

CALL FOR OBSERVATIONS:

## Eclipses of Amalthea and Thebe by the Galilean Satellites and by Jupiter

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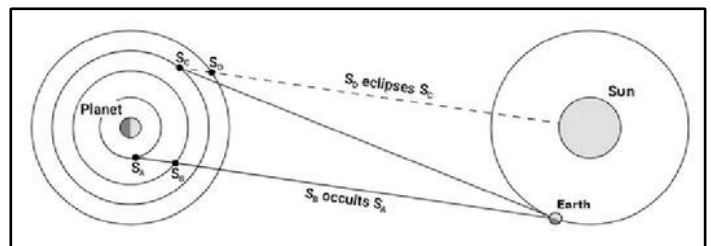
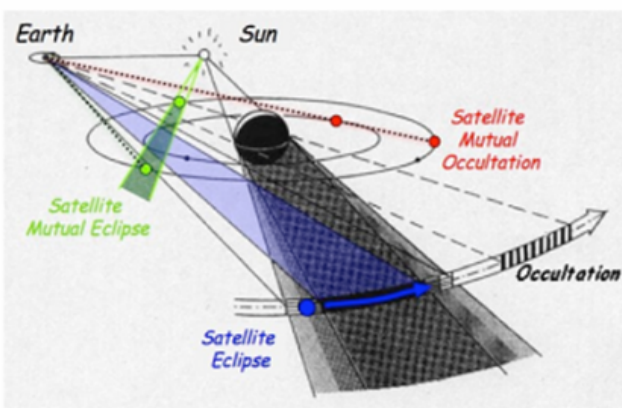
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**ABSTRACT:** The PHEMU (mutual phenomena) campaign is one of the oldest periodic ProAm collaborations proposed to the worldwide amateur community. About every 6 years, occultations and eclipses between the Galilean satellites provide very easy events to catch with small telescopes. Same synchronised phenomena could be observed from the hemisphere of Earth with Jupiter above the horizon. It enabled the improvement of ephemerides of these satellites which were the targets of space probes. These ephemerides now meet high accuracies thanks to these space missions or exceptional stellar occultations. Small inner Jupiter satellites could be the target of amateurs to improve their respective ephemerides. It will allow us to place constraints on the radial density distribution inside Jupiter. These events are more difficult to catch. However, previous recordings and trials performed with new sensitive digital cameras demonstrate selected events are now in the range of amateur abilities. This paper is introducing the 2026 - 2027 campaign to the amateur community able to deal with telescope availability, longitudes and weather constraints. In the coming year, amateurs have dates with the best eclipses of Amalthea and Thebe close to when Jupiter is at quadratures. Paris Observatory LTE is waiting for your accurately time-stamped light curves!

### Introduction

Since 1973, every six years for about one year, the mutual phenomena of Jupiter's moons have provided a rendezvous between observers and celestial mechanics. These observations have greatly contributed to improve our understanding of the dynamics of Jupiter's moons and their ephemerides [1], [2]. The last observation campaign took place in 2021, and another campaign is being planned for 2026-2027.

The Galilean moons are celestial bodies well known to all observers. They have always been a favourite of researchers, and even more since they became a target for space probes. They are fast-moving bodies perturbed by the Sun, the oblateness of Jupiter and Saturn, and also by each other. These characteristics make them a solar system in miniature, where certain poorly understood effects can be observed more quickly. Curiously, they are not the most frequently observed bodies in the solar system, even though they are among the brightest. In fact, it is their magnitudes (they are too bright!) that hinder their observation and, to measure their positions, we have often used the observation of their eclipses by Jupiter or, better, their mutual eclipses and occultations (Figures 1a, 1b).



Figures 1a, 1b. The configurations allowing the phenomena of eclipses and occultations. The maximum angular shifts between Earth and Sun are met during the 2 quadratures, they bring the best conditions to catch the eclipsed satellite light curve.

Jupiter also has other moons, much smaller and less bright: a series of small bodies between Io and Jupiter, and another series beyond Callisto. The latter are easy to observe (Jupiter is far away and not troublesome), but the former, closer to the planet, are flooded in Jupiter's halo and difficult to detect. Yet, scientifically, a precise understanding of their motion can tell us about the actual nature of Jupiter. Our knowledge of the dynamics of these moons is still incomplete. For example, the accuracy of the ephemeris of Amalthea is on the order of 200 km, while that of the Galilean moons is about 30 km. This is why astrometric observations are encouraged, and, of course, so are observations of their eclipses. During the 2009 and 2015 campaigns, professionals and amateurs successfully recorded some events with 2 m, then 1 m and 60 cm telescopes [3], [4]. Thus, for the very favourable period of 2026-2027, we propose here a campaign to attempt observations of the eclipses of the small inner satellites Amalthea and Thebe by the Galilean satellites or by the planet Jupiter.

### The 2026-2027 Occurrence

The period 2026-2027 is favourable for observing the mutual phenomena of Jupiter's moons : the planetocentric declination of the Earth and the Sun becomes zero (the Earth and the Sun are then in Jupiter's equatorial plane, which is also the orbital plane of the satellites) at a date close to Jupiter's opposition. The northern hemisphere is favoured, as Jupiter's declination is positive at these dates (Figure 2 and Table 1).

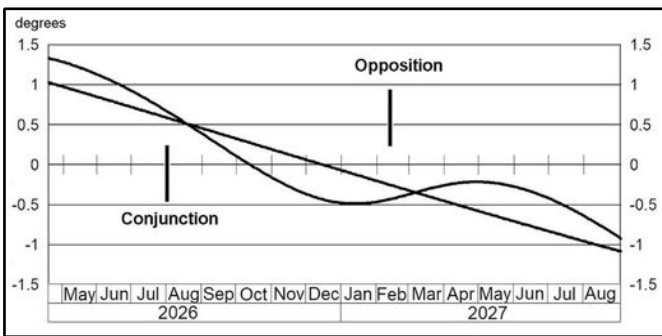
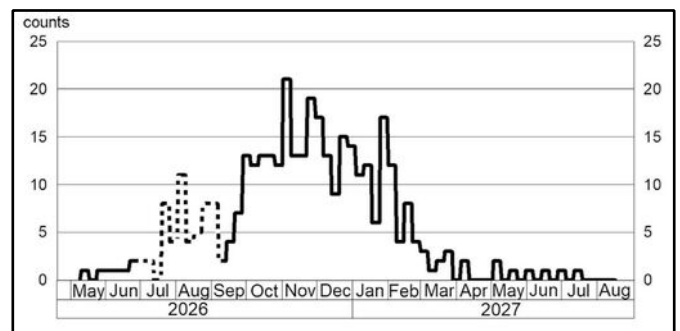
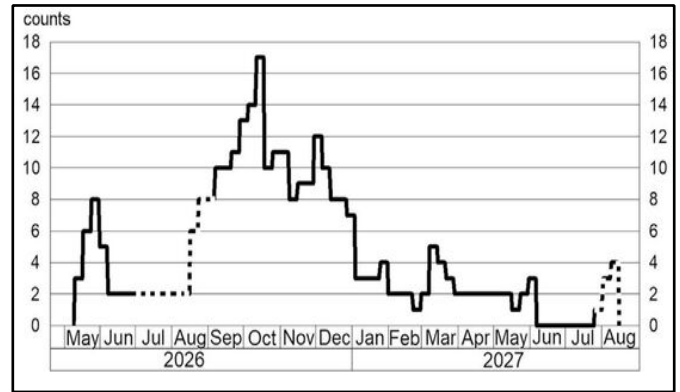


