

PHEMU havaitseminen

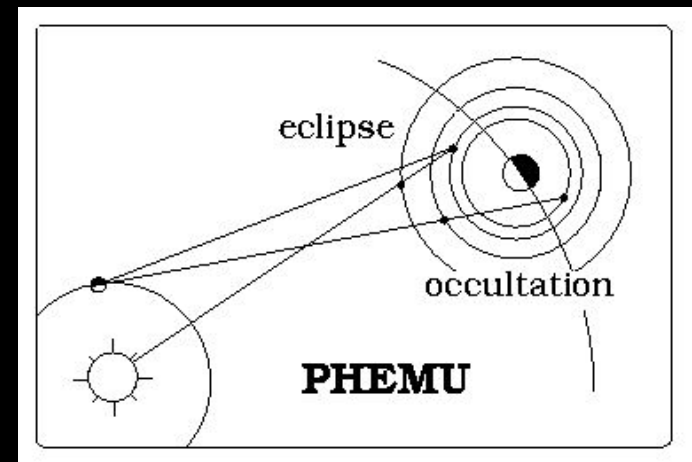


Arto Oksanen

Aurinkokuntatapaaminen
7.2.2026 - Artjärvi

PHEMU-havaintokampanja

- ★ **In 2002-2003, the Earth and the Sun go through the common orbital plane of the galilean satellites of Jupiter. This occurs only every 6 years and allows the observation of mutual eclipses and occultations between the satellites.**
- ★ These observations were made during the last opportunities since 1973 until the former campaign of 1997 and they have led to interesting results well in astrometry (dynamics of the system) as in planetology (physics of the surfaces of the satellites) thanks to the large number of data obtained on a long interval of time.
- ★ Observations are easy to perform even with a small telescope (Galilean satellites have a magnitude about 5) and, in order to make them possible to the observers, we propose the information provided here.



Miksi havaita?

E Saquet et.al. The PHEMU15 catalogue and astrometric results of the Jupiter's Galilean satellite mutual occultation and eclipse observations made in 2014–2015:

“Photometric observations of mutual events of the Galilean moons are essential to improve their ephemerides, mainly because we are able to extract highly precise astrometric positions of the satellites from the photometry. The precision of the mutual event observations is up to 20 mas for the Galilean moons (Arlot et al. 2014), or 60 km at the distance of Jupiter. Moreover, Robert et al. (2017) have recently demonstrated, for the inner satellites of Jupiter, that the positional accuracy derived from photometric observations still remains more precise than that derived from direct astrometry, even if the use of the most recent Gaia-DR1 catalogue (Gaia Collaboration et al. 2016) allowed them to eliminate the systematic errors due to the star references. Thus, our work is crucial for current and future spacecraft navigation (Dirkx et al. 2016), and for dynamical purposes, since the ephemerides are improved by adjusting the new astrometric positions to the theories.”

Havainnot vuonna 2003

- ★ **105 tapahtumaa oli havaittavissa Nyrölässä**
 - ★ **Auringon korkeus < -10.0 astetta**
 - ★ **Jupiterin korkeus > 10.0 astetta**
 - ★ **etäisyys planeettaan > 1.0 sädettä**
 - ★ **himmeneminen > 0.01 magnitudia**

International Pro-am collaboration

- ★ A. Oksanen
 - ★ havainnot
- ★ A. Christou (Armagh Observatory, Northern Ireland)
 - ★ kalibrointi
 - ★ fotometria
- ★ IMCCE (Paris Obs, France)
 - ★ koordinointi
 - ★ lopullinen analyysi
 - ★ tulosten julkaisu



Havainnot 2003

- ★ CCD-kuvat lyhyellä valotusajalla V-suotimella
- ★ 40 cm Meade LX200 + SBIG ST8XE
- ★ Tarkka aikareferenssi (Nyrölän ntp-palvelin, GPS)
- ★ Lyhytkestoisia ilmiöitä (muutamia minuutteja)
- ★ Helppo löytää



