

CCD-observations of Galilean Satellites of Jupiter during their mutual occultations and eclipses in 2003 at Pulkovo observatory.

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The CCD-observations of mutual events (occultations and eclipses) in the system of Galilean Satellites of Jupiter have been carried out in the period of January to April 2003 at Pulkovo observatory with the help of 26-inch Refractor and CCD ST-6. The description of the parameters of CCD ST-6 and the methods and the programs of observations were presented in [1]. The observations were carried out in corresponding of the ephemerides of mutual events calculated by N.V.Emelianov. The experience of such observations have been obtained in 1997 in previous campaign of observations of mutual events [2].

20 photometric observations for 10 occultations and 10 eclipses have been produced. Photometric observations have been accompanied by astrometric observations and 19 astrometric observations of occultations and eclipses were carried out. Of 100 to 1000 CCD frames were used for each photometric observations of occultations and eclipses. The moments of time were fixed in the time scale UTC. The accuracy of registration of moments equals to 0.05^s . The frames of CCD observations followed one by another through not more than 10 sec. The time exposures for each frame was about of 0.1^s . The combination of yellow and blue filters was used for observations in effective wave long of 5500 A.

The pictures 1 - 10 show 10 light curves plotted by photometric observations of mutual eclipses and occultations. The light curves presents changing with time of sums or differences of magnitudes of satellites in occultations or eclipses.

The Gaussian model was used to approximate of light curves:

$$m(t) = \exp(-a(t - T_0)^2 - b) + c$$

The parameters of model (a , b , c , T_0) characterized of physical picture of events (drop of brightness, duration, the moment of occultation or eclipses) were determined by the least

square method. The results of reducing of photometric CCD-observations present in table 1.

Table 1. The results of CCD photometric observations of mutual events in the system of Galilean Satellites in 2003.

Data and events	T_0 h m s	σ_{T_0} s	T_1 h m s	T_2 h m s	Δmag	$\sigma_{\Delta mag}$
0106 2E1	23 32 50.879	00.657	23 25 30.815	23 40 10.942	0.676	0.022
0203 4O1	17 12 12.794	00.676	17 09 27.472	17 14 58.116	0.597	0.023
0203 2O3	23 31 08.646	01.452	23 24 43.976	23 37 33.316	0.288	0.009
0203 2E3	23 39 41.208	01.112	23 32 06.039	23 47 16.377	0.254	0.005
0218 4E3	20 48 37.401	02.155	20 41 35.689	20 55 39.113	0.567	0.028
0306 1O2	19 47 41.088	02.100	19 46 21.140	19 49 01.036	0.331	0.055
0315 3E4	22 14 43.936	00.787	22 07 05.318	22 22 22.554	0.994	0.016
0320 1O2	23 52 21.334	00.946	23 50 59.892	23 53 42.776	0.163	0.018
0326 2E1	20 40 44.675	04.810	20 39 32.469	20 41 56.880	0.215	0.048
0421 1O2	21 29 04.764	00.725	21 27 37.407	21 30 32.121	0.210	0.021

T_0 - moments of events; σ_{T_0} - mean square errors of T_0 ;
 T_1, T_2 - the moments of the beginning and the ending of events;
 Δmag - maximum drop of brightness; $\sigma_{\Delta mag}$ - mean square errors of maximum drop of brightness.

The maximum of drop were determined by formula:

$$\Delta mag = |m(T_0) - c|$$

To determine the moments T_1 and T_2 the supposition was used:

$$m(T_{1,2}) = c + \sigma_{\Delta mag}$$

The parallel astrometric observations of events have been carried out also. The astrometric observations were beginning before the events and finished after the events. The whole period of observations were continued during 1 - 1.5 hours. The moments of minimum distances, the minimum distances and relative velocities of satellites for the occultations with their errors were determined [2]. The errors of minimum distances equals to 0.01 - 0.02", the errors of moments of events equal to 0.7 - 7 sec by the astrometric observations of occultations. The minimum of distances by astrometric observations of occultations runs up to 0.05" - 1". The agree of astrometric and photometric moments of occultations is in the limits of 10 sec.

The astrometric observations of pair of Galilean satellites near the eclipses consisted in measuring of differences of coordinates on average moment of observations[3]. The accuracy of such observations is the same as for the astrometric observations of occultations.

The results of astrometric observations of occultations in the system of Galilean satellites of Jupiter were presented in tables 2.

Table 2. The results of astrometric observations of mutual occultations.

Data and Events	T ₀ h m s	N	r ₀ arcsec	X arcsec	Y arcsec	V _x arcsec/h	V _y
01 07 201	01 25 15.858 7.285	197	1.0270 0.0083	0.3419 0.0107	0.9684 0.0080	-4.9956 0.0155	1.7634 0.0115
01 16 402	00 43 58.148 2.887	300	0.4907 0.0094	-0.1546 0.0107	-0.4657 0.0092	-12.5194 0.0025	4.1570 0.0022
02 03 401	17 12 02.918 0.972	149	0.0479 0.0072	-0.0152 0.0079	-0.0454 0.0072	-27.3507 0.0230	9.1727 0.0210
02 03 203	23 30 49.057 1.238	110	0.3334 0.0023	0.1058 0.0044	0.3162 0.0020	-11.6509 0.0032	3.8977 0.0014
02 15 201	19 15 56.453 0.875	238	1.0943 0.0044	-0.3243 0.0041	-1.0451 0.0044	-16.4691 0.0109	5.1112 0.0116
03 06 102	19 47 42.557 0.835	136	0.3506 0.0115	0.1040 0.0072	0.3348 0.0118	31.7936 0.0188	-9.8765 0.0310
03 20 102	23 52 15.444 0.858	103	0.4524 0.0076	0.1333 0.0075	0.4323 0.0076	30.2036 0.0225	-9.3120 0.0228
03 25 203	20 47 57.791 1.148	157	0.7415 0.0102	-0.2022 0.0044	-0.7133 0.0105	-16.0298 0.0143	4.5449 0.0343
04 01 203	23 55 34.990 4.250	62	0.9353 0.0216	-0.2591 0.0199	-0.8987 0.0217	-16.3076 0.0210	4.7015 0.0230
04 21 102	21 29 05.551 0.785	246	0.3621 0.0048	0.1062 0.0059	0.3462 0.0047	25.5804 0.0214	-7.8438 0.0171

The comparison of moments of events obtained by photometric observations with the ephemerides are presented in table 3.

Table 3. The comparison of moments of mutual events with the ephemerides.

Data	Events	(O - C) _{T₀} s
01 06	2E1	-7.121
02 03	401	+23.794
02 03	203	+14.146
02 03	2E3	-0.792
02 18	4E3	-1.600
03 06	102	-6.912
03 15	3E4	+13.436
03 20	102	-7.166
03 26	2E1	-7.325
04 21	102	-12.236

We call attention that astrometric observations of occultations allow to determine the parameters of occultations (timing, minimum distances) also in the case when the photometric observations were not succeeded (for example the observations of 7.01, 17.01, 15.02, 25.03, 01.04-in table 2).

As well from table 3 the accuracy of moments of events equals to $\pm 12^s.0$. This value corresponds to relative positions of two satellites not more than $0''.107$. It testifies about small errors of observations and ephemerides.

The astrometric and photometric observations of mutual events in the system of Galilean satellites may be used for the improvement of the theories of motions of satellites, for the construction of the model of events and to the more accurate definition of size and form of satellites.

References.

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