Figure 2. Planetocentric declination of the Earth and the Sun.



Figures 3a, 3b. The number of observable events (by week) of the Galileans (3a, top) and Amalthea and Thebe (3b, bottom). Dotted lines correspond to events too close to the conjunction of Jupiter and the Sun and so are unobservable.

Table 1 gives the key dates for observational conditions for the period 2026-2027: the best observations are made between opposition and quadrature, and the phenomena are more numerous near the equinox and when the Earth is in the orbital plane of the satellites.

Year	Date	Configurations
2026	April 5	Jupiter at quadrature
	May 11	Mutual events begin
	July 26	Conjunction of Jupiter and the Sun
	October 10	<b>Earth is in the orbital plane of the Galilean satellites</b>
	November 18	Jupiter at quadrature
2027	December 16	<b>Equinox on Jupiter</b>
	February 11	<b>Opposition of Jupiter</b>
	May 16	Jupiter at quadrature
	August 10	Mutual events end
	August 25	Conjunction of Jupiter and the Sun

Table 1. the observational conditions depend on key dates and defined time periods shown in Figures 3a and 3b.

Satellites	Periods of revolution	Eccentricities	Inclinations to Jupiter's equator (°)	Magnitudes at opposition	Maximum elongation at opposition
Amalthea J-5	11.956296 h	0.003	0.4	14.1	59 arcsec
Thebe J-14	16.188 h	0.015	0.8	15.7	73 arcsec

Table 2. Characteristics of Amalthea and Thebe.

## The Satellites Amalthea and Thebe

Among the small inner satellites of the Jupiter system, we will limit our observations to the satellites Amalthea and Thebe because they are the brightest (magnitude 14 and 16) and therefore the most accessible even if their detection and observation remains a challenge.

We can see that these satellites always remain very close to the planet Jupiter. Therefore, they must be observed when they are close to their maximum elongation, but for observing eclipses, the timing is not a matter of choice. Amalthea is brighter but it is closer to Jupiter than Thebe. Therefore the ability to detect them are in the same range (Figure 6), in the most favourable conditions, with maximum elongations. Of course, we are not chasing transits or occultations of small satellites with Galilean satellites but only eclipses. The most interesting geometry to catch eclipses is around the quadrature periods (Figures 1a, 1b and 3b). This allows to get Amalthea and Thebe far from the eclipsing Galilean satellite while crossing its shadow. We may notice in Table 2, Amalthea's period is 11.956296 h, it is very close to the half Earth sidereal period: 11.967146 h. Therefore, one night before an event or one Earth sidereal period (23h56m04s) or two Amalthea periods around Jupiter, you get a similar geometry of the relative angular position of Amalthea vs Jupiter and a similar Jupiter angular line of sight (Azimuth and Elevation) in the sky from your observatory to train yourself, record and measure your SNR.

## The Eclipses

These satellites undergo two types of eclipse: eclipse in the shadow of the planet Jupiter and eclipse in the shadow of a Galilean satellite.

### • Eclipses in the shadow of Jupiter

Jupiter's shadow is very large, and the satellites are very close. Therefore, there is an eclipse at each revolution of the moon around the planet. Unfortunately, all phenomena will not be easy to observe, why? It's important to note that such an eclipse corresponds to an alignment of the Sun, Jupiter, and satellite. Thus, from the Sun, we cannot observe such an eclipse, and unfortunately, viewed from Jupiter, the Earth is very close to the Sun, so the eclipse is hardly more visible from Earth than from the Sun. We must therefore wait until the Earth is as far from the Sun as possible, as seen from Jupiter, in order to have the eclipse occurring as far away from one

side of the limb of Jupiter as possible. These are the periods close to the two quadratures, while opposition being the worst time! In addition, we have to remember that Jupiter's atmosphere gives a blurred shadow giving a gradual light curve attached to an eclipse.

### • Eclipses in the shadow of the Galilean satellites

The shadows produced by the Galilean moons are much smaller than Jupiter's, and for the occurrence of an eclipse, the Sun, the smaller moons, and the Galilean moons must be in the same plane. This happens around the equinox on Jupiter because all the moons are in Jupiter's equatorial plane. Eclipses can therefore occur whenever the Sun passes through this plane, which is during a period of several months around the equinox (every six years). For this campaign the events around the 18<sup>th</sup> of November will be the most favourable.

## The Observation of Eclipses

Please, refer to the technical notes concerning the observational techniques for Jupiter satellites mutual phenomena [5], [6] and Saturn satellites mutual phenomena [7], [8]. However, there are some important differences compared to phenomena involving only the Galilean satellites:

- Observations are simpler because the photometry does not need to be absolute: it's an ON/OFF phenomenon. The flux drop does not need to be quantified and measured; it is total. The satellite is visible and disappears as it enters the umbra, more or less rapidly depending on the penumbra surrounding the satellite's shadow. The eclipse ends when the satellite emerges from the umbra and the penumbra. It is necessary to time – very precisely in UTC to better than 0.1 seconds – the entry and exit of the satellite from the shadow of the Galilean satellite that is eclipsing it; that is, the beginning and end of the eclipse (the timings are given in the predictions).
- Observations are more difficult because the satellites are magnitude 14 (Amalthea) and 16 (Thebe), and this occurs very close to the planet Jupiter, which floods the satellites in a halo that must be mitigated. Amalthea is the brightest and can be up to 59 arcseconds from Jupiter, or 34 arcseconds from the planet's bright limb. Thebe is the faintest but can be up to 72 arcseconds from Jupiter, or 47 arcseconds from the limb. Unfortunately, the eclipses do not necessarily occur at the time of elongation.