Havaitut tapahtumat 2003

<u>DATE</u>	<u>TYPE</u>	<u>OBS. START</u>	<u>OBS. END</u>	<u>SAMPLES</u>	<u>EXPTIME</u>	<u>FILTER</u>	<u>OBS.</u>
30/12/02	2 ECL 1	20:30:08	20:59:02	144 (154)	5.0	V	I/II
30/12/02	4 OCC 3	21:06:32	21:36:21	180	1.0+5.0	V	III+IV/I
06/01/03	2 ECL 1	23:24:08	23:49:04	400	0.5	C	I/II
14/01/03	2 ECL 1	02:19:47	02:53:34	523 (537)	0.5	C	I/II
16/01/03	4 OCC 2	23:46:32*	01:05:27	502 (604)	1.0	V	IV+II/III
19/02/03	4 OCC 1	20:19:29	20:41:30	282	1.0	V	IV+I/III
19/02/03	4 ECL 1	22:00:25	22:27:47	448	1.0	V	I/III
15/03/03	3 ECL 4	21:47:40	22:32:30	579 (599)	1.0+2.0	R	IV/III
17/03/03	1 ECL 3	18:09:20	18:40:14	560	1.0	V	III/I
20/03/03	1 OCC 2	23:46:04	00:00:00	201	1.0	V	I+II/III
25/03/03	1 ECL 3	19:58:18	20:20:41	250 (420)	0.5	V	III+II/I
25/03/03	2 OCC 3	20:37:18	20:56:16	353	0.5	V	III+II/I
25/03/03	2 ECL 3	23:58:35*	00:20:21	305 (326)	1.0	V	III/II
11/04/03	3 ECL 2	20:53:23	21:11:15	261	1.0	V	II/III

* in these cases the dataset was truncated by removing data points before midnight in order to facilitate plotting. The actual data files contain the full dataset.

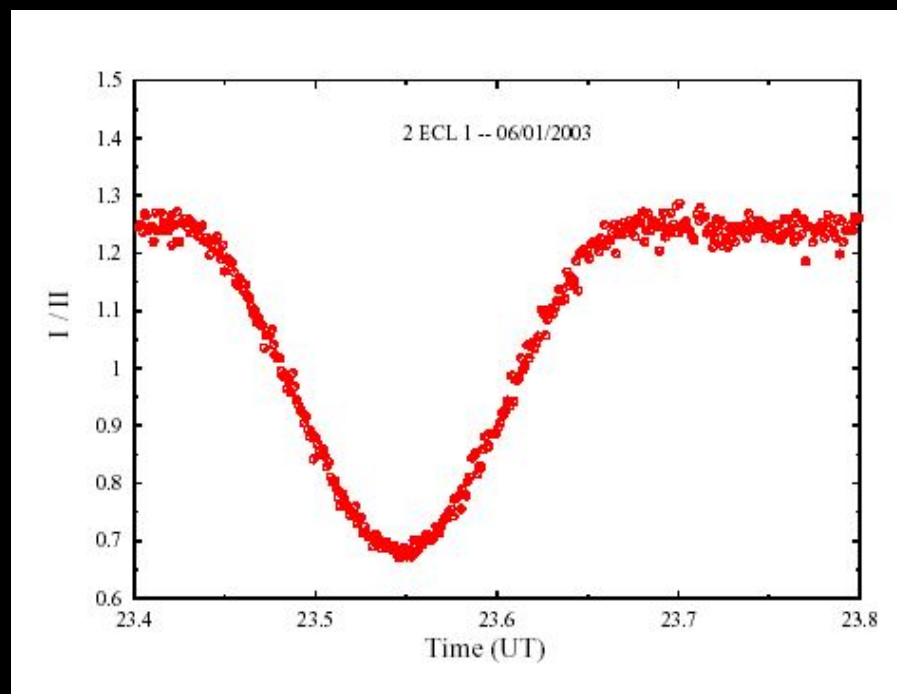
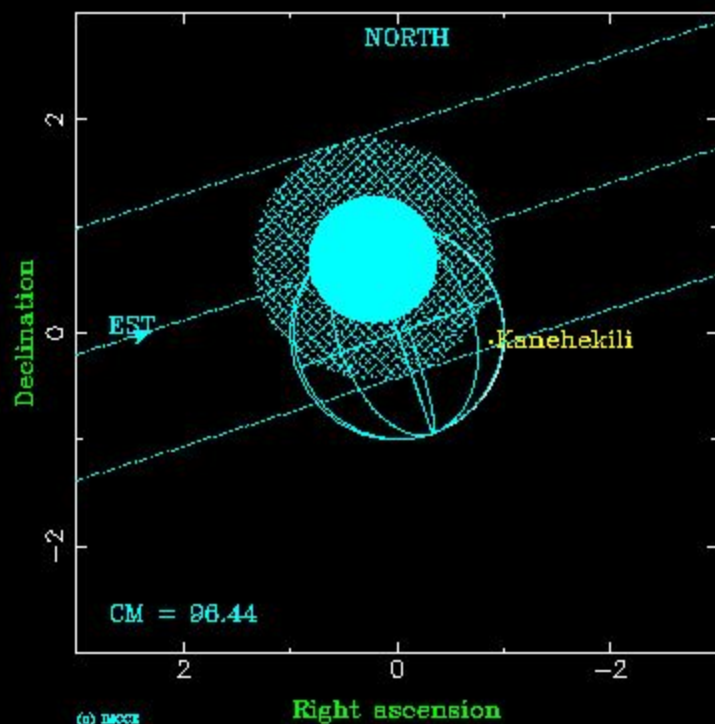
Fotometria: dr. Christou

