Archive of photographic plates in Nikolaev Observatory and some results obtained from them

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Introduction

Epoch of astrophotography in astronomy influenced greatly the development of astrometry, left behind a large number of astronomical observations. The intensity of the observations and the complexity of measurement led to large amounts of astronomical observations by the epoch of CCD implementation, which were not even measured and reduced in many observatories, so the information occasionally became outdated and lost actuality due to the imperfect reference systems used in the reductions. Contemporary possibilities of digitization of astronomical plates and fast processing of the corresponding files induced observatories to draw attention to the enormous scientific potential, preserved in the old photographic observations, and engage actively their classification, creation of databases containing information about each astronomical observation, as well as to preserve storage conditions of this invaluable research material.

Archive of photographical plates of Nikolaev Observatory

Photographic observations of Solar system bodies in Nikolaev Observatory began after installation of Zone Astrograph (D = 0.12 m, F = 2.04 m, field of view 5° x 5°) in 1961. This instrument was one of three identical telescopes, built in 1926 by Carl Zeiss Jena for Pulkovo Observatory in order to make new observations for Astronomische Gesellschaft Katalogs. Characteristics of the telescope and four-element lens objective provided good image quality and minimal distortion for almost the entire field of the plate. It allowed to get stars up to 12 magnitude in 20 minutes of the exposure time, and to put observations for stellar catalogs into the observational programs. During regular observations from 1961 till 1998, there were made more than 8.9 thousands of photographic observations in Nikolaev.

Stellar Catalogs

1. The North Pole zone from +70° to +90° of declination was observed twice. The first epoch (the catalog of S.N. Belyavsky) was obtained in Pulkovo in 1928-1930. It contains about 200 plates. The positions were published in [1]. The second epoch was photographed in Nikolaev in 1973 for determination of proper motions. It contains 250 plates.
2. Zodiacal zone within +/–10° of the ecliptic was observed with twice overlapping. The mean epoch is 1979. It contains 1196 plates.
3. Equatorial zone within +/–4° of the celestial equator was observed with four-time overlapping. The mean epoch is 1992. It contains 485 plates.
4. Stars of the list of A.A. Mikhailov were observed and measured on 104 plates. The mean epoch is 1978. The positions were published in [2].
5. The ROAS observational program. The mean epoch is 1980. There were observed 131 fields with optical counterparts of radio-sources on 217 plates.

A bit of scientific information was taken out from the photographic archive as there were reduced and submitted results to publication only for 354 plates, i.e. 18% of the total amount of plates.

Solar system bodies

All photographic observations of Solar system bodies were processed and published regularly (references to these publications can be found on the website of the observatory). From 1996 till 2000, all measurements of this part of the photographic archive (except for Venus, Jupiter, Saturn, Neptune and comets) were re-reduced in the ICRS, see Table 1. The positions of the asteroids in the ICRS were used in the further research [3-5].

Table 1. Statistics of observations of the Solar system bodies

Planets	Observational Periods	Number of Positions
Venus	1967-80	384
Mars	1961-97	445
Jupiter	1961-97	450
Saturn	1961-97	372
Uranus	1961-97	212
Neptune	1961-97	210
Satellites of Jupiter and Saturn		
Io	1962-98	304
Europa	1962-98	331
Ganymede	1962-98	340
Callisto	1962-98	339
Tethys	1961-97	105
Dione	1961-97	173
Rhea	1961-97	109
Titan	1961-97	192
Iapetus	1961-97	25
In total	6.5 thousands of plates	

Asteroids	Observational Periods	Number of Positions
(1) Ceres	1961-97	217
(2) Pallas	1961-97	264
(3) Juno	1961-96	245
(4) Vesta	1961-97	241
(5) Astraea	1983	4
(6) Hebe	1961-97	226
(7) Iris	1961-97	197
(11) Parthenope	1961-97	196
(15) Eunomia	1987-91	12
(18) Melpomene	1961-97	212
(25) Phocaea	1976-91	34
(39) Laetitia	1961-93	237
(40) Harmonia	1961-94	203
(148) Gallia	1977-78	8
(185) Eunike	1972-73	6
(389) Industria	19991	4
(433) Eros	1975	11
(532) Herculina	1975-91	68
(704) Interamnia	1974-90	65

Some results of observations of the Galilean satellites of Jupiter

Observations of satellites of Jupiter and Saturn are the most promising way not only to improve the ephemerides of natural satellites and their central bodies, but also to link the ephemerides to the dynamical reference system. The Galilean satellites of Jupiter can be thought as one of the most interesting objects, as their motions appear to have all kinds of perturbations that are typical for the problems of celestial mechanics.

Determination of astrometric positions for four bright satellites of Jupiter in Nikolaev was made for the first time in 1965. And later, for that purpose, there were used the plates with Jupiter, received in 1962-65, which have images of its bright satellites. Regular photographic observations for the purpose of astrometry of the Galilean satellites were begun in Nikolaev Observatory in 1973.

