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Observations of Jupiter's moons

These remote satellites have revealed scant details to earthbound observers for more than 400 years, and offer a great observing challenge.

BY KLAUS BRASCH AND LEO AERTS

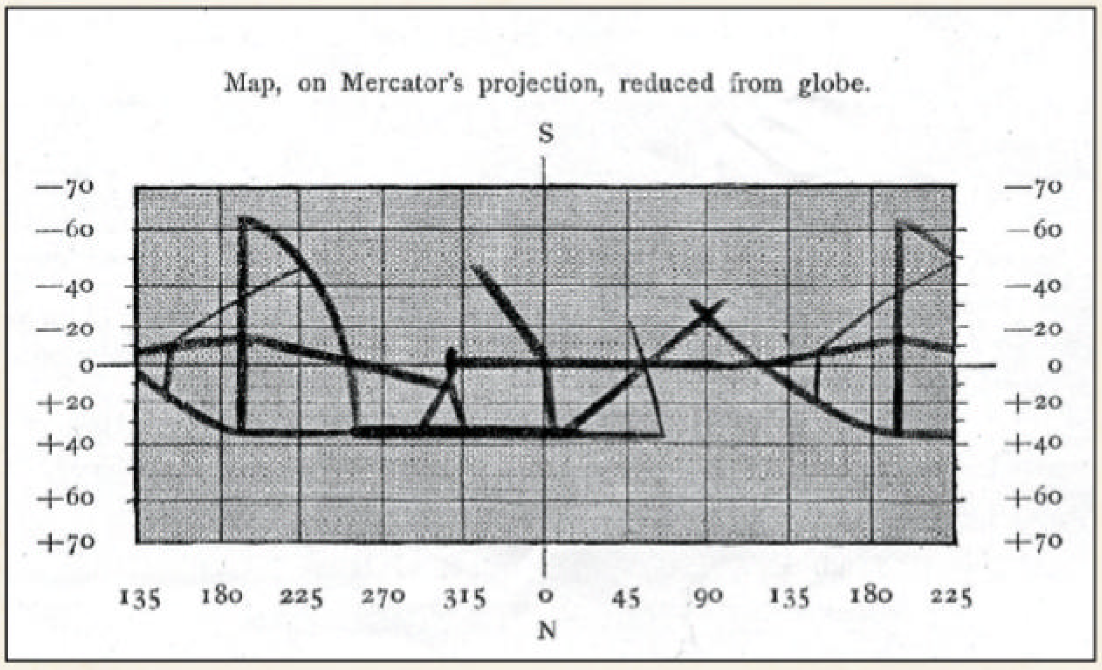
THE FOUR LARGE satellites of Jupiter, discovered in 1610 by Galileo Galilei, have been viewed by more people than any other planetary satellites besides the Moon. They are favorites at star parties and make an attractive sight alongside Jupiter. The famous moons also comprise a distinctive association of bodies which individually would qualify as planets in their own right. But, linked with Jupiter, they are instead considered a small analog of the larger solar system.

If the seeing (atmospheric steadiness) is good, a 6-inch or larger telescope at high magnification will reveal the tiny but distinct disks of all four Galilean moons. Moreover, under really steady seeing with a medium-size scope, experienced observers can occasionally glimpse elusive markings on Ganymede, Jupiter's largest moon.

Observational history

Exactly what could be observed on the jovian moons was a topic of considerable dispute in the late 19th and early 20th centuries. In 1900, astronomers Andrew E. Douglass and William H. Pickering published an extensive monograph in the *Annals of Lowell Observatory, Volume II*, detailing observations of Jupiter and its

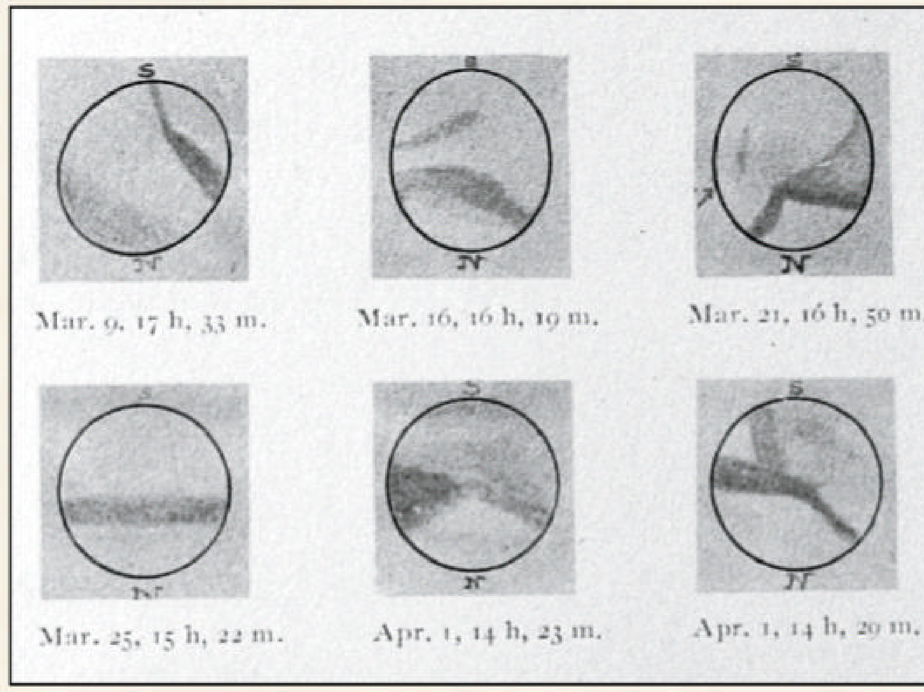
ABOVE: William H. Pickering, along with Andrew E. Douglass and Percival Lowell, founded Lowell Observatory in Flagstaff, Arizona. While there, Pickering made extensive observations of planetary satellites. LOWELL OBSERVATORY ARCHIVES



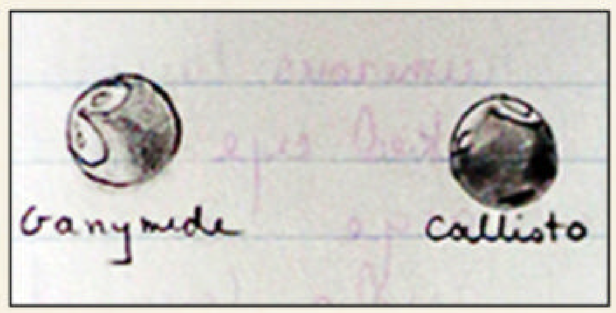
LEFT: Douglass made this map of Ganymede showing the general locations of features he observed through Lowell Observatory's 24-inch Clark refractor. LOWELL OBSERVATORY ARCHIVES

ABOVE: Douglass discovered a relationship between the sunspot cycle and tree rings, thus establishing the science of dendrochronology. He was also instrumental in founding the Steward Observatory at the University of Arizona. LOWELL OBSERVATORY ARCHIVES

Edward E. Barnard was an American astronomer best known for discovering Barnard's Star, unique for having the highest proper motion, and for creating a catalog of dark nebulae within the Milky Way. INTERNET ARCHIVