.I.Lukatskaya (3)	15	1956-1963
A.F.Pugach (3)	15	1963-1964
V.S.Kysljuk (1)	15	1963-1970
D.P.Duma (Kotovych) (2)	14	1978-1983
V.P.Taraschuk (3)	13	1964-1966
A.I.Yatsenko (1+2)	13	1974-1983

Table 4: Observers at the “others” telescopes.

Observers	Plates.	Obs.period
Yu.V.Sizonenko	100	1983-1990
S.P.Major	98	1986-1991
I.V.Kulyk (Ledovskaya)	89	1985-1990
S.V.Shatokhina	46	1987-1991
G.N.Khimeridze	46	1990
O.M.Yizhakevych	23	1988-1991
E.M.Sereda	32	1986,1988
K.O.Major	9	1986

Table 4 gives the distribution of the number of plates obtained by individual observers in accordance with the observation periods at the Z-600, DAZ, CA, 2CAA, SCHC, 53/Sch and BYU telescopes.

Basically photographic observations of the SSB at MAO NAS of Ukraine have been finished in 1996. However, the date of complete cessation of the optical observations is 2005, when L. M. Kizyun (record holder in observations) completed observations of artificial satellites.

#### 4. Catalogs of positions of the Solar system bodies

The results of elaborating of old observations, their analysis and methods of processing are presented in numerous publications (Kolchinskii & Onegina, 1977; Yizhakevych et al, 2001, Golovnya, 2000, 2001). However, the accuracy of the SSB positions based on old stellar catalogs is currently insufficient to refine modern motion theories and to reveal subtle effects in satellite motions. Creating the LINUX/MIDAS/ROMAFOT software and archive of digitized books – UkrVO JDA at MAO NASU made it possible to conduct a new astrometric treatment of some SSBs (Andruk et al, 2005, 2012, Protsyuk et al, 2014a, 2014b; Golovnya, 2010). On the basis of the digitization and reduction in a system of ICRS with a reference catalogue of TYCHO-2, new catalogues of the SSB positions have been created (Golovnya, 2000, Shatokhina et al., 2016, 2017; Vavilova, 2016; Vavilova et al, 2014, 2017; Kazantseva et al, 2015; Protsyuk et al, 2015, 2016, 2017; Yizhakevych et al, 2014, 2015, 2017).

Table 5: The results of processing of the SSB observations

Name of SSB	Plates	Positions	Observation period
Venus	378	284	1959-1985
Moon	657	≈345	1950-1980
Mars+2sat (1318+831)	859	2149	1963--1988
J6, J7, J8	32	33	1987-1990
8 sat. of Saturn	209	1385	1961-1990
Uranus + 4 sat. (61+56)	33	117	1963-1990
Neptune+ 1 sat. (43+7)	29	50	1963-1990
Pluto	25	25	1961-1982
Minor planets	2037	≈1643	1950-1996
Comets	1422	≈447	1950-1996
Artificial satellite	3064	6024	1977-1981

Table 5 shows the distribution of the number of plates and number of positions received for the corresponding objects of the Solar system in the specified periods. Some positions of Minor planets are published in the “Manuscripts of VINITY”, so the number of the positions in the table is given approximately.

Except for the plates with the SSB, the JDA includes about 18 thousands of direct sky area plates, which have been taken for various astronomical projects. Those plates also contain large number of the images of minor planets and others Solar system bodies (Shatohina et al., 2017).

## 5. Conclusions

The MAO NAS of Ukraine was the initiator and a participant of the international scientific programs and projects: astrometric observations of planets and their natural satellites, selected minor planets, minor planets, comets, Moon, artificial satellites.

9245 photographic plates with the images of the SSB were obtained and stored in the UkrVO JDA. For half a century, 12502 positions of the Solar system bodies were calculated and their catalogs were created.

The collected data were processed and used by IPA, Sternberg Institute and IMCCE, Minor Planet Center for the improvement of the ephemerides of minor planets, planets and their natural satellites, comets.

The result of many years of work has become a long, homogeneous series of observations of various Solar system bodies, obtained with the greatest possible accuracy and became the basis for further astrometric research. Some observations were made during the space missions such as VEGA, FOBOS, CORONAS.

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