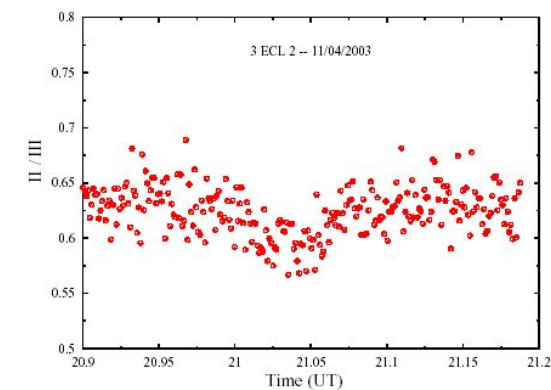
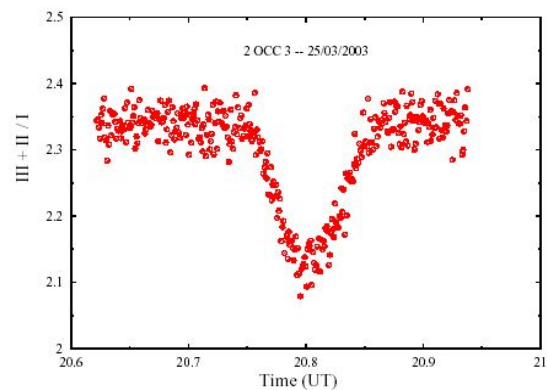
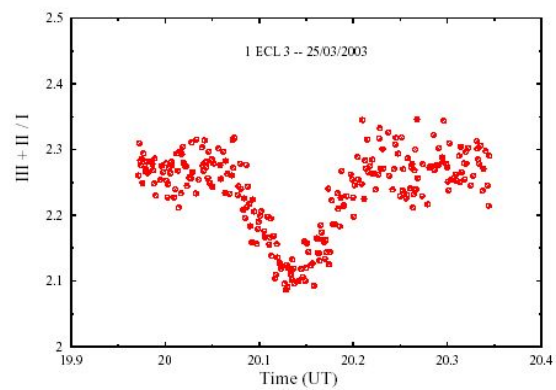
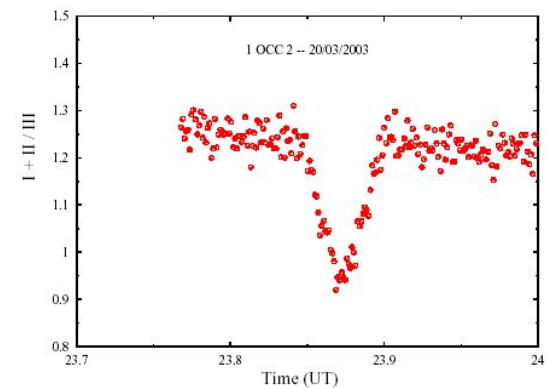
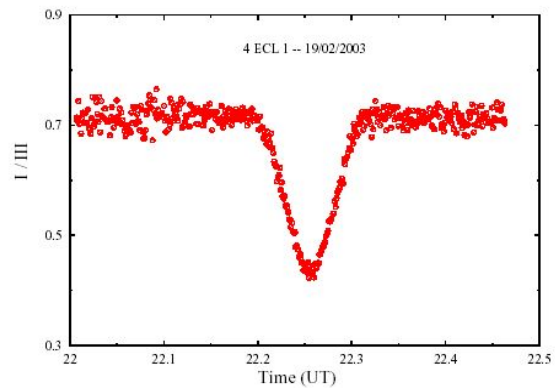
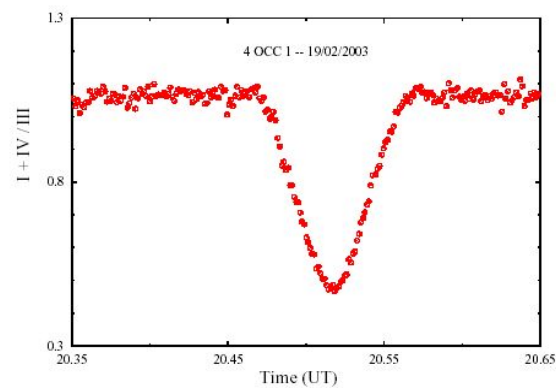
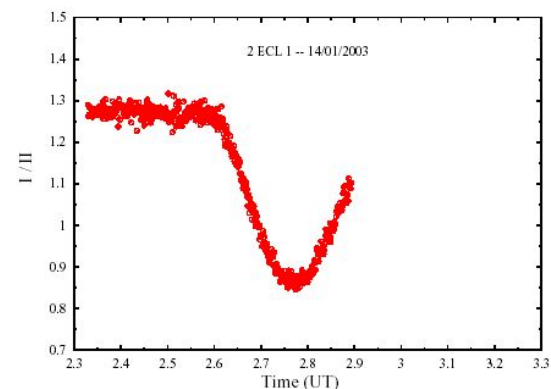
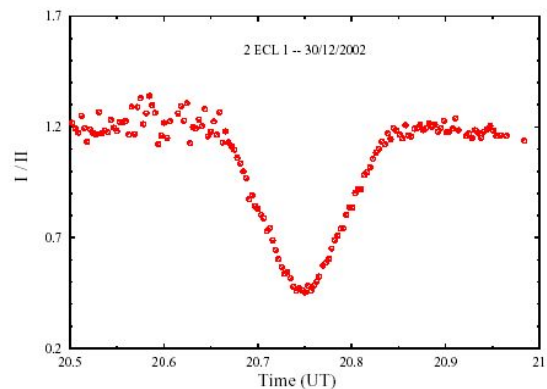
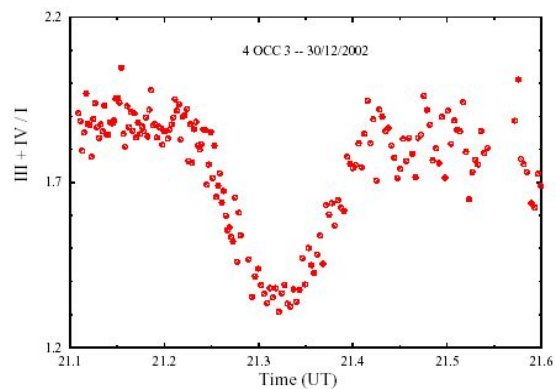
- ★ Aperature photometry with IDL
- ★ Relative flux of
 - ★ eclipsed moon vs. eclipsing moon
 - ★ occulting moon + occulted moon vs. third moon
- ★ Moons move during events
- ★ Photometry data given to IMCCE

