PHOTOMETRIC OBSERVATIONS OF THE MUTUAL EVENTS OF THE GALILEAN SATELLITES OF JUPITER MADE AT NIKOLAEV ASTRONOMICAL OBSERVATORY IN 2002–2003

J-E. ARLOT[1], G.K. GOREL[2], L.A. HUDKOVA[2], A.V. IVANTSOV[2], EU.S. KOZYREV[2]

[1] Institut de mecanique celeste (IMCCE) of Observatoire de Paris
UMR 8028 du CNRS, 77 avenue Denfert-Rochereau, F-75014, Paris, France
e-mail: arlot@imcce.fr

[2] Research Institute Nikolaev Astronomical Observatory
vul. Observatorna 1, Mykolaiv, 54030, Ukraine
e-mail: gudkova@mao.nikolaev.ua

ABSTRACT. For the first time at Nikolaev during 2002–2003 there have been made CCTV observations of the mutual phenomena of the Galilean satellites. Guide-telescope of the Zone Astrograph (D=0.115 m, F=2.0 m) and CCTV-camera with 1/3" diagonal have been used for the observations. During the entire period of the observations there were obtained 22 TV series of mutual events (9 occultations and 13 eclipses). Preliminary photometric processing of FITS frames of one event was made with the help of STARLINK software. Analysis of light curve has shown a threshold of detected flux drop nearly 0.1 magnitude.

1. INTRODUCTION

Occultations and eclipses of satellites by each other are usually called as mutual phenomena or events in the systems of Jupiter satellites or other outer planet satellites that can be observed from the Earth. Such events occur in the system of Galilean satellites of Jupiter every 6 years, when the Earth and the Sun go through the common plane of the satellites orbits (Arlot, 2002). From the observational point of view these events are characterized with a small drop of magnitude, which take place in a short time. As a rule maximum brightness fall doesn't exceed one magnitude.

Fast photometry of these events became possible in the last decades only due to a wide spread of cameras with CCD sensors. Such observations make it possible to determine precise moments of maximum magnitude drop that can be equivalent to position observation of satellites with accuracy to 1 mas (Arlot, 2002). Moreover these observations give a vast material for astrophysical research.

2. THE OBSERVATIONS

Photometrical observations of mutual phenomena in the system of Galilean satellites of Jupiter in PHEMU03 campaign were made in Nikolaev Astronomical Observatory at the first time. From October 28, 2002 till June 5, 2003 according to the ephemeride of the Institut de

mecanique celeste et de calcul des ephemerides
(*http : //www.imcce.fr/ephem/ephesat/en/visiphemu_formulaire_eng.html*) there should be 128 events in the geographical conditions of Nikolaev for our instrumental possibilities. Weather conditions allowed us to get only 22 events, among them 9 occultations and 13 eclipses (observers were Hudkova L.A., Ivantsov A.V., Gorel G.K.).

Telescope-guide (D=0.115 m, F=2.0 m) of Zone Astrograph with a television 1/3" CCD camera fixed at it was used to observe the mutual phenomena. An ordinary TV-tuner was used for 8-bit A/D conversion of TV frames. Field of view 7'x 9' of such a system has allowed to record at least one reference satellite simultaneously with event. All records were made without any filter.

Time moments in UTC with necessary accuracy were provided by time service of Nikolaev Observatory. Software under OS Windows, written by Kozyrev Eu.S., uses standard library avicap32.dll for video capture and allows to record observational moments for every frame with the accuracy of 1 ms by means of syncronometer. The frequency of records was from 1 to 4 frames per second that depended on the duration of the event. The mean record of one event had about 3000 frames in length.

Video series of dark and flat field frames were additionally recorded every observational night. For extinction correction the records of stars like the Sun spectral class (Khaliullin et al., 1985) were made at different zenith distances in the beginning and at the end of every observation of mutual phenomena.

3. PRE-PROCESSING AND ANALYSIS

Processing of CCD frames is making with STARLINK software
(*http : //www.starlink.rl.ac.uk*) which allows for astronomer to inspect and transform frames.

For presentation of observations made in Nikolaev there were processed 3038 frames of occultation (J4OJ1) on December 16, 2002. The French ephemerides of this event gives magnitude drop in 0.36, duration of the event was 395 seconds and the place of the satellites was at 3.8 planet radiuses from Jupiter.

A study of dark frames allowed us to remove noise pattern that was present at all frames. As far as the work with flat-fielding and Jupiter background is still continuing, their corrections were not made for. The results given below were got by the aperture photometry with growth curves applying to every object to find an optimal aperture radius.

In Fig. 1 one can see: (a) magnitude change of J2 versus time (in seconds) with arbitrary zeropoint (background), standard error is 0.081; (b) the same change, but for J3, standard error is 0.067. The change of the magnitude difference between J2 and J3 is present in Fig. 2a, standard error is 0.094. Given errors are in such agreement, when there is no correlation between magnitude measurements of J2 and J3 on the same frame as you can see in Fig. 2b. A small difference between standard errors for magnitude measurements of two reference satellites may be caused by the not uniform background close to the satellites and the complexity of processing such frames. The figures show that magnitude measurements with arbitrary zeropoint in such a processing are more accurate than relative ones.

Also this fact confirms Fig. 3 where you can see the change of magnitude for phenomena in time: a) relatively to the J3 and b) relatively to the background. Presented results give the less detectable magnitude change in 0.1 magnitude, and testify about the necessity to improve method of the processing that will be a subject of our further work.

Acknowledgments. Astronomers of Nikolaev Astronomical Observatory would like to thank Institut de mecanique celeste et de calcul des ephemerides, especially Dr. J.-E. Arlot for financial support for the grant in the PHEMU03 campaign. Besides, we acknowledge the software pro-

a) b)

Figure 1: Change of Jupiter satellites magnitude of with time (in seconds) for a) J2 (Europe) and b) J3 (Ganimed).

a) b)

Figure 2: a) Change of magnitude difference between J2 and J3 with time (in seconds) and b) correlation between magnitude measurements of J2 and J3.

a) b)

Figure 3: The changes of magnitude for phenomena with time relatively to the a) J3 and b) background.

vided by the Starlink Project, which is run by CCLRC on behalf of PPARC. The authors thank Dr. Malcolm Currie from the Quick Programming Service (Starlink) whose suggestions on FITS format and discussions on data processing were useful.

4. REFERENCES

Arlot, J.-E., 2002, Presentation of the Galilean Satellites of Jupiter and of their Mutual Phenomena, $http://www.imcce.fr/Phemu03/ntph01\_eng.html$.

Khaliullin, Kh., Mironov, A. V., Moshkalyov, V. G., 1985, A New Photometric WBVR System, *Astrophysics and Space Science*, **111**, 291.