The observational methods will therefore differ from those used to observe the Galilean moons.

• **Faint objects**

The faint magnitudes of the satellites will require the use of telescopes with a sufficient diameter to reach magnitude 14 for Amalthea (easy) and 16 for Thebe (difficult) with limited exposure to be above a minimum frame rate to improve timing resolution of the event. In previous recordings [4] rates were lower than 0.04 Hz for 20 s exposures. The eclipse monitoring was done for 15 min around the predicted event. Most of the event durations are in the range of 1 to 5 min except four events in the range of 13 min and 60 min. Again, we need to get your precise time-stamped light curve of the eclipse ingress and egress. Normally, a 30 cm telescope can detect an object of magnitude 14, but in our case, we need to record a fairly fast light flux drop, and we cannot integrate the light over too long a time for a wished 10 s exposure to be above 0.1 Hz (1 frame per 10 seconds). A 60 cm telescope is therefore much better suited. For Thebe, a 1 m telescope was necessary. Thanks to the sensitivity improvement of digital APS CMOS cameras have shown, the satellite could now come into the range of smaller telescopes. Very clean optics are an important requirement to meet these events.

• **The presence of a bright Jupiter**

The planet Jupiter is very bright, and Earth's atmosphere, along with optical scattering, propagates a halo of light over a great distance, enveloping the moons. They must be visible in order to unambiguously determine the timing of their disappearance into the shadow of the planet or another moon.

To observe these moons, it is important to observe from a site far from any light pollution, high above the horizon, with a sky free of even the slightest haze. The most troublesome source of light pollution is Jupiter's own. One way to reduce it is to use a methane (CH<sub>4</sub>) filter, which darkens the planet's atmosphere by a factor of about 10 (Figures 4a and 4b) with a filter wavelength transmission bandwidth between 880 and 900 nm. The drawback is that this also reduces the amount of light from the satellite (though less than that from Jupiter's atmosphere, thus increasing the contrast) at the detector, requiring a more powerful telescope. This solution was successfully used by B. Christophe and O. Dechambre [4] with a 60 cm telescope in using an Edmund 890 nm, 10 nm bandwidth filter (Figure 9), in front an EMCCD Raptor Camera.

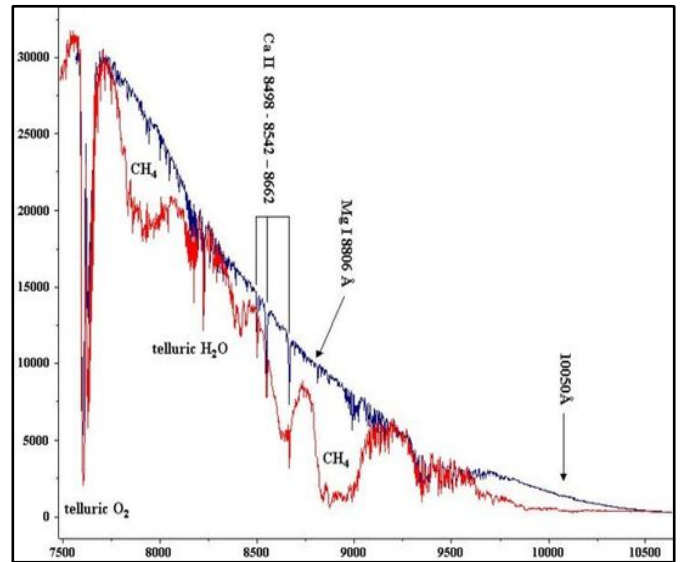


Figure 4a (top). Jupiter's atmospheric spectrum showing the CH<sub>4</sub> absorption bands. The absorption spectrum darkens the planet; the 890-900 nm band must be chosen, and a larger telescope is then required. (Observatorio Astronomica "G.V. Schiaparelli" Spettrometria, [9])

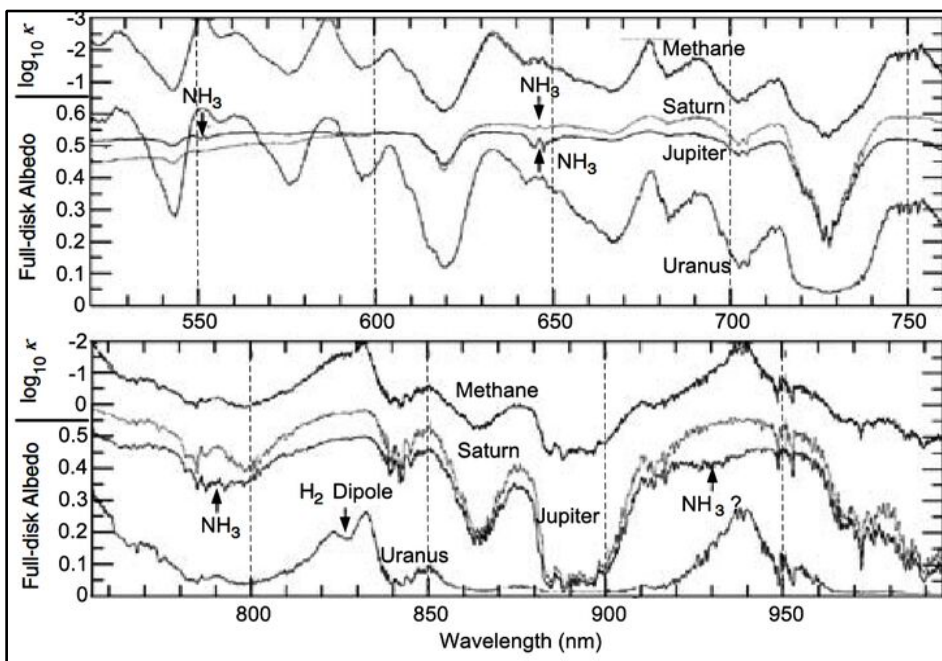


Figure 4b. Full disk albedo spectrum of Saturn, Jupiter and Uranus showing the 880 – 900 nm Methane absorption band. (from M. Mohler, J. Bühl et al. Exp Astron, [10])

Another way will be to put a mask in front of the focal plane on the detector cover glass or the camera window. The size of the mask is fitted to the defocused image size of Jupiter, in order to block the glare from the planet and to detect the satellite outside of the mask. A sharp edge alumina ribbon or a black velvet-like coated ribbon could be an effective solution. Figure 6 shows an image made by F. Colas at Pic du Midi with the 1 m telescope [4].