The observations were made with a diffraction grating put in front of objective or with an optical filter,

which decreased brightness of satellites in two magnitudes. There were made 3-4 three-minute expositions of the objects. These several images presented on one plate were measured and averaged to produce one position per object. The averaging was made in directly measured coordinates with a purpose to decrease the subsequent computations. The observations were made usually within one hour from culmination of Jupiter. During the period of visibility of the planet each year, consisted of 4-5 months, there were received 10-15 plates suitable for determination of coordinates of the satellites. Considerable importance was put to make uniform distribution of observational dates during the planet visibility.
Some deviations from the adopted methods of observation were made in 1997 and 1998. In 1997, during the period of mutual phenomena of Galilean satellites, the observations were made in much larger hour angles, reaching three hours. In 1998, during the period of projective approach of the satellite system with the star 117881 of Hipparcos catalog, the number of exposures on the plate was increased to 9. From 1962 till 1998, covering 27 oppositions of Jupiter, there were obtained 360 images of the Galilean satellites.
The measurements were performed using the machine "Ascorecord-2". Each measured coordinate was obtained by averaging the coordinates obtained in two positions of prism. Accidental measurement errors for the positions of the Galilean satellites were 0.08″ in right ascension and 0.07″ in declination and they were obtained from comparison of double measurements.
Current reduction of the observations was made using available reference catalogs of that period of time: Yale, SAO, AGK3, PPM, FOCAT, which did not provide homogeneous results during observation of these objects in Nikolaev in 1962-1998. So, in 1997, all the positions of the satellites of Jupiter were reduced to the system of FK5 using the reference catalog PPM, and then to the system of ICRS catalogs using stars of Hipparcos, Tycho positions and ACTRC proper motions. As a result of re-reduction of all observations of the Jupiter satellites in Nikolaev Observatory there were obtained the following number of observations for each satellite, given in column 10 of Table 2.

Table 2. Comparison of observed and calculated positions in arcsec

Galilean Satellite	(O–C)α s.e.α	σα	(O–C)δ s.e. δ	σδ	(O–C)α s.e.α	σα	(O–C)δ s.e. δ	σδ	Number of positions
1	2	3	4	5	6	7	8	9	10
I	0.028 12	0.203	–0.065 11	0.195	0.046 10	0.151	–0.097 8	0.128	304
II	0.026 10	0.191	–0.012 9	0.162	0.047 7	0.122	–0.040 7	0.118	331
III	0.047 10	0.184	–0.007 9	0.159	0.047 8	0.128	–0.028 7	0.122	340
IV	0.033 9	0.166	–0.005 8	0.141	0.039 7	0.111	–0.030 7	0.111	339
Using all satellites	0.034 10	0.183	–0.021 9	0.162	0.045 8	0.128	–0.049 7	0.120	1314

Comparison of the observed positions of the Galilean satellites with positions predicted by the theory of motion E-5 by J. Lieske and DE421 ephemerides was made using on-line software available on the website of Institut de mécanique céleste et de calcul des éphémérides – Observatoire de Paris (http://www.bdl.fr/hosted_sites/saimirror/nsso-c5he.htm). Preliminary assessment of the quality of the material is shown in Table 2. In columns 2 and 4, there are given mean values of (O–C) with their standard errors in the same units. The standard deviations of (O–C), calculated from the entire set of observations of the particular satellite, are given in columns 3 and 5. Columns 6-9 give also mean values of (O–C) and their standard deviations which were obtained by averaging (O–C) with respect to 22 oppositions, covering the years 1975-98 or two full revolutions of Jupiter.

