Mutual Events of Galilean Satellites

By Brad Young

Soon after learning about Jupiter and its four Galilean satellites, the next thing many amateur astronomers observe are the events between these satellites and their parent Jupiter. Watching each moon being occulted or eclipsed by Jupiter or transiting and casting its shadow on the giant planet's disc is an interesting thing to watch even years after you have learned about this phenomenon. However, there is a set of correlating events between the moons themselves that you may find even more interesting, although they are much rarer and can be more difficult to observe. These are the mutual events between each moon and one of its sisters, not the disc of Jupiter.

There are, as with the planet, occultations and transits. There are also partial and total eclipses which are visible when the shadow of the closer moon crosses or completely covers the moon behind it. The reason that the events are rare is that they occur during a time when we are passing through the plane of Jupiter's equator over which all the main satellites orbit. Only when they are all in our line of sight can they have mutual events. This occurs approximately every five years, centered around the sixth year, because we pass through this plane twice in Jupiter's 12-year orbit.

We are coming along to this point next year, and so the events are starting this year and will be visible as soon as Jupiter returns to the morning sky after passing through solar conjunction on July 29, 2026. By September, a few of the brighter mutual events may be visible, although the likelihood of you observing them will increase as the planet gets higher throughout autumn. There are several sites and resources available to plan for these events. I have listed a few below and have shown a partial example output for my location for upcoming season.

It is probably interesting also to many readers that there is an Astronomica League Observing Challenge associated with observing these phenomena. You may be familiar with Galileo's TOES Phase 1 challenge, which deals with the Jupiter and its moons events that many of us are able to see fairly easily. Galileo's TOES Phase 2 is the award for seeing the mutual events and comes in two classifications. One is seeing all the events for a season such as the upcoming one and the other is an award (the "Complete" version) for seeing all the events that are possible, which may require more than one season to accomplish. For the 2026-2027 season, it is possible to see all the events and complete both versions of the award. For further details see the Jupiter toes observing challenge page at the AL site: https://www.astroleague.org/galileos-t-o-e-s-phase-2/

To successfully observe these events, it's important to realize they are not quite like their more visible partners with the Jupiter disc. The occultation or transit of one Moon by another may not decrease the total magnitude of the two moons by much at all so be prepared and look carefully as the event occurs. With the eclipses, a partial eclipse will of course be more difficult to see

than a total eclipse. However, eclipses can occur with the two moons separate from each other, unlike occultations so it is possible to view one Moon seeming to dim while the other remains at the same magnitude. Not all these events are easy to see or very impressive visually or with imaging, but the events are quite interesting when you realize what's happening. If you image these events and can provide photometric data with accurate time included, you can report your findings to such and such and they will be used to check the physical characteristics of the Galilean satellites.

Resources

IMCEE – French campaign to plan and report observations of mutual events of satellites: https://www.imcce.fr/recherche/campagnes-observations/phemus/phemu

NASA list of satellite numbering scheme for output of predictions: https://naif.jpl.nasa.gov/pub/naif/toolkit_docs/C/req/naif_ids.html#Planets%20and%20Satellites

Example of output I adapted from output of IMCEE site for my location – on Sep 5 at 5:35 a.m. CDT, Io partially occults Europa for 4.7 minutes.

		TIME CT	DURATION (MIN)	A		B
SEP	5	5:35	4.17	501	OC(P)	502
SEP	24	4:57	5.54	502	EC(P)	501
OCT	2	5:10	7.29	502	OC(P)	503
OCT	14	4:50	4.96	501	EC(A)	502
OCT	14	5:40	4.51	501	OC(P)	504
OCT	22	4:19	3.74	504	EC(P)	501
OCT	26	3:08	6.42	502	EC(P)	501
OCT	30	2:31	9.37	502	EC(A)	504
NOV	2	4:26	6.34	502	EC(P)	501
NOV	4	3:00	7.56	503	EC(P)	502
NOV	18	2:08	1.12	503	OC(P)	501
NOV	21	5:32	12.2	502	OC(P)	503
NOV	25	2:55	4.77	503	EC(P)	501
NOV	27	12:41	4.16	502	EC(P)	501

501	'IO'
502	'EUROPA'
503	'GANYMEDE'
504	'CALLISTO'

Other data included in the output (not shown here) will help determine the suitability of an event. For instance, the Sep. 5 event above also has these parameters:

I	Δf (%)	D (r)	S (")	H (°)	H ⊙ (°)	Phase ☾ (°)	e ☾ (°)
0.29	32	2.71	0.22	10.3	-16.8	104.6	46.5

I	Impact parameter – from 0 for a central phenomenon to 1 for a grazing phenomenon.
Δf	Maximum flux drop.
D	Distance from the satellite undergoing the phenomenon to the limb of the planet, referred to the apparent radius of the planet in the direction of the satellite at the maximum.
S	Angular distance between the two bodies involved at the time of the maximum.
H	Elevation of the planet (without refraction) with respect to the horizon.
$H_{\odot}$	Elevation of the Sun (without refraction) with respect to the horizon.
$Phase_{☾}$	Phase of the Moon.
$e_{☾}$	Elongation between the planet and the Moon – angle between the Earth-planet's direction and the Earth-Moon direction.

So, we see it is an impactful event, with 32% of the flux (brightness) diminished for the pair, and it is 2.7 Jupiter radii away from Jupiter. The planet is 10° up and the Sun still 17° below the horizon, so it would be a challenge but is visible. The waning moon is 47° away and not an issue.

Note that the output is very complete and you may want to filter Jupiter events, those of lesser moons and change formats.