These methods need many training runs before the occurrence of the phenomena to allow you to tune exposure time, then frame stacking to measure your effective SNR (Signal to Noise Ratio).

### • When could we observe?

Observations of Amalthea's (or Thebe's) eclipses in the shadow of Jupiter must be made when these bodies are at the greatest possible angular distance from Jupiter's limb. The most observable planetary eclipses will be those occurring near quadratures, but even then, the distance from Jupiter's limb will be a maximum of 8 arcseconds for Amalthea and 10 arcseconds for Thebe.

Mutual eclipses, that is, eclipses of Amalthea and Thebe by a Galilean moon, are far more favourable in every respect: from an astrometric point of view, the connection with the eclipsing object is much more precise than with Jupiter's shadow (Galilean moons have no atmosphere), and from an observational point of view, the distance to the planet's limb is greater (however, note that the eclipsing satellite can be close to the small eclipsed satellite, and the difference in magnitude is significant (14 or 16 for small moons and six for Galilean moons). The distance to the Jupiter limb can reach 40 arcseconds. Table 3 lists the eclipses of Amalthea that are easiest to observe from Paris (and throughout France), and Table 4 lists those of Thebe.

From the web sites [11] you may compute the inner satellite events from your observatory, and the web sites [12], [13], [14], [15] and [16] you may get all the data related to Galilean satellites and useful data to prepare your campaign.

Observatory N: 007 - Paris																
Timescale: UTC.																
Mutual events of satellites J1, J2, J3, J4 eclipsing J5:																
Date	begin: h	m	s	end: h	m	s	Type	Dur(m)	Impact	m	$\Delta m$	limb(")	dist(")	Planet(°)	Sun(°)	Moon phase
2026	11	8	2 55 50	4	3	28	4E5	67.6	0.999	14.69	-	27.24	86.71	33.783	-38.022	0.076
2026	11	10	4 44 58	4	47	48	1E5	2.8	0.184	14.67	-	26.69	21.56	49.509	-20.771	0.066
2026	11	17	5 20 41	5	22	41	1E5	2.0	0.134	14.63	-	11.16	27.28	54.019	-16.446	0.484
2026	11	26	3 7 13	3	10	23	1E5	3.2	0.166	14.57	-	29.12	21.35	44.535	-40.108	0.879
2026	12	3	3 47 20	3	49	25	1E5	2.1	0.105	14.53	-	14.52	27.09	51.602	-34.856	0.369
2026	12	10	2 35 45	2	39	59	3E5	4.2	0.384	14.48	-	23.72	56.27	47.128	-47.415	0.070
2026	12	12	1 27 28	1	31	4	1E5	3.6	0.293	14.47	-	31.02	19.38	39.115	-57.273	0.184
2026	12	19	2 13 57	2	16	6	1E5	2.1	0.129	14.43	-	17.57	24.55	48.705	-51.742	0.627
2026	12	24	5 10 17	5	12	51	1E5	2.6	0.420	14.39	-	22.79	20.03	49.855	-23.813	0.975
2026	12	27	23 44 5	23	48	40	1E5	4.6	0.292	14.37	-	32.01	15.50	33.321	-64.594	0.697
2027	1	4	0 40 39	0	42	54	1E5	2.2	0.109	14.34	-	20.29	19.41	45.748	-62.620	0.230
2027	1	9	3 34 57	3	37	32	1E5	2.6	0.080	14.31	-	21.47	15.92	52.713	-39.840	0.079
2027	1	12	21 51 29	21	59	15	1E5	7.8	0.223	14.30	-	30.91	9.93	26.375	-52.808	0.309
2027	1	14	23 1 11	23	6	48	3E5	5.6	0.096	14.29	-	29.75	31.92	38.767	-60.097	0.442
2027	1	19	23 7 36	23	9	58	1E5	2.4	0.100	14.27	-	22.58	11.84	42.956	-59.510	0.801
2027	1	25	2 1 29	2	3	22	1E5	1.9	0.632	14.26	-	20.07	9.21	54.784	-52.030	0.802
2027	2	19	19 20 1	19	25	7	3E5	5.1	0.821	14.25	-	33.89	11.82	30.151	-20.575	0.912
2027	3	21	2 56 24	3	47	18	1E5	50.9	0.974	14.35	-	30.18	12.06	16.062	-28.017	0.904

Table 3. The best eclipses of Amalthea observable in France and in Europe (calculations made for Paris)

Legend:

*Dur(m)* is the duration of the eclipse in minutes

*Impact* corresponds to the minimum distance between the satellite and the centre of the shadow (0 for the centre, 1 for the radius of the eclipsing satellite)

*m* is the magnitude of Amalthea

*limb(")* is the angular distance from Amalthea to the limb of Jupiter in arcsec

*dist(")* is the angular distance from Amalthea to the eclipsing satellite in arcsec

*Planet(°)* is the elevation of Jupiter in Paris

*Sun(°)* is the elevation of the Sun in Paris

*Moon phase* is the phase of the Moon (1 = Full Moon, 0 = New Moon)

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v5.21.05i Planet: Jupiter (INPOP17a)
Planet
Observatory N: 007 - Paris
Timescale: UTC
Mean equator and equinox of J2000. ICRF.
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Mutual events of satellites:

