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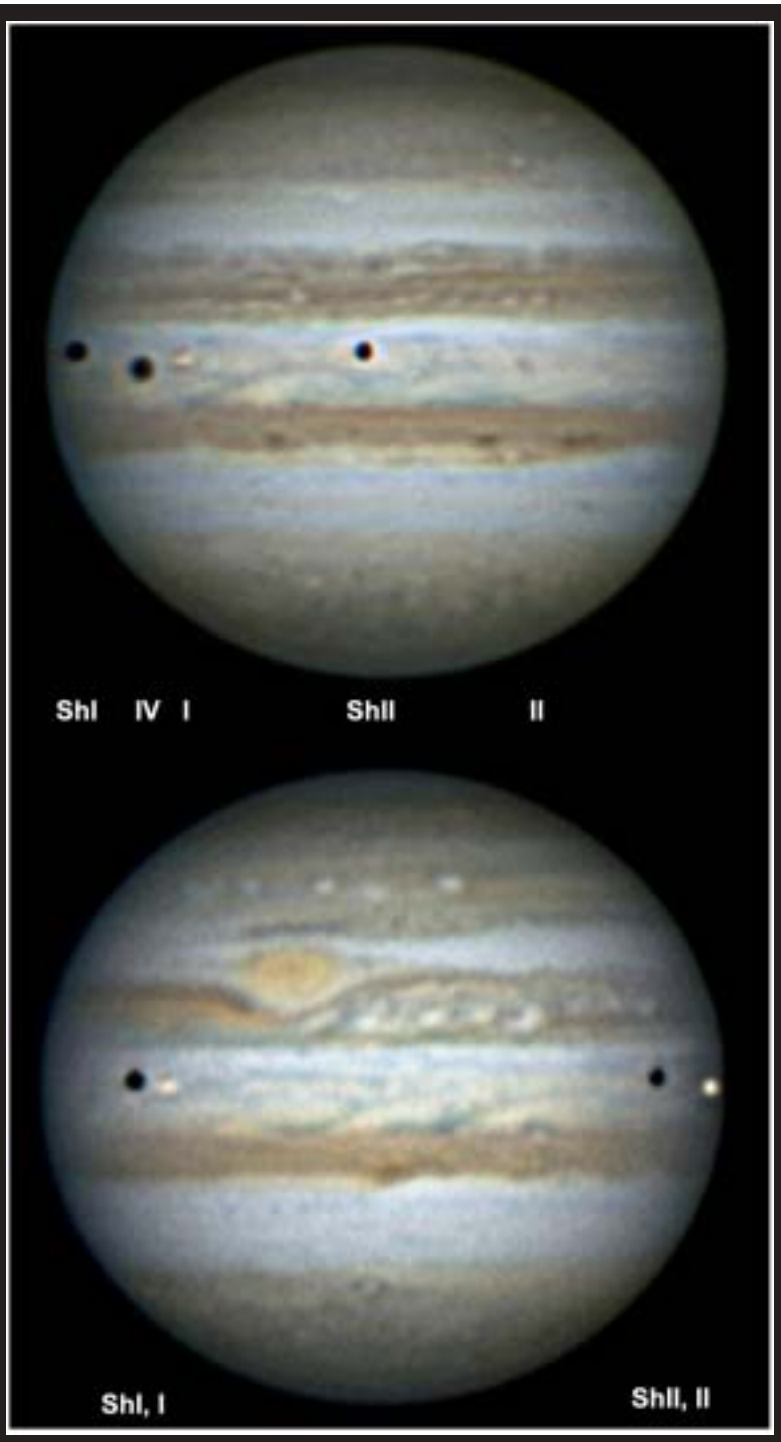

Moons over Jupiter: transits and shadow transits

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(see also page 128)

