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Observations of mutual phenomena of Galilean's satellites at Catania

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Abstract. The mutual phenomena between Jupiter and Saturn's satellites occur every half orbital period of these planets, when the Earth and the Sun cross their equatorial plane. At Physics and Astronomy Department of Catania University the events between Jupiter's satellites have been observed during the 1973, 1979, 1985/86, 1991, 1997 and 2009 campaigns and the ones between Saturn's satellites during the 1980/81 and 1995 campaigns. An overview of the main results obtained since 1973 is presented.

Keywords. techniques: photometric, telescopes, planets and satellites: Jupiter, planets and satellites: galilean satellites

1. Introduction

Prior to the Voyager missions the possibility to define the physical parameters and the surface morphology of the moons of the greatest Solar System planets was entrusted to the few photographs or to the drawings by astronomers. The lightcurves of the mutual phenomena give the objective data to better define the surface characteristics. As an example, the comparison between the albedo of the eclipsed areas and the drop in magnitude in different colors, the duration and the time of the minimum of light inferred, during the 1973 campaign, the existence of bright polar caps on Io, Europa and Ganymede, suggested by the drawings of many authors.

Since the Voyager missions have provided accurate physical parameters for all the satellites and described surface features and albedo variations, the observations of mutual events were best used for astrometric purposes. As an example, during the 1979 campaign, the relative separations in right ascension, $\Delta\alpha\cos\delta$, and declination, $\Delta\delta$, of a satellite pair at midevent were estimated.

The improvement of the integration time up to measures of the order of 0.1 sec, can supply relative positions with relevant residuals near 100 Km at Jupiter's mean distance, with the possibility, due to the great number of observed events, to evidence tidal effects on Io's orbit.

After the 1980 campaign, the observing conditions were completely changed by the incoming of the CCD detectors. Their spatial resolution of the order of arcsec per pixel, by the analysis of the lightcurve behavior during the event, also with small telescopes, makes it possible to obtain morphological details of the order of few kilometers. The use of several infrared wavelengths during Io's occultations by the other satellites, allows the detection of emitting hot spots associated to an intense volcanic activity on the first Galilean satellite of Jupiter.

2. Previous observational campaigns

At Physics and Astronomy Department of Catania University the events between Jupiter's satellites have been observed during the 1973, 1979, 1985/86, 1991, 1997 and 2009 campaigns. All the observations were carried out at M. G. Fracastoro Station of INAF - Catania Astrophysical Observatory.

During the 1973 campaign, the 61/41-cm Schmidt telescope equipped with a synchronous three-channel photometer able to obtain contemporaneous observations in the *UBV* bands (Blanco & Catalano 1974) was used. Two mutual occultation and one mutual eclipse were observed (see Table 1). The observed depth of all events is shallower than the predicted one by about $0^m.2$, apart from the JII occultation on October 22^{nd} 1973, when the observed depth is much deeper than the predicted one. However, the observations of this event were made in the *B* band while the predictions refer to the *V* magnitude. The observed times of occurrence for all events are in close agreement with the predictions by Aksnes 1974.

Since the 1979 campaign, the 91-cm Cassegrain telescope was used and since the 1985 campaign it was equipped with photon counting photoelectric photometer.

Table 1. Relevant data on the events observed during the 1973 campaign (Blanco & Catalano 1974). Predicted values of the light minimum (UT) and the light loss were taken by Aksnes (1974).

Date	**Event**	**Predicted minimum**	**Observed minimum**	**Predicted Light loss**	**Observed Light loss**
OCT 22	3O2P	$17^h 43^m$	$17^h 43^m 45^s \pm 0^s.3$	$0^m.01$ (ΔV)	$0^m.08 \pm 0^m.04$ (ΔB)
NOV 15	4E3T	$18^h 10^m$	$18^h 09^m 45^s$	$0^m.80$ (ΔV)	$0^m.615 \pm 0^m.03$ (ΔV) $0^m.625 \pm 0^m.03$ (ΔB) $0^m.660 \pm 0^m.03$ (ΔU)
NOV 22	2E1A	$16^h 55^m$	$16^h 53^m 10^s$	$0^m.73$ (ΔV)	$0^m.530 \pm 0^m.03$ (ΔV) $0^m.525 \pm 0^m.03$ (ΔB) $0^m.450 \pm 0^m.03$ (ΔU)

Table 2. Relevant observed data on the 1979 mutual events of Jupiter satellites (Blanco 1996).