Date	begin: h m s	end: h m s	Type	Dur(m)	Impact	m	$\Delta m$	limb(")	dist(")	Planet( $^{\circ}$ )	Sun( $^{\circ}$ )	Moon phase
2026	9 28	2 44 58	2E6	1.6	0.761	16.50	-	12.35	25.36	10.909	-28.828	0.893
2026	10 12	7 17 32	2E6	0.4	0.993	16.43	-	19.99	29.32	54.976	10.620	0.115
2026	10 18	4 31 3	1E6	2.3	0.167	16.40	-	26.60	21.65	37.996	-17.681	0.472
2026	10 28	2 52 28	3E6	14.5	0.327	16.35	-	12.48	40.10	27.419	-35.843	0.849
2026	10 28	4 56 21	3E6	12.9	0.389	16.35	-	36.81	44.62	45.965	-15.898	0.842
2026	11 6	5 25 46	2E6	2.0	0.538	16.30	-	4.89	38.90	52.120	-13.171	0.197
2026	11 8	2 34 49	4E6	4.7	0.488	16.29	-	25.41	95.41	30.450	-41.224	0.077
2026	12 3	0 20 14	3E6	3.4	0.837	16.13	-	40.22	55.97	23.059	-62.242	0.379
2026	12 5	0 18 56	1E6	3.9	0.124	16.11	-	42.09	19.28	24.090	-62.628	0.249
2026	12 19	4 6 20	1E6	3.9	0.400	16.02	-	43.50	17.17	54.656	-33.908	0.632
2026	12 24	4 22 42	1E6	3.0	0.346	16.00	-	35.48	19.26	53.536	-31.636	0.976
2027	1 22	0 34 25	3E6	3.5	0.413	15.87	-	2.98	27.42	53.450	-60.396	0.961
2027	1 26	20 31 14	1E6	1.4	0.784	15.85	-	18.80	9.56	23.595	-37.898	0.673
2027	1 28	21 57 37	3E6	0.9	0.985	15.85	-	35.34	17.65	38.846	-50.068	0.533
2027	2 3	3 1 8	1E6	1.5	0.772	15.84	-	23.57	4.65	45.685	-42.044	0.213
2027	2 11	22 20 55	1E6	2.0	0.040	15.84	-	1.94	1.59	50.642	-48.987	0.338
2027	2 26	2 16 51	1E6	1.3	0.777	15.86	-	1.15	11.02	38.168	-41.420	0.632
2027	3 6	3 13 42	3E6	2.2	0.899	15.88	-	28.96	30.53	23.536	-31.143	0.141
2027	3 8	19 11 48	1E6	3.2	0.303	15.89	-	39.70	12.83	41.073	-14.907	0.032
2027	3 22	23 5 14	1E6	3.5	0.169	15.96	-	39.17	17.02	50.430	-39.100	0.955

Table 4. The best eclipses of Thebe observable in France and in Europe (calculations made for Paris).

• **What is needed to observe?**

We have seen that a powerful telescope is necessary. In fact, to observe a celestial object of magnitude 14, a very large telescope is not required; a 30 cm telescope may be sufficient. For a magnitude 16 object, a 60 cm telescope is sufficient. However, in the case of Amalthea and Thebe, we recommend telescopes of 60 cm (for Amalthea) and 1m (for Thebe) and as you will see in chapter 'Trials with a C11', now 30 cm telescopes could be successful. The presence of a bright Jupiter nearby will also necessitate a perfect sky, perfect optics, and a perfect receiver. To reduce the brightness of Jupiter, two methods are possible:

- either block Jupiter using a cleverly placed mask in front of the receiver; this is feasible but difficult and requires careful preparation (see Figure 6).
- either use a filter (see Figure 9): Methane infrared filter from 880 to 900 nm. The absorption spectrum of methane darkens Jupiter's atmosphere. In this case the received flux decreases and it is necessary either to have a larger telescope or to integrate the light with longer exposures. It seems today, according to the filter bandwidth and optical transmission, the best Methane filter is provided by ZWO (Figures 5a, 5b and 5c).

Since the goal is to precisely time a rapid transition, an extinction, or a reappearance (carefully planning the location before observing the reappearance!), desired exposures have to be around 1 s or less than 10 s, otherwise it will be impossible to time the mid-phenomenon within 0.1 s.

One advantage arises with these phenomena, which are total eclipses: therefore, precise photometry is unnecessary, as the light flux will disappear, and it is the times of the ingress then the egress we want to record. Managing offset and gain on an APS-CMOS sensor will allow us to accurately catch the sky background with the attached noise and maximise sensitivity. There are, therefore, choices to be made and several tests should be made before the observation of these satellites.

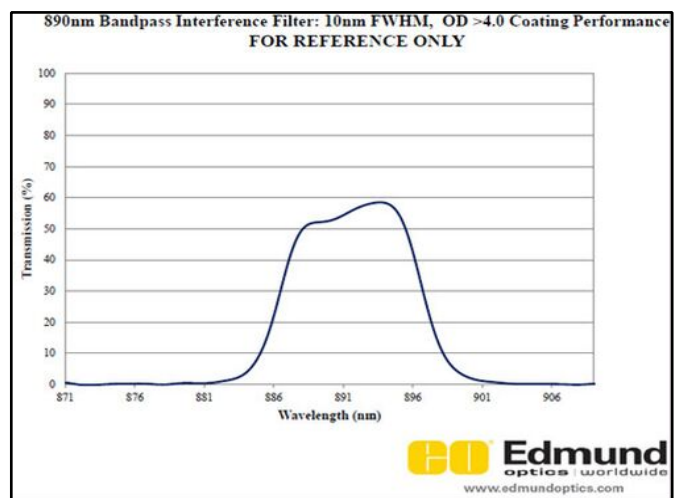


Figure 5a. Transmission curve of Methane fitted optical filter from Edmund 890 nm HBW 10 nm.

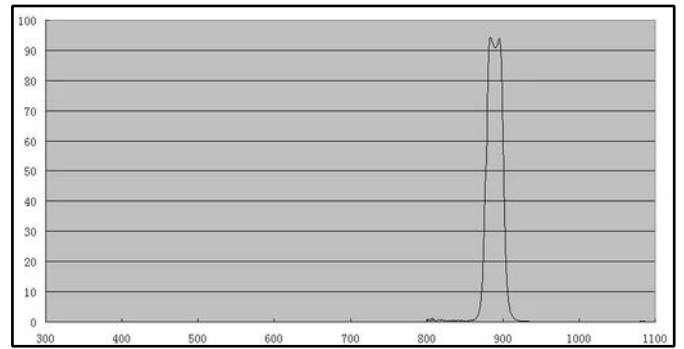
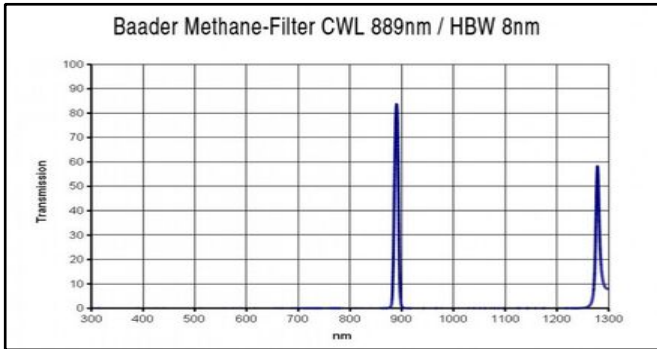


Figure 5b and 5c. Transmission curves of Methane fitted optical filters from Baader 889 nm HBW 8 nm (left) and from ZWO 20 nm FWHM (right).

