

# Unobservable mutual events of the Galilean satellites

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**Abstract.** Mutual eclipses and occultations of the Galilean satellites of Jupiter which will occur in 2002–2003 were predicted independently by J.-E. Arlot and by K. Aksnes, and information on the visibility of the events from any site on the Earth is provided on the IMCCE web site based on Arlot's predictions. However, many unobservable events, such as the eclipsed satellites are in the shadow of Jupiter, are included in Arlot's predictions and there is no way of eliminating of such unobservable events from his predictions. This paper lists all such events.

**Key words.** eclipses – occultations – planets and satellites: general

## 1. Introduction

The mutual events of the four Galilean satellites occur every six years when the Earth and the Sun cross the orbital planes of the Galilean satellites. Observations of such events are especially valuable for the investigation of the orbital motion of the satellites. The next season for these events begins near the end of 2002, and the predictions of them were independently given by Arlot (2002) and by Aksnes (2001). In Aksnes's predictions all events with a light loss of less than 0.03 and all events occurring closer than 1.5 Jupiter radii from the planet's center were dropped due to the difficulty of their observations. Aksnes's predictions are also available on the U.S. Naval Observatory web site at the address [http://aa.usno.navy.mil/data/docs/Galilean\\_Occult.html](http://aa.usno.navy.mil/data/docs/Galilean_Occult.html). On the other hand all events and even some grazing ones are listed in Arlot's predictions and Arlot provides software on the web site of IMCCE/Observatoire de Paris at the address [http://www.bdl.fr/Phemu03/phemu03\\_eng.html](http://www.bdl.fr/Phemu03/phemu03_eng.html) which allows the determination of visibility of the events for any given site. However, since Arlot did not take into account Jupiter's position with respect to the satellites positions many unobservable events are included in Arlot's predictions that cannot be eliminated by the software. Such unobservable events are listed in this paper.

In addition some events are missing from Arlot's predictions. Observers should also be alerted about this fact.

## 2. Unobservable events

Among the predicted mutual events by Arlot (2002) the following events are physically or practically unobservable (the

figures in the parentheses show the numbers of the respective events):

- occultations in which
  1. the occulting satellite is in front of Jupiter and the occulted satellite is behind Jupiter so that the event cannot be seen physically (35),
  2. the occulted satellite is in the shadow of Jupiter so that the light drop is not observed (17), and
  3. the event occurs when the satellites are on Jupiter as seen from the Earth so that the observation of the event is difficult (9), and
- eclipses in which
  4. the shadow of the eclipsing satellite falls on Jupiter and the eclipsed satellite is in the shadow of Jupiter so that the event does not occur physically (17),
  5. both of the eclipsing and eclipsed satellites are in the shadow of Jupiter so that the event does not occur physically (3),
  6. the eclipsed satellite is behind Jupiter as seen from the Earth so that the observers on the Earth cannot observe the event (this event may be seen from space) (12), and
  7. the event occurs when the eclipsed satellite is on Jupiter as seen from the Earth so that the observation of the event is difficult (4).

In Table 1 only the events categorized as 2, 4, and 5 are listed because the events 1, 3, 6, and 7 can be eliminated by setting the distance limit of the satellite from Jupiter to 1.0 times the planetary radius using the software given on the IMCCE web site at the address given in Sect. 1. The meaning of the event column in Table 1 is the same as that of Arlot: e.g. "1 OCC 2" means that satellite 1 occults satellite 2, and "3 ECL 4" means that satellite 3 eclipses satellite 4, and the next character "P"

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**Table 1.** Unobservable events.