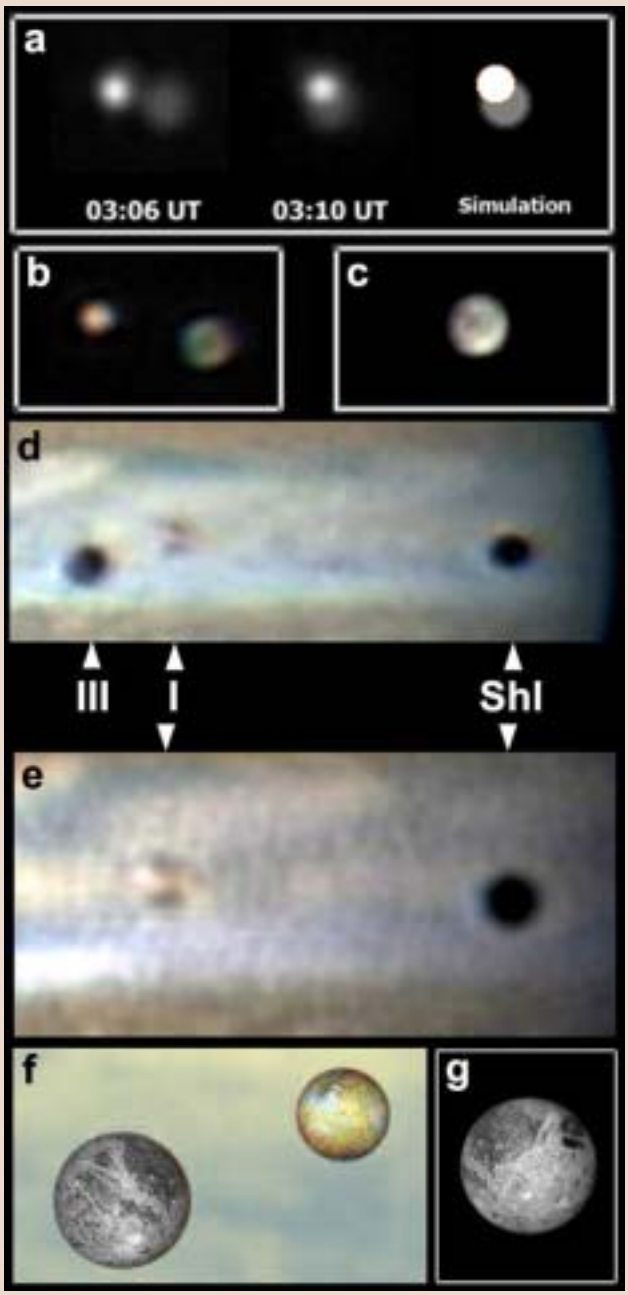

Figure 1. Some of the highest-resolution views of Jupiter's satellites so far obtained by amateurs, including surface detail on Io (I) and Ganymede (III). North is up (whereas south is up in all other images). **(a)–(d)** by Damian Peach (Tenerife), **(e)** by Eric Ng (Hong Kong).
(a) Io (I) occults Callisto (IV): 2002 Dec.24, 03.06 and 03.10 UT.
(b) Close passage of Io and Ganymede: 2002 Dec.26, 02.34 UT. The satellite diameters are 1.1" and 1.6" respectively.
(c) Best view of Ganymede: 2002 Dec.10, 04.31 UT.
(d) Ganymede and Io in transit over Jupiter's equator, with shadow of Io: 2003 Jan.2, 02.24 UT. Ganymede appears dark in transit, especially its Np. (top right) part which is the dark plain, Galileo Regio. Io's shadow is elliptical as it moves towards the terminator.
(e) Io and its shadow in transit again, at higher magnification: 2003 Jan.12, 17.09 UT. The detailed shape of the dark reddish polar caps agrees well with the spacecraft view below.
(f, g) Simulated spacecraft images matching (d) and (c), from the NASA-JPL Solar System Simulator <http://space.jpl.nasa.gov>. Both views of Ganymede show the large circular dark plain, Galileo Regio, which is clearly visible on the actual images.