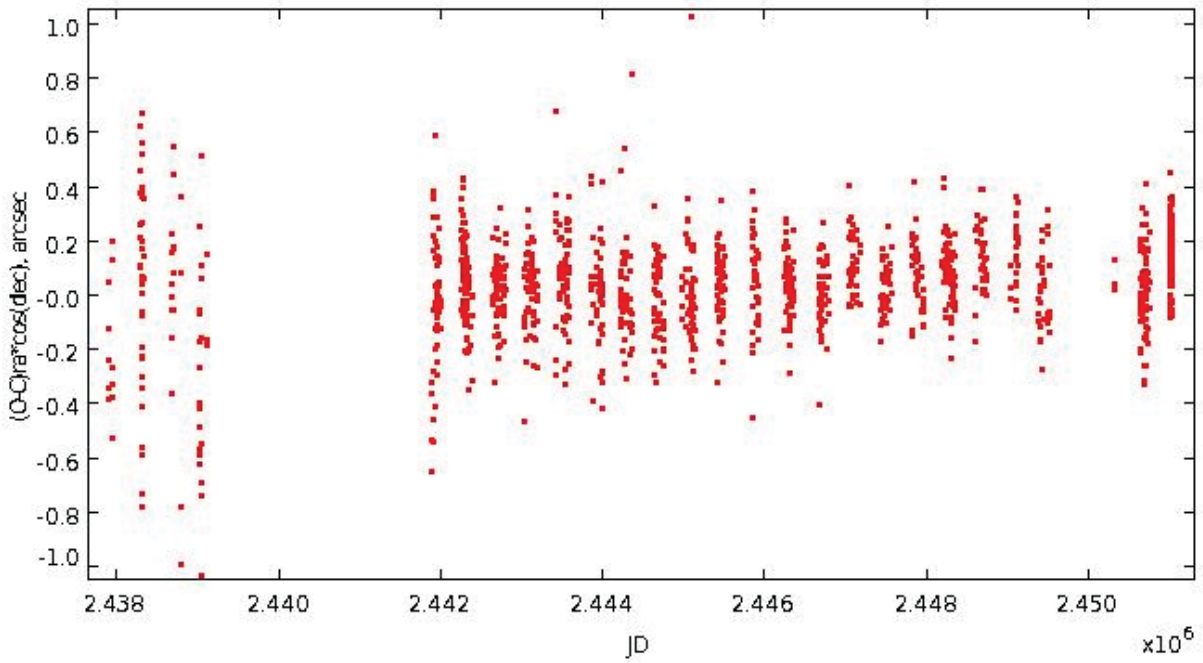

Fig. 2. Distribution of (O–C) in right ascension with respect to time

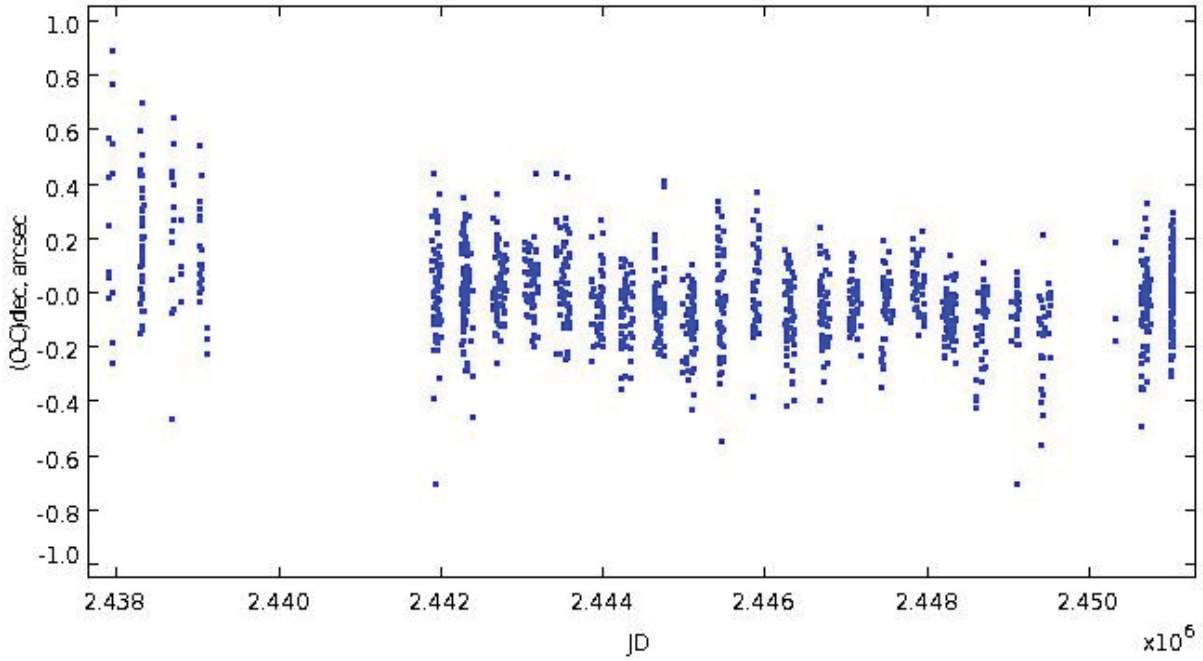

Fig. 3. Distribution of (O–C) in declination with respect to time

The Table 2 shows that the errors of a single measurement (columns 7, 9) decreased by 20-30% while averaging their values by oppositions, that probably is the result of the partial elimination of errors of our observations and theories of motion (E-5 and DE421) from (O–C). The presence of systematic errors in the observations of the Galilean satellites is evident on the graphs demonstrating dependencies of coordinates with respect to time of the observations.

In Fig. 2 and 3 one can find distribution of (O–C) for the Galilean satellites altogether with respect to Julian dates. A close look at these graphs allows clearly visible changes $(O–C)_{\alpha,\delta}$ with a period of 11.9 years equals to the sidereal period of revolution of Jupiter.

Preliminary analysis of this series of observations allows us to say that the duration of observations, the amount and accuracy of the observations of the Galilean satellites of Jupiter make them useful for improvement of the ephemerides of Jupiter and its satellites, determination of the orientation of the reference catalog system with respect to the dynamical one.

Conclusions

In the archive of photographic observations of Nikolaev Observatory, consisting of 8.9 thousands of plates, there are observations of 1961-1998 years. They represent images of the bodies of the Solar system (22% pertain to the planetary satellites, 28% to the asteroids, 23% to the planets) and star catalogs (27%). To ensure broad access to the material of observations, it is necessary to digitize it.
The appropriateness of new measurements as a result of digitization can be determined by the less level of accuracy that can be achieved. The presented results of astrometric measurements of the Galilean satellites of Jupiter show accidental errors 0.18″ in right ascension and 0.16″ in declination of a single measurement.

References

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