Europe ecl. Io Jan 6, 2003



Europe ecl. Io on 1/6/2003





The PHEMU03 catalogue of observations of the mutual phenomena of the Galilean satellites of Jupiter[★]

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Received 19 June 2008 / Accepted 23 September 2008

ABSTRACT

Context. In 2003, the Sun and the Earth passed through both the equatorial plane of Jupiter and therefore the orbital planes of its main satellites.

Aims. During this period, mutual eclipses and occultations were observed and we present the data collected.

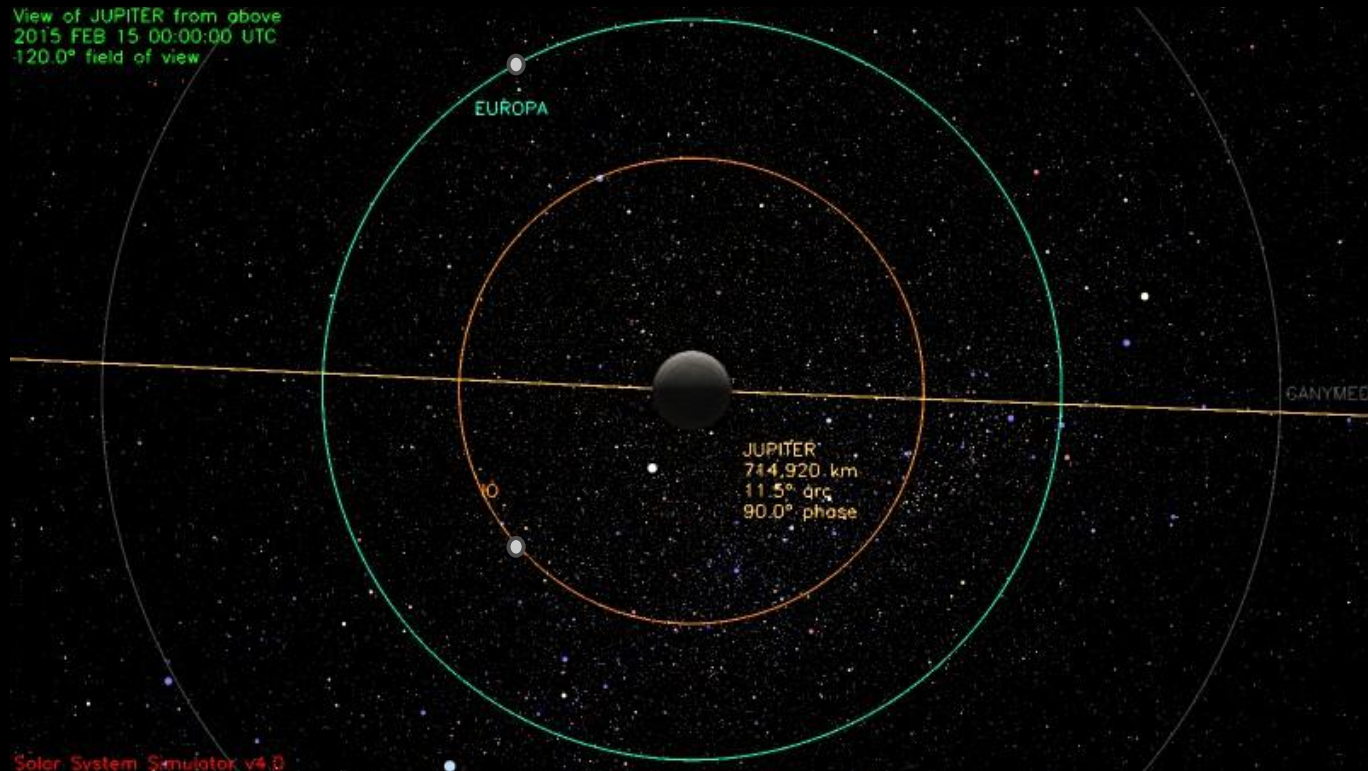
Methods. Light curves of mutual eclipses and occultations were recorded by the observers of the international campaign PHEMU03 organized by the Institut de mécanique céleste, Paris, France.