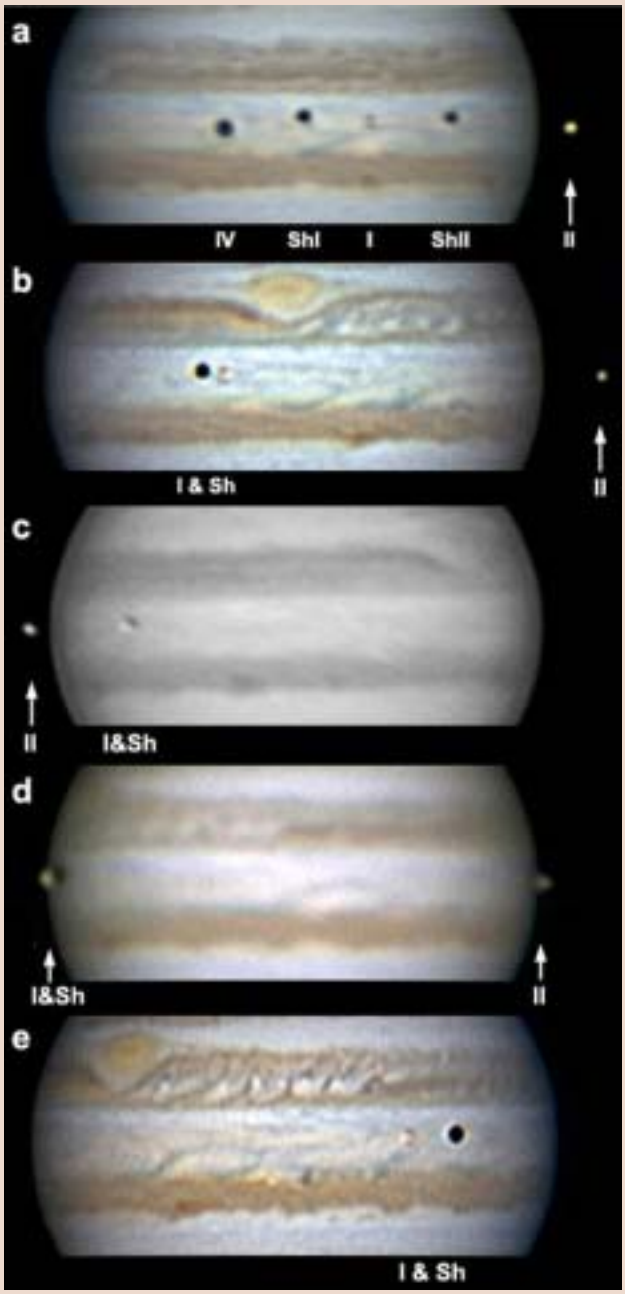

Figure 2. A series of transits of Io (I), also involving Europa (II). The dark reddish poles of Io are resolved in transit. Also one can see how Io's shadow precedes the satellite before opposition, is partly occulted by it on the night of opposition (Feb.2), and follows it after opposition. South is up. Images (a,b,d,e) were taken at multiples of Europa's orbital period (3.5 days) and on each occasion Europa transited shortly after Io. Image (c) was taken at an alternate orbit when Europa was about to be occulted behind the planet.
(a) 2003 Jan.17, 23.39 UT; Peach. This was during the triple transit with Callisto also in transit; see also Figure 3.
(b) 2003 Jan.28, 14.55 UT; Ng. (Also see the cover picture.)
(c) 2003 Feb.2, 22.41 UT; Lazzarotti.
(d) 2003 Feb.4, 17.28 UT; Lau.
(e) 2003 Feb.11, 17.35 UT; Tan Wei Leong.

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Papers (three copies) should be sent to the Papers Secretary at the address shown inside the back cover of this issue. They will be refereed, and, if approved by Council, published as soon as reasonably possible. Those wishing to speak at a meeting should contact the Meetings Secretary.

All other contributions should be sent to the Editor. As well as *Letters to the Editor*, she will be pleased to receive contributions to *Observers' Forum*, particularly interesting astronomical photographs providing they are not submitted or published elsewhere. Colour as well as black and white photographs are welcomed. Photographs will be returned only if a suitable stamped addressed envelope is enclosed.

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Contents

Cover pictures

Satellites and their shadows in transit across the face of Jupiter. These exceptionally high-quality images show some of the recent multiple satellite transits, and even resolve the dark reddish polar caps on Io. The satellites and shadows are projected on the equator, and are identified by labels below each image. South is up. See the article on page 128.

Top: 2003 January 18, 00.43 UT, CM1 = 98.9, CM2 = 226.7; Damian Peach (Tenerife). This was taken during the remarkable triple transit. Callisto (IV) is dark, Io (I) has a bright equatorial region, and Europa (II) is just discernible because of its dusky equatorial region.