Date	Max. TT	Event	*	Date	Max. TT	Event	*	Date	Max. TT	Event	*
y M d h m s				y M d h m s				y M d h m s			
2002 12 4 14 43 20		3 OCC 2	2	2003 2 11 19 15 18		1 ECL 4	4	2003 5 28 22 18 9		1 ECL 3	4
2002 12 6 19 13 25		2 OCC 4 P	2	2003 2 11 21 32 37		2 ECL 4	4	2003 5 31 6 16 59		4 OCC 2 P	2
2002 12 6 19 59 50		1 OCC 4 A	2	2003 2 28 17 12 36		1 OCC 4 P	2	2003 6 5 1 1 29		1 ECL 3	4
2002 12 11 17 40 50		3 OCC 2 P	2	2003 3 14 16 42 42		3 ECL 1	4	2003 6 12 3 44 33		1 ECL 3	4
2003 1 9 7 25 56		1 OCC 4 P	2	2003 3 17 9 22 2		1 ECL 4	4	2003 7 3 18 27 41		4 OCC 3 P	2
2003 1 9 9 28 31		3 OCC 4 P	2	2003 3 21 19 26 14		3 ECL 1	4	2003 7 18 2 41 43		2 OCC 3 P	2
2003 1 16 5 30 8		1 ECL 2	4	2003 3 25 7 39 44		1 ECL 3 P	5	2003 7 25 6 12 51		2 OCC 3 P	2
2003 1 19 18 35 48		1 ECL 2	4	2003 3 28 22 9 28		3 ECL 1	4	2003 8 15 17 58 18		1 ECL 3 P	5
2003 1 19 20 5 49		1 OCC 3 P	2	2003 4 11 13 5 5		4 ECL 2	4	2003 8 15 18 25 37		1 OCC 3 P	2
2003 1 23 7 41 31		1 ECL 2	4	2003 4 19 23 15 21		2 OCC 4 P	2	2003 8 17 11 42 5		1 ECL 2 P	5
2003 1 26 20 47 15		1 ECL 2	4	2003 4 19 23 30 44		1 ECL 4	4	2003 8 17 11 55 19		1 OCC 2 P	2
2003 1 30 9 53 3		1 ECL 2	4	2003 5 6 13 43 42		2 OCC 4 A	2				
2003 2 2 22 58 53		1 ECL 2	4	2003 5 23 8 44 59		1 OCC 4 P	2				

\* Category number as given in the text.

stands for partial, “A” for annular, “T” for total, and blank means eclipse by the penumbra or grazing occultation with no duration.

There is one more thing to be noted here. In the case of mutual occultations the flux drop is calculated for the combined brightness of the occulting and occulted satellites, but if the occulting satellite is in the shadow of Jupiter while the occulted one is not, the flux drop should be larger than the calculated one because the occulting satellite is dark. There is only one such event during the current occultation season, which is “1 OCC 4 P” on 2002 Nov. 3 (maximum at 18<sup>h</sup> 28<sup>m</sup> 59<sup>s</sup> TT). According to this author’s calculation, the flux drop would be 0.02 if the occulting satellite were not in the shadow of Jupiter, but its actual flux drop is 0.08 due to the darkness of the occulting satellite, so that the observation is easier. However, this event occurs at 1.1 Jupiter radii from Jupiter’s center, which may not be too far for a reliable observation.

It should also be noted that some important events are missing from Arlot’s predictions. Due to the small inclinations of the orbits of the Galilean satellites the season of the mutual events extends for almost two years. The current season actually begins on 2002 May 30 and ends on 2004 March 19. In Arlot’s predictions the events occurring at the earliest and latest periods of the season are missing. The events at the earliest period (2002 May 30–June 16) are not in favorable condition because Jupiter is seen close to the Sun (the conjunction being 2002 July 20), but the events at the latest period (2004 March 16–19) are in very favorable condition (the opposition being 2004 March 4). Moreover the flux drops of the events

occurring at these periods are sensitive to the inclinations of the orbital planes of the satellites, so that one will be able to get valuable information about the orbits from these observations. For the missing events from Arlot’s predictions please refer to the U.S. Naval Observatory web site which was already mentioned in Sect. 1.

### 3. Conclusion

Unobservable mutual events that should be eliminated from the predictions were detected and listed in this paper.

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### References

- Aksnes, K. 2001, The Astronomical Almanac for the year 2003 (U.S. Government Printing Office, Washington, DC), F42
- Arlot, J.-E. 2002, A&A, 383, 719
- Lieske, J. H. 1995, JPL Engineering Memorandum 312–583, JPL internal publication
- Lieske, J. H. 1997, CM, 66, 13