Results. We completed 377 observations of 118 mutual events from 42 sites and the corresponding data are presented in this paper. For each observation, information about the telescope, receptor, site, and observational conditions are provided.

Conclusions. This paper gathers all data and indicates a first estimate of its precision. This catalogue of these rare events should constitute an improved basis for accurate astrometric data useful in the development of dynamical models.

Key words. astrometry – eclipses – occultations – planets and satellites: individual: Jupiter

15.2.2015 1O2 (00:03 UT) & 1E2 (00:24 UT)



JUPITER
651.967 mil km
45.2" arc
1.7° phase

IO EUROPA



https://www.youtube.com/watch?v=lzyNg6Rt_NA

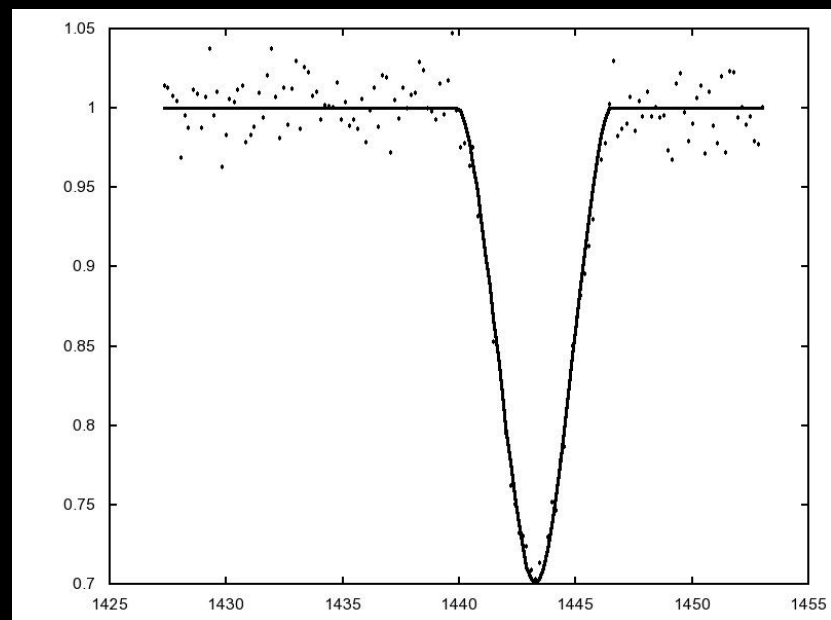
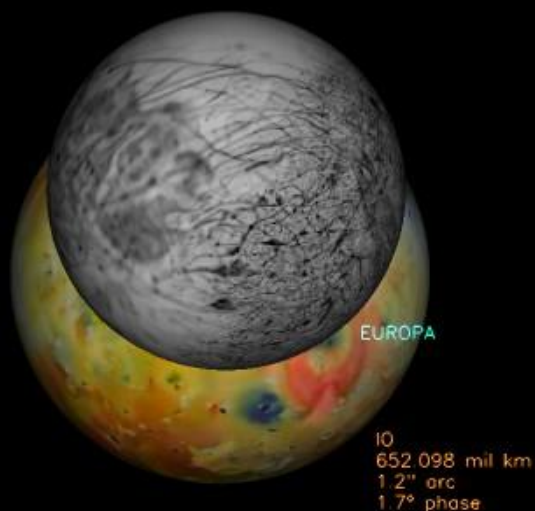
Havainnot Hankasalmella

- 40 cm etäkäytettävä RC teleskooppi
- SBIG STL-1001E CCD-kamera
- Kuvaus ja fotometria MaxImDL-ohjelmalla
- Aikareferenssi NTP linux-palvelimelta