Bottom: 2003 January 28, 15.20 UT, CM1 = 54.7, CM2 = 101.5; Eric Ng (Hong Kong). Five nights before opposition, Io and Europa and their shadows are poised on opposite sides of the planet.

Jupiter Section

Moons over Jupiter: transits and shadow transits

There is no more beautiful illustration of orbital motions than the movements of Jupiter's satellites. Every six years, their motions are most strikingly displayed, when the jovian system is presented edge-on to Earth. This means that there is a higher frequency of multiple transits over the face of the planet, as all the moons transit across the equatorial zone, whereas in other years Ganymede and Callisto transit near the poles or not at all. Also, for a few months, the satellites pass in front of each other, displaying mutual eclipses and occultations. In 2002/2003 we have been able to observe a fine series of these multiple and mutual events. On the cover, and on these pages, are some of the highest-resolution images received.

These images are partly a tribute to the new technology of web cameras. While CCD cameras are now well established for producing the best possible images under perfect conditions, many observers are now switching to webcams which are much cheaper and can perform well even under mediocre seeing conditions. With exposures as short as 1/25 to 1/50 of a second, hundreds of exposures are automatically aligned and stacked to produce the final image. As shown here, webcams (especially the Philips ToUcam Pro) have enabled new observers to produce some of the best images ever obtained, even with a 250mm telescope, while plenty of detail can be recorded even with a 180mm telescope.

Table of observers

Observer	*Location*	*Telescope*	*Camera*
Ed Grafton	Houston, Texas	356mm SCT	ST5 CCD
Canon Lau	Hong Kong	356mm SCT	ToUcam Pro
Paolo Lazzarotti	Massa, Italy	178mm Mak.-Cass.	KC381 video-CCD
Martin Mobberley	Bury St Edmunds, UK	360mm reflector	ToUcam Pro
Eric Ng	Hong Kong	250mm reflector	ToUcam Pro
Damian Peach	Tenerife	280mm SCT	ToUcam Pro & ST-5c CCD
Jesus R. Sanchez	Cordoba, Spain	280mm SCT	ToUcam Pro
David Strange	Worth Matravers, UK	500mm reflector	SXF CCD
Andrea Tasselli	Wolverhampton, UK	203mm Mak.-refl.	Vesta Pro
Tan Wei Leong	Singapore	250mm reflector	ToUcam Pro

(*ToUcam Pro and Vesta Pro are webcams made by Philips.*)