## Observations Made in the Past

We show here an observation of Amalthea and Thebe made with the 1 m telescope from *Pic du Midi Observatory* (OMP Observatoire Midi Pyrenees) with a mask in front of Jupiter (Figure 6).

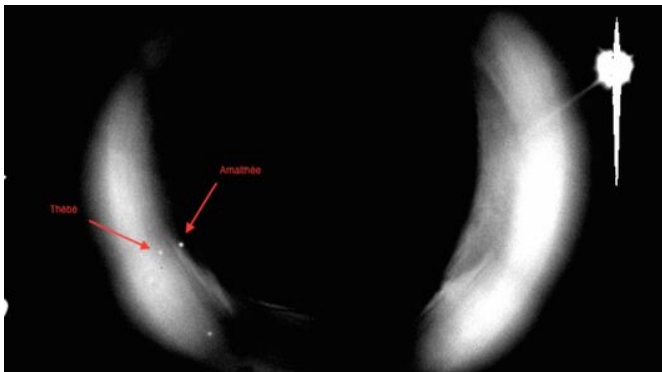


Figure 6. Amalthea and Thebe observed in visible light with a mask in front of the planet at Pic du Midi in 2015.

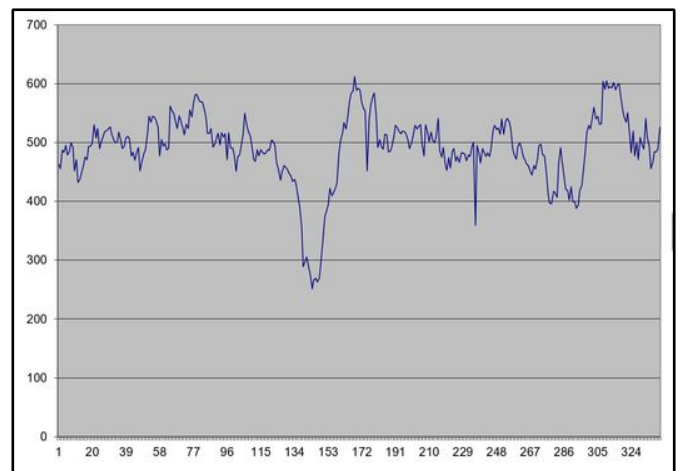
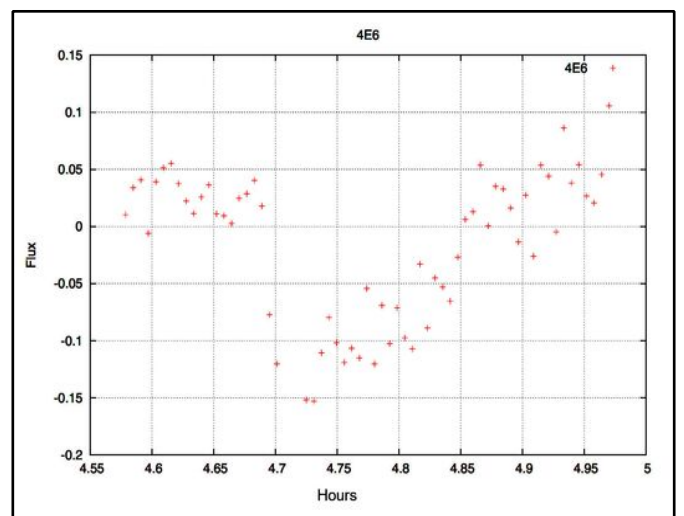
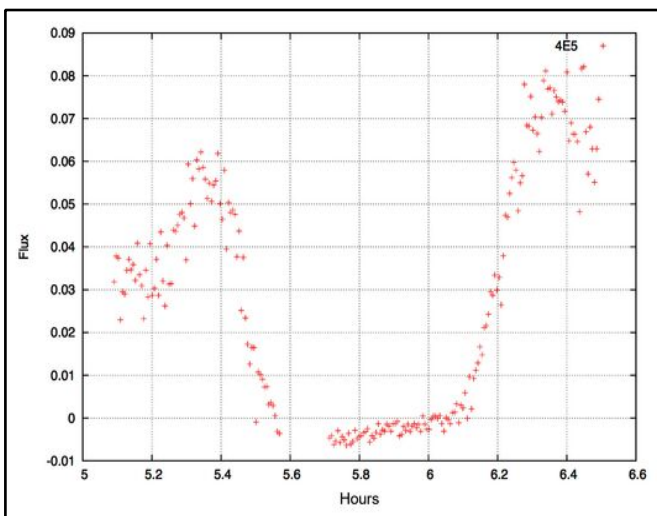


Figure 8. 2015 April 08, 20h18m00s +/-3 s UTC. Light curve of Europa eclipsing Amalthea (2E5) from 360 frames of 5 s exposure. The slipping stacking from 40 down to 5 frames along the 360 frames allows to perform a tradeoff between SNR and timing accuracy. It allows to detect the eclipse from the noise and to improve the edge timing on the light curve.

(B. Christophe, A. Fernandez processing, Meudon Observatory)



Figures 7a, 7b. Examples of light curves obtained. An eclipse of Amalthea (left) and of Thebe (right) by Callisto. (Pic du Midi with a mask on 2015 January 7)

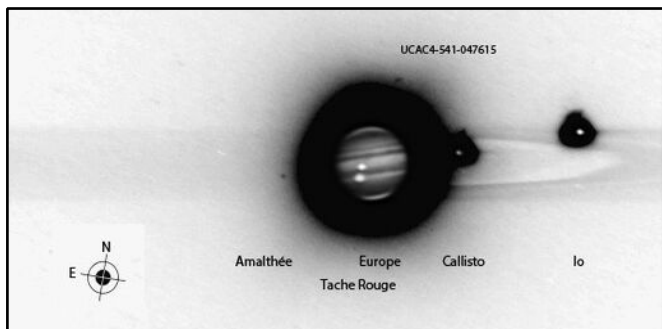


Figure 9. Stacked picture of Jupiter and Amalthea from Saint Sulpice 60 cm telescope with an Edmund 890 nm filter 10 nm (Figure 5a) in front of EMCCD Raptor camera using a 9  $\mu\text{m}$  pixel pitch EMCCD gain 50%, from Texas Instruments. Stack of 360 images of 5 s exposure for Amalthea and the star (20:20 UT), 360 images of 0.5 s exposure for the Galilean satellites and Jupiter (20:38 UT). (B. Christophe, O. Dechambre, Saint Sulpice Observatory, Club Eclipse, 2015 April 08)