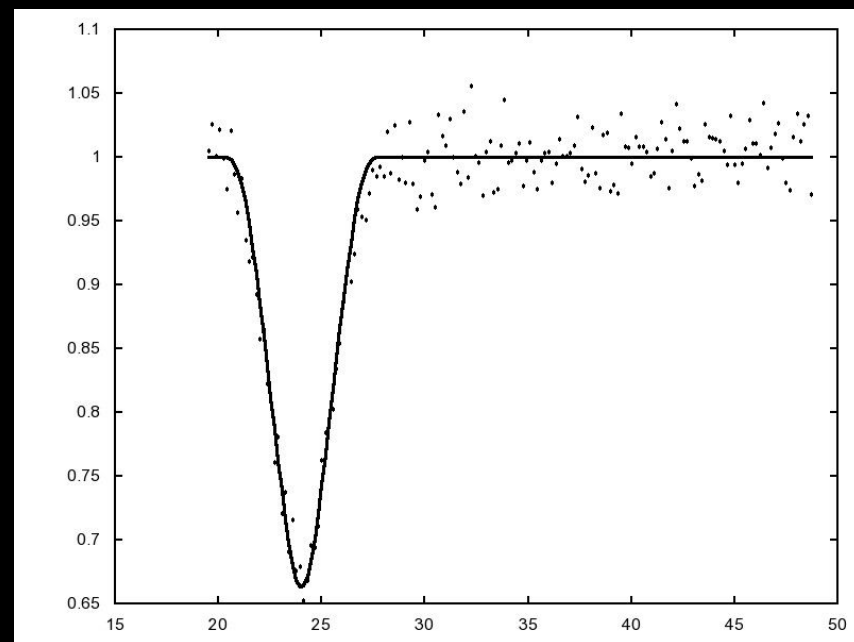
Europe ocl. Io 15.2.2015

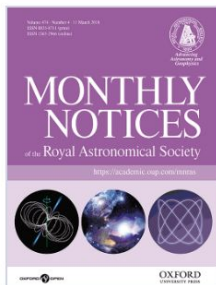
Date	begin: h	m	s	end: h	m	s	Type	Dur minutes	Impact arcsec	mag	flux drop	distance to limb(")	sat(")
2015 02 14	23	59	46	0	6	26	201	6.7	0.215	4.5	0.466	103.67	:



Europe ecl. Io 15.2.2015

Date	begin: h	m	s	end: h	m	s	Type	Dur minutes	Impact arcsec	mag	flux drop	distance to limb(")	sat(")
2015 02 15	00	20	03	00	27	51	2E1	7.8	0.130	4.5	0.849	101.18	7.94 :





Volume 474, Issue 4
March 2018

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Abstract

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RESULTS

7 CONCLUSIONS

Acknowledgements

JOURNAL ARTICLE

The PHEMU15 catalogue and astrometric results of the Jupiter's Galilean satellite mutual occultation and eclipse observations made in 2014–2015 FREE

E Saquet ✉, N Emelyanov ✉, V Robert, J-E Arlot, P Anbazhagan, K Baillié, J Bardecker, A A Berezhnoy, M Bretton, F Campos, L Capannoli, B Carry, M Castet, Y Charbonnier, M M Chernikov, A Christou, F Colas, J-F Coliac, G Dangl, O Dechambre, M Delcroix, A Dias-Oliveira, C Drillaud, Y Duchemin, R Dunford, P Dupouy, C Ellington, P Fabre, V A Filippov, J Finnegan, S Foglia, D Font, B Gaillard, G Galli, J Garlitz, A Gasmi, H S Gaspar, D Gault, K Gazeas, T George, S Y Gorda, D L Gorshanov, C Gualdoni, K Guhl, K Halir, W Hanna, X Henry, D Herald, G Houdin, Y Ito, I S Izmailov, J Jacobsen, A Jones, S Kamoun, E Kardasis, A M Karimov, M Y Khovritchev, A M Kulikova, J Laborde, V Lainey, M Lavayssiere, P Le Guen, A Leroy, B Loader, O C Lopez, A Y Lyashenko, P G Lyssenko, D I Machado, N Maigurova, J Manek, A Marchini, T Midavaine, J Montier, B E Morgado, K N Naumov, A Nedelcu, J Newman, J M Ohtert, A Oksanen, H Paylov, E Petrescu, A Pomazan, M Popescu, A Pratt, V N Raskhozhev, J-M Resch, D Robilliard, E Roschina, E Rothenberg, M Rottenborn, S A Rusov, F Saby, L F Saya, G Selvakumar, F Signoret, V Y Slesarenko, E N Sokov, J Soldateschi, A Sonka, G Soulie, J Talbot, V G Tejfel, W Thuillot, B Timerson, R Toma, S Torsellini, L L Trabuco, P Traverse, V Tsamis, M Unwin, F Van Den Abbeel, H Vandenbruaene, R Vasundhara, Y I Velikodsky, A Vienne, J Vilar, J-M Vugnon, N Wuensche, P Zeleny

Monthly Notices of the Royal Astronomical Society, Volume 474, Issue 4, March 2018, Pages 4730–4739, <https://doi.org/10.1093/mnras/stx2957>

Published: 21 November 2017 **Article history** ▼

Ennusteet havaintopaikalle

Tapahtumia yhteensä: 305 (11 May 2026 - 10 August 2027)

Työkalu ennusteille: <https://www.sai.msu.ru/neb/nss/html/multisat/nsszph5he.htm>

Natural Satellites Ephemeride Server. MULTI-SAT.

Ephemerides of the mutual eclipses and occultations
of the Galilean satellites of Jupiter

in 2026-2027

[Return ...](#)

To see the ephemerides of the events which are
observed at your observatory with circumstances
(object and sun altitudes, Moon phase)

enter Observatory code (XXX) See [the list](#)
or enter **500** to see all the events.

[\(Explanation of the data in output\)](#)

Number of events: 305

The first event: 11 May 2026

The last event: 10 August 2027

Really, 269 events are observable
from 11 May 2026

to 29 June 2026

and

from 1 September 2026

to 6 June 2027

[See](#)

Earth-Sun-Jupiter
configuration
parameters

[See](#) References
to the papers on
the subject

Comments.

These are ephemerides in the form of a table being immediately appearing in a separate window. They are calculated previously with the main software of the MULTI-SAT server as it is called running by the item

Search for mutual occultations and eclipses and eclipses of satellites by planet.

The theory by V.Lainey 2.0 (Lainey et al., 2009) is used.

Advantage of this form is that you have immediately ephemerides only for those events which are observed at your

Ennusteet Hankasalmelle (A91)

v5.21.05i Planet: Jupiter (INPOP17a)

Planet

Observatory N: A91 - Hankasalmi Observatory

Timescale: UTC

Mean equator and equinox of J2000. ICRF.

Mutual events of satellites:

Date	begin: h	m	s	end: h	m	s	Type	Dur(m)	Impact	m	Δm	limb(")	dist(")	Planet(°)	Sun(°)	Moon phase
2026	5	14	17 53 7	18	29	2	1E2	35.9	0.178	5.1	0.618	96.08	15.63 :	35.794	5.289	0.159
2026	5	21	21 33 20	21	50	11	1E2	16.9	0.432	5.1	0.367	99.09	16.59 :	8.338	-7.247	0.391
2026	5	24	17 11 40	17	22	50	1E2	11.2	0.878	5.2	0.034	56.33	14.44 :	36.577	11.512	0.587
2026	5	28	22 7 39	22	17	29	102	9.8	0.868	5.2	0.032	77.77	:	2.949	-6.335	0.852
2026	5	31	21 35 12	22	51	2	1E2	75.8	0.994	5.2	0.000	27.66	8.30 :	4.877	-5.592	0.956
2026	6	15	19 2 25	19	7	53	1E2	5.5	0.826	5.2	0.063	90.23	14.49 :	15.353	3.523	0.061
2026	7	17	17 47 56	17	51	0	1E2	3.1	0.900	5.3	0.029	70.59	5.28 :	11.544	8.815	0.253
2026	8	15	2 56 37	3	0	38	1E2	4.0	0.740	5.3	0.129	50.55	7.10 :	12.196	3.440	0.177
2026	8	18	16 35 44	16	37	42	102	2.0	0.909	5.3	0.018	52.62	:	7.300	9.237	0.417
2026	8	27	1 3 27	1	6	4	2E1	2.6	0.867	5.3	0.048	33.41	14.26 :	3.417	-10.594	0.928
2026	8	27	1 44 44	1	47	20	201	2.6	0.790	5.3	0.060	41.22	:	7.701	-7.061	0.930
2026	9	3	3 16 17	3	19	59	2E1	3.7	0.721	5.3	0.147	36.26	17.29 :	20.268	0.371	0.583
2026	9	3	4 7 26	4	11	25	201	4.0	0.419	5.3	0.288	45.74	:	26.203	6.241	0.580
2026	9	6	16 22 52	16	26	60	2E1	4.1	0.646	5.3	0.212	37.74	18.76 :	1.654	4.212	0.325
2026	9	9	2 31 20	2	40	10	304	8.8	0.754	5.1	0.048	190.86	:	16.882	-6.333	0.146
2026	9	16	1 0 39	1	5	32	1E2	4.9	0.393	5.2	0.495	26.09	23.50 :	8.649	-17.276	0.332
2026	9	16	2 8 31	2	12	37	102	4.1	0.152	5.2	0.562	37.98	:	16.426	-10.889	0.335
2026	9	19	15 19 15	15	23	8	102	3.9	0.309	5.2	0.404	36.02	:	3.247	6.727	0.549
2026	9	23	3 13 37	3	18	35	1E2	5.0	0.293	5.2	0.608	20.45	27.29 :	26.204	-5.925	0.764
2026	9	23	4 29 47	4	33	21	102	3.6	0.473	5.2	0.262	34.02	:	34.234	2.926	0.767
2026	9	27	0 39 32	0	45	26	104	5.9	0.260	5.3	0.212	31.70	:	9.650	-22.725	0.968
2026	9	28	0 30 6	0	33	14	201	3.1	0.780	5.2	0.065	61.09	:	8.900	-23.803	0.900
2026	9	30	5 26 12	5	31	13	1E2	5.0	0.200	5.2	0.626	14.77	31.06 :	40.221	7.179	0.741
2026	10	2	14 12 32	14	17	23	103	4.9	0.913	4.8	0.014	80.09	:	5.243	9.127	0.569
2026	10	4	1 20 50	1	35	46	4E3	14.9	0.570	5.0	0.512	177.58	73.83 :	16.707	-21.442	0.462

Taulukon sisältö

Explanations to the table of the ephemerides of the mutual occultations and eclipses of the natural satellites.

Date begin: h m s - moment of the start of event.

end: h m s - moment of the end of event.

Type - type of the event is given in the form "nEm" or "nOm" where n is the number of eclipsing or occulting satellite, m is the number of eclipsed or occulted one. "E" denotes an eclipse and "O" denotes an occultation.

Dur(m) - expected duration of the event in minutes.

Impact - impact factor which is equal to zero if the event is a central passage of satellite through the shadow or through the apparent disk of another satellite. Impact factor is equal to unit in the case of a grazing event.

m - combined magnitude of the pair of satellites in the event.

Δm - expected maximum drop of the combined magnitude.

limb(") - angular apparent distance of the occulted or eclipsed satellite from the limb of the planet (in arcseconds).

dist(") - angular apparent distance of the eclipsed satellite from the eclipsing one (in arcseconds).

Planet(°) - elevation of the planet above the horizon (in degrees).

Sun(°) - angular apparent depth of the Sun under the horizon (in degrees).

Moon phase - Moon phase (0.0 for new Moon, 1.000 for full Moon).

Haasteita ja vaatimuksia

- ★ Sää !
 - ★ vain pieni osa tapahtumista on havaittavissa
- ★ Kuiden kirkkaus
 - ★ lyhyt valotusaika -> skintillaatio -> kohina
- ★ Ajoitus (UTC)
 - ★ FITS aikaleimat (1s - 0.001s?)
 - ★ suljinviive (0.2s?)
 - ★ NTP palvelimen tarkkuus (0.1s?)
 - ★ Windows (0.1s?)
- ★ Fotometria
 - ★ Jupiterin valo
 - ★ Kohdistus liikkuvaan kohteeseen
 - ★ Suuri määrä kuvia





NSDB1-Access to Natural Satellites Astrometric Data Files

Observations of the mutual phenomena of the Galilean Satellites of Jupiter - Raw data

[guide for observations of the phenomena of the satellites](#)

Period of observations	Number of observations	of sites of observation	References	Download files		Available as standard data
				content	data1 data2	
1973-1973	1 observ.	1 site	Arlot et al (1974)	Content	Data1 Data2	no
1973-1973	46 observ.	17 sites	Aksnes et al (1984)	Content	Data1 Data2	no
1979-1980	9 observ.	7 sites	Arlot et al (1982)	Content	Data1 Data2	no
1979-1980	19 observ.	13 sites	Aksnes et al (1984 & 1984)	Content	Data1 Data2	no
1985-1985	167 observ.	25 sites	Arlot et al (1992)	Content	Data1 Data2	no
1990-1991	375 observ.	55 sites	Arlot et al (1997)	Content	Data1 Data2	no
1996-1997	275 observ.	42 sites	Arlot et al (2006)	Content	Data1 Data2	no
2003-2003	377 observ.	42 sites	Arlot et al (2009)	Contenu	Data1 Data2	no
2009-2009	457 observ.	74 sites	Arlot et al (2014)	Content	Data1 Data2	yes
2014-2015	607 observ.	74 sites	Saguet et al (2018)	Content	Data1 Data2	no
2014-2015	21 observ.	2 sites	Zhang et al (2018)	Content	Data1 Data2	no
2021-2021	85 observ.	29 sites	Emelyanov et al (2022)	Content	Data1 Data2	no
2021-2021	8 observ.	3 sites	Catani et al. (2023)	Content	Data1 Data2	no

Note: data1= data on the timing of the mutual events: date of the maximum in UTC and observed magnitude drop (until 1985 occurrence)
 data1= data on the astrometric positions extracted from the mutual events (from 2009 occurrence)
 data2= data of the observed photometric lightcurves; date and magnitude drop for each point

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Kysymyksiä?



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