Date	**Event**	$\Delta\alpha\cos\delta$	$\Delta\delta$	**Duration (sec)**	**Observed Light loss**
OCT 01	1E2P	+0.072	+0.182	$445 \pm 0^s.3$	$1^m.80 \pm 0^m.05$ (ΔV) $1^m.83 \pm 0^m.05$ (ΔB) $1^m.65 \pm 0^m.05$ (ΔU)
NOV 02	1E2P	–0.160	–0.390	260	$0^m.80 \pm 0^m.03$ (ΔV) $0^m.80 \pm 0^m.03$ (ΔB) $0^m.75 \pm 0^m.03$ (ΔU)
NOV 02	3E2P	+0.094	+0.321	140	$1^m.30 \pm 0^m.03$ (ΔV) $1^m.10 \pm 0^m.03$ (ΔB) $1^m.12 \pm 0^m.03$ (ΔU)
NOV 09	1E2P	–0.262	–0.635	235	$0^m.20 \pm 0^m.03$ (ΔV) $0^m.17 \pm 0^m.03$ (ΔB) $0^m.17 \pm 0^m.03$ (ΔU)

Relevant observed data on the 1979 mutual events of Jupiters satellites are reported in Table 2 (Blanco 1996). Due to Catania geographic coordinates, the 1979 apparition was a poor one, requiring most observations to be made through large air masses, thus

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resulting in uncertain sky corrections and approximate lightcurves. The observations of mutual events of this campaign were best used for astrometric purposes.

A total of 37 mutual events were observed in 1985 and 22 of these were of such good quality to improve the computations of satellites' orbits. These events are reported in Table 3 (Blanco 1988; Franklin *et al.* 1991). Predicted values of the light minimum (UT) here shown were computed by Arlot (1984) by using the ephemerides given by Arlot (1982). The predicted light losses were by Aksnes & Franklin (1984). The observed light losses and values of the light minimum do not show relevant regular deviations from the predicted ones.

During the 1991 campaign we observed 29 mutual events. In Table 4 we report relevant data for some of them (Arlot *et al.* 1997).

As part of the PHEMU97 International Campaign, 28 lightcurves were obtained at M. G. Fracastoro Station. The mutual events that present little noise and allowed us to compare themself with predictions are 10 and they are reported in Table 5 (Blanco 1999; Blanco *et al.* 2001; Arlot *et al.*, 2006). A global analysis of these data shows that the times of occurrence of the observed minima normally come early compared to the predicted ones. Moreover, the observed light losses in seven cases are greater than the predicted ones while they are comparable in the remaining three cases.

Table 3. Mutual events observed in 1985 (Blanco 1988; Franklin *et al.* 1991). Predicted values of the light minimum (UT) here shown were computed by Arlot (1984) by using the ephemerides given by Arlot (1982). The predicted light losses were by Aksnes & Franklin (1984).