## Trials with a C11

New APS CMOS (Active Pixel Sensor from Complementary Metal Oxide Semiconductor foundry) Cameras bring enhanced quantum efficiency in a wide spectral band, with small pixels allowing a nice sampling of the PSF (Point Spread Function) given by the telescope's native focal length and turbulence, with a less than  $1e^-$  rms read out noise in high gain mode. Thanks to the photodiode fill factor and thickness improvements new generation of Starvis Sony sensors brings this enhancement. Figure 10 shows the Quantum Efficiency from 400 nm up to 1000 nm of IMX462 Sony focal plane array. It is a full HD 1936  $\times$  1096 array, with 2.9  $\mu\text{m}$  pixel pitch and 0.5e rms read out noise in high gain mode. You may notice the 40% QE at 890 nm or more than 80% in the complete Visible band.

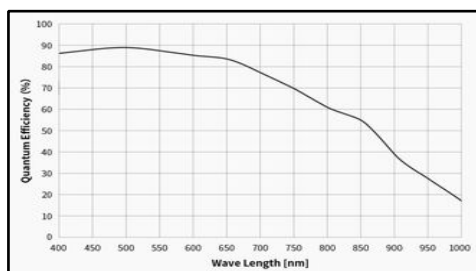


Figure 10. Quantum efficiency from latest SONY Starvis APS CMOS arrays IMX462.

Similar is the IMX585 providing a larger array. In using *SharpCap* you may accurately tune the exposure, the offset and the gain on the camera through several iterations, allowing you to put the image dynamic you need to record in the digital dynamic of the array to get both the sky background and the signal from the satellite you are looking for with the maximum sensitivity. Getting one Galilean, or better a nearby star, could be useful to track the field of view and perform frame stacking to enhance the SNR.

In addition, *SharpCap* allows you to have a smart and accurate frame time-stamping either coming from a GPS receiver like the TimeBox II or from Meinberg NTP if you are connected to Ethernet to drive the clocking of your PC.

This year M. Irzyk performed tests with a coronagraph-like sub-assembly on a C11 in order to reduce stray light. In the telescope focal plane aperture is integrated a wire with a diameter fitted to the Jupiter disk size. Then, a lens conjugates the telescope focal plane to the CMOS array. This is provided by a 25 mm macrolens in 1:1 ratio. A simple setup has been tested (during the full Moon period) in order to evaluate the efficiency of the occultation of Jupiter with a mask with the objective to increase the detectivity of Amalthea and improve SNR during Pheму events.

The setup (Figure 11) is using:

- a filter wheel ( for selection Clear, Red, CH<sub>4</sub>, ... band)
- a 3D printed part
- a wire placed at the telescope focal point. The wire diameter is fitted to the Jupiter's disk size.
- a 25 mm focal length macro 1:1 lens
- a CMOS camera using IMX 585

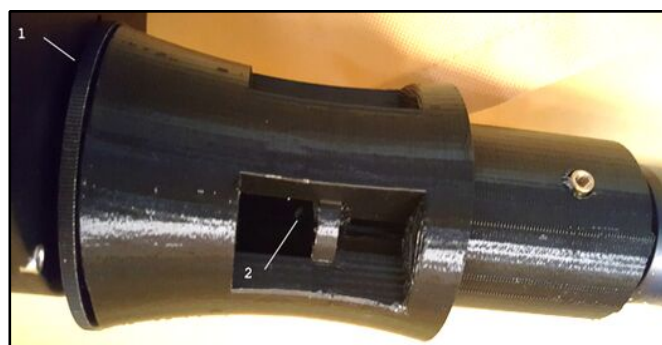


Figure 11. A specific 3D printing part has been used, linked to the filter wheel (location 1). The focus is achieved on a wire (placed in location 2). A 25 mm focal length macro lens reimages the wire in 1:1 geometry, (and so the focal plane) to the camera.

The lens is reimaging the wire (and so the telescope focal plane) on the camera. The wire has been selected to be slightly larger than Jupiter at the focus point. As a result, Jupiter is fully hidden, and only a part of the stray diffuse light is observed (Figure 12).

(Note: An autoguider would have improved the efficiency of the occultation, but was not available at the time of the test.)

The use of a relay lens with an occulting mask, slightly reduces the stray light around Jupiter and increases the SNR for the photometry measurement. It demonstrates that a 280 mm aperture with a modern CMOS camera can perform Amalthea detection. In addition, some stars in the field of view can be detected in the range of Amalthea's magnitude (Figure 13).

## The 2026-2027 Phemu Campaign

The 2026 – 2027 Phemu campaign has started thanks to the first light curves released on the 2026 May 15 from Victor Bao, New Zealand and from France by J.-F. Coliac from Marseille (Figure 14). These events are easy to record, it is a nice way to start to work in the field of occultations even with small telescopes. These time stamped recordings are less important now to improve the Galilean satellites ephemerides. However, accurate photometric light curves are interesting to probe the albedo of each satellite. Through a deconvolution process on the light curves, thanks to an accurate geometry built on accurate ephemerides, we may provide a map of the albedo distribution on the satellites. It could be done during the opposition period in a retroreflexion geometry and in the other periods with an aspect angle between the Sun illumination and from the Earth line of sight. Previous Phemu campaigns displayed some albedo discrepancies still to be understood.

## Conclusion

The 2026-2027 Phemu campaign is now open! Beyond the occultations and eclipses between the Galilean satellites, we are inviting the amateur community to chase the eclipses of the inner satellites Amalthea and Thebe. These observations are difficult, and satellite observations must be practiced before the occurrence of events to determine the feasibility and the best technique. The latest APS CMOS cameras bring improved sensitivity while reducing the pixel pitch allowing amateur telescopes from 60 cm down to 30 cm diameter to try to record such light curves. Observations are encouraged because they will be useful for improving dynamical models of these satellites and thus our understanding of the Jovian system and if we may detect tides on Jupiter. The improvement of the ephemeris of Amalthea and Thebe will allow the *Juice* Mission to capture images of these targets during flyby.

For more information  
and for sending the observations:

[phemu.imcce@obspm.fr](mailto:phemu.imcce@obspm.fr)

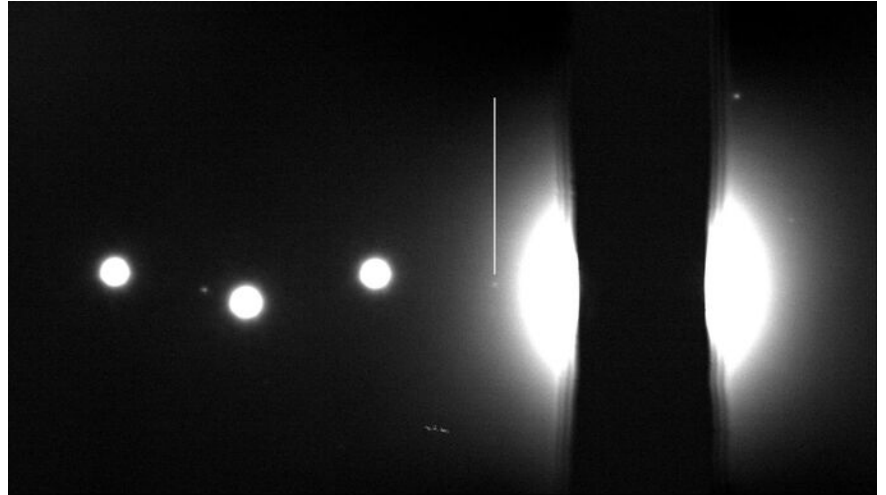


Figure 12. Stacked image of multiple short (140 × 0.5 s) exposure without any filter (Clear window). As no auto-guiding was used, the small variation of position of the mask produced the unsharp mask edge. Amalthea is clearly detected on the left of Jupiter. Figure 13 shows the identification of the detected targets.

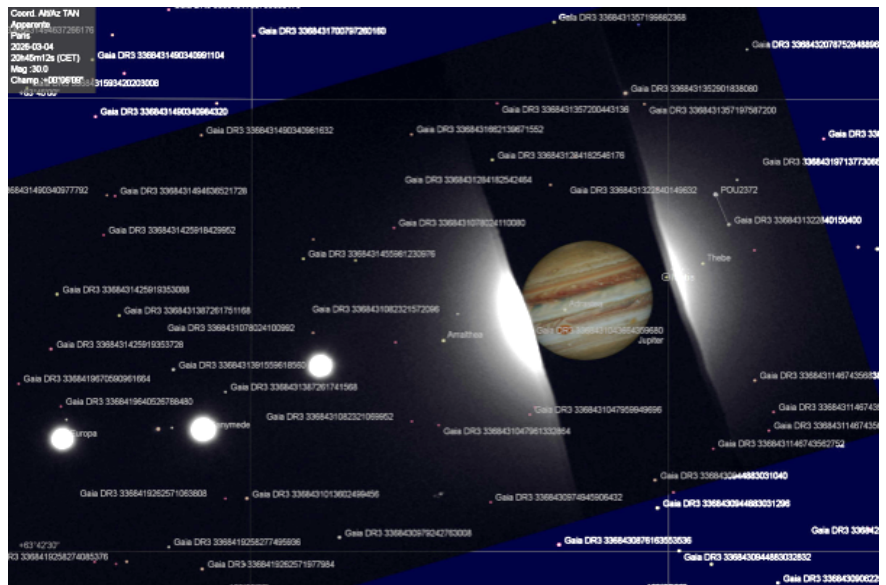


Figure 13. Due to the magnitude of Amalthea, cartography software (here Stellarium) is used to confirm Amalthea's position so as not to confuse it with nearby stars.

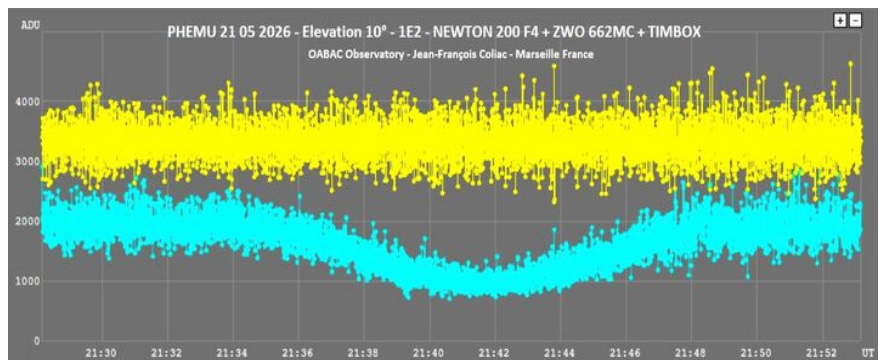


Figure 14. Phemu recorded on 2026 May 21 by J.-F. Coliac. Signal-minus-background, normalised, binning of 32 frames.

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## Articles and Web Links on Previous Phemu and PheSat

- [5] Arlot J.-E., Emelyanov N., The Campaign of Observation of Mutual Occultations and Eclipses of the Galilean Satellites of Jupiter in 2021. *Journal for Occultation Astronomy*, Vol. 10, No. 4, pp. 3-10, [https://iota-es.de/JOA/JOA2020\\_4.pdf](https://iota-es.de/JOA/JOA2020_4.pdf)
- [6] Campagne Phému 2021 Gemini Workshop proceedings (in French), <https://gemini.obspm.fr/20210101-phemus-2021/>
- [7] Campagne PheSat 2024 Gemini Workshop proceedings (in French), <https://gemini.obspm.fr/20240215-phesat/>
- [8] Observational campaign of the mutual phenomena of Saturn's and Jupiter's satellites, IMCCE web page, <https://www.imcce.fr/recherche/campagnes-observations/phemus/phemu>

## Links to Prepare the Upcoming Campaign

- [11] Inner satellites eclipses depending on the observing sites: <https://www.sai.msu.ru/neb/nss/html/multisat/nsszph519he.htm>
- [12] Formulaires de calcul des éphémérides SEOP: <https://ssp.imcce.fr/forms/satellites-events>
- [13] Natural Satellites Ephemeride Server MULTI-SAT: <https://www.sai.msu.ru/neb/nss/html/multisat/nsszph5he.htm>
- [14] Configuration of the Jovian system at any date: <https://www.sai.msu.ru/neb/nss/html/multisat/nssima5he.htm>
- [15] The site «Phemu26» providing information on the observations of mutual phenomena: <https://www.imcce.fr/recherche/campagnes-observations/phemus/phemu#1>
- [16] The site «Pro-Am Gemini» to link observers during the Phemu26-27 campaign: <https://gemini.obspm.fr/20260613-phemus-2026-2027/>