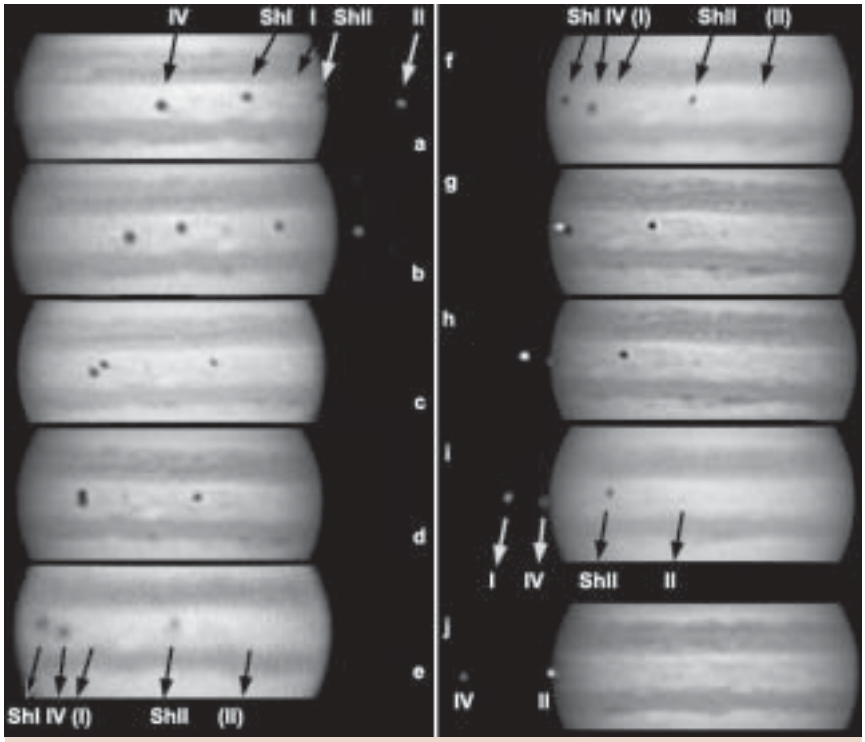

Figure 3. The remarkable triple transit of 2003 January 17/18.
This began with II eclipsing I twice, at 16.38-17.18 and 19.24-20.16; the second eclipse, 52%, was observed visually by John Rogers. Callisto's shadow was already in transit and Callisto (IV) began transit at 20.38, soon appearing as a dark spot. Then I and II successively transited across the planet with their shadows, until 02.46 when II was the last to clear the planet. Meanwhile IV occulted I at 00.51-01.05, while in transit; however no observers were able to resolve this event, as cloud briefly supervened in Tenerife, and observers elsewhere could only see that Io appeared suddenly as a bright spot adjacent to the dark IV just before its transit ended. Finally IV was due to occult II (04.50-05.12) but no-one reported watching this event.
These images show the whole course of the triple transit. South is up. **(a)** 23.08 UT; Sanchez. **(b)** 23.39 UT; Sanchez. **(c)** ~00.10 UT (approx.); Lazzarotti. **(d)** 00.21 UT; Peach. **(e)** 00.36 UT; Mobberley. **(f)** 00.42 UT; Tasselli. **(g)** 01.06 UT; Peach. **(h)** 01.21 UT; Peach. **(i)** 01.30 UT; Tasselli. **(j)** 02.46 UT; Peach.

All observers apply some degree of image processing before submitting images, to enhance local contrast and sharpness. Therefore one must beware of artefacts, such as a bright ring around a satellite shadow or around a dark satellite in transit, or more subtle distortions around other dark or bright features. Markings are generally easier to see in transit, because real markings can be masked by contrast effects against dark sky, generated during image processing whether in the eye or in the computer.

Figure 1 (page 126) shows some of the sharpest images of the satellites, including a mutual occultation (a) and a double transit (d). Ganymede, the largest of the four moons, displays surface markings, both against dark sky (b,c) and against Jupiter's cloud-tops (d); compare the simulated views (f,g). Io has a bright equatorial zone and dark poles, which are best detected when in transit (d,e).

Another fascinating aspect of the orbital motions is the coupling between the orbits of Io (I), Europa (II), and Ganymede (III), each of which has almost exactly twice the orbital period of the previous one. As the period of III is almost exactly one week, similar multiple events tend to recur at weekly intervals. Figure 2 shows paired transits of I and II, several of which occurred on Tuesday nights for observers in East Asia. These images also show how Io's shadow precedes the satellite before opposition, is partly occulted by it on the night of opposition (February 2), and follows it after opposition.

The coupling between the orbits has the additional condition that I, II, and III can never all be in transit at the same time. (During the events in Figure 2, III was at its ▸

maximum elongation.) However, the orbit of Callisto (IV) is not precisely coupled to the others, so it can transit with two of the others. Thus, a rare triple transit of I, II, and IV took place on 2003 January 17/18, ideally timed for West European observers. (Moreover, there were mutual events just before and after the triple transit.) Fortunately, the night was entirely clear and calm in England, so observers were able to follow the event both visually and with imaging, even though the seeing was poor. Images were obtained from England and Italy (in spite of bad seeing), from mainland Spain (in spite of thick fog), and from Tenerife (in excellent conditions). This event is shown on the cover, and in Figures 2a and 3.

In addition to the images shown here, at least two observers have displayed time-lapse movies on their web sites. The triple transit on January 17/18 was 'filmed' by David Strange: <http://www.dstrange.freeserve.co.uk/jupiter2003.html>. The double transit and mutual occultation of Ganymede and Io, on January 2 (Figure 1d), was also 'filmed' by Jesús R. Sánchez: <http://www.arrakis.es/~stareye/newweb/index.htm>.

John Rogers & Damian Peach