Date	**Event**	**Predicted minimum**	**Observed minimum**	**Predicted Light loss (ΔV)**	**Observed Light loss (ΔV)**
JUN 17	3O4P	$01^h 44^m.91$	$01^h 45^m.24 \pm 0^m.005$	$0^m.09$	$0^m.06 \pm 0^m.03$
JUL 08	3O2P	$22^h 17^m.21$	$22^h 18^m.20$	$0^m.31$	$0^m.36 \pm 0^m.01$
JUL 12	4O3P	$00^h 39^m.86$	$00^h 39^m.90$	$0^m.45$	$0^m.32 \pm 0^m.01$
JUL 16	3O2P	$01^h 14^m.31$	$01^h 14^m.19$	$0^m.27$	$0^m.26 \pm 0^m.08$
AUG 05	3O4P	$23^h 26^m.96$	$23^h 28^m.85$	$0^m.11$	$0^m.04 \pm 0^m.01$
AUG 27	3O2P	$19^h 36^m.95$	$19^h 36^m.60$	$0^m.18$	$0^m.25 \pm 0^m.01$
AUG 29	4O1P	$20^h 18^m.57$		$0^m.02$	$0^m.03 \pm 0^m.01$
AUG 30	1E2P	$20^h 03^m.90$	$20^h 02^m.11$	$0^m.40$	$0^m.20 \pm 0^m.01$
SEP 03	3O2P	$22^h 03^m.47$	$22^h 03^m.72$	$0^m.15$	$0^m.17 \pm 0^m.01$
SEP 04	3E2T	$21^h 46^m.91$	$21^h 54^m.36$	$1^m.00$	$0^m.25 \pm 0^m.01$
SEP 06	1O2P	$21^h 49^m.45$	$21^h 51^m.88$	$0^m.04$	$0^m.03 \pm 0^m.01$
SEP 07	1E2P	$00^h 29^m.73$	$00^h 29^m.67$	$0^m.59$	$0^m.25 \pm 0^m.02$
SEP 07	1O3P	$20^h 33^m.75$	$20^h 34^m.07$	$0^m.05$	$0^m.03 \pm 0^m.01$
SEP 07	1E3P	$23^h 22^m.31$	$23^h 22^m.02$	$0^m.31$	$0^m.26 \pm 0^m.01$
OCT 01	4E2A	$19^h 06^m.66$	$19^h 07^m.20$	$0^m.68$	$0^m.34 \pm 0^m.01$
OCT 01	1E2A	$21^h 52^m.16$	$21^h 51^m.08$	$0^m.94$	$0^m.92 \pm 0^m.02$
OCT 02	4E1A	$19^h 33^m.11$	$19^h 35^m.00$	$0^m.81$	$0^m.85 \pm 0^m.01$
OCT 31	3E1P	$19^h 17^m.06$	$19^h 16^m.29$	$0^m.47$	$0^m.46 \pm 0^m.01$
NOV 07	2E1A	$16^h 52^m.53$	$16^h 52^m.09$	$0^m.55$	$0^m.65 \pm 0^m.01$
NOV 14	2E1A	$19^h 06^m.56$	$19^h 06^m.36$	$0^m.58$	$0^m.68 \pm 0^m.02$
DEC 04	1O2P	$17^h 18^m.31$	$17^h 18^m.23$	$0^m.10$	$0^m.08 \pm 0^m.01$
DEC 14	3E2P	$17^h 34^m.66$		$0^m.98$	$0^m.77 \pm 0^m.03$

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Table 4. Relevant data of some mutual events observed during the 1991 campaign (Arlot *et al.* 1997). Predicted values of the light minimum (UT) and the light loss were by Arlot (1997).

Date	Event	Predicted minimum	Observed minimum	Predicted Light loss (ΔV)	Observed Light loss (ΔV)
JAN 02	2O3A	$01^h 40^m 07^s$	$01^h 39^m 07^s \pm 0^s.3$	$0^m.479$	$0^m.299 \pm 0^m.02$
JAN 05	2O1P	$00^h 19^m 26^s$	$00^h 22^m 01^s$	$0^m.136$	$0^m.180 \pm 0^m.01$
JAN 09	2E3P	$03^h 03^m 00^s$	$03^h 03^m 06^s$	$0^m.232$	$0^m.253 \pm 0^m.01$
JAN 12	2O1P	$01^h 53^m 10^s$	$01^h 54^m 45^s$	$0^m.749$	$0^m.533 \pm 0^m.01$
FEB 13	2E1A	$02^h 04^m 44^s$	$02^h 05^m 21^s$	$0^m.712$	$1^m.761 \pm 0^m.02$
FEB 23	2E1A	$17^h 42^m 40^s$	$17^h 43^m 50^s$	$0^m.714$	$0^m.628 \pm 0^m.01$
MAR 09	2E1A	$20^h 58^m 13^s$	$20^h 58^m 28^s$	$0^m.221$	$0^m.228 \pm 0^m.01$
APR 29	2E4A	$22^h 18^m 12^s$	$22^h 18^m 28^s$	$0^m.434$	$0^m.291 \pm 0^m.01$
MAY 07	3E1P	$20^h 29^m 11^s$	$20^h 29^m 06^s$	$0^m.446$	$0^m.484 \pm 0^m.01$
JUL 04	3E1P	$19^h 42^m 26^s$	$19^h 43^m 03^s$	$0^m.942$	$1^m.351 \pm 0^m.01$

Table 5. Relevant data of some mutual events observed during the 1997 campaign (Blanco 1999; Blanco *et al.* 2001; Arlot *et al.* 2006). Predicted values of the light minimum (UT) and the light loss of each event are by Arlot 1999.

Date	Event	Predicted minimum	Observed minimum	Predicted Light loss (ΔV)	Observed Light loss (ΔV)
JUN 18	2E1A	$01^h 05^m 46^s$	$01^h 04^m 42^s \pm 0^s.3$	$0^m.647$	$1^m.25 \pm 0^m.01$
JUL 26	3O1P	$23^h 24^m 24^s$	$23^h 23^m 19^s$	$0^m.296$	$0^m.50$
JUL 29	1O3P	$23^h 50^m 43^s$	$23^h 49^m 30^s$	$0^m.206$	$0^m.23$
AUG 01	4E3A	$00^h 21^m 53^s$	$00^h 20^m 52^s$	$0^m.601$	$0^m.95$
AUG 02	3O2T	$02^h 54^m 07^s$	$02^h 53^m 30^s$	$0^m.259$	$0^m.57$
AUG 28	1E3P	$00^h 37^m 25^s$	$00^h 37^m 25^s$	$0^m.199$	$0^m.20$
SEP 29	3O2P	$18^h 43^m 22^s$	$18^h 42^m 21^s$	$0^m.196$	$1^m.22$
OCT 06	3O2P	$22^h 13^m 33^s$	$22^h 12^m 58^s$	$0^m.217$	$0^m.38$
NOV 17	3O1P	$16^h 48^m 30^s$	$16^h 47^m 35^s$	$0^m.278$	$0^m.52$
NOV 18	3E1	$19^h 18^m 48^s$	$19^h 18^m 48^s$	$0^m.007$	$0^m.01$

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3. PHEMU09

During the 2009 observational campaign, the 91-cm Cassegrain telescope equipped with the new KODAK KAF 1001E CCD camera (1024x1024 pixels; 24-micron pixel-size) and, for the first time, the 80-cm Cassegrain telescope (APT2) equipped with the KODAK KAF 09000 CCD camera (3056x3056; 12-micron pixel-size) were used. The observations have been carried out in the *B* band and, depending on the nightly weather conditions and the telescope/CCD set-up used, with exposure time varying from 0.3 to 5 sec. Table 6 shows the mutual events observed during the 2009 campaign. Predicted values of the light minimum (UT) and the light loss, for each event, were by http://ftp.imcce.fr/pub/ephem/satel/phemu09/visibility. The acquired data are currently under reduction.

Table 6. Mutual events observed during the 2009 campaign. Predicted values of the light minimum (UT) and the light loss were by http://ftp.imcce.fr/pub/ephem/satel/phemu09/visibility.

Date	Event	Predicted minimum	Predicted Light loss (ΔV)
JUL 23	4E2	$23^h 12^m 35^s$	$0^m.139$
JUL 24	1E2P	$00^h 16^m 46^s$	$0^m.367$
JUL 24	1O2P	$01^h 15^m 09^s$	$0^m.214$
SEP 01	1O2P	$20^h 03^m 22^s$	$0^m.192$
SEP 01	1O2P	$21^h 05^m 16^s$	$0^m.349$
OCT 03	1O2P	$18^h 31^m 24^s$	$0^m.161$
OCT 03	1E2P	$20^h 23^m 36^s$	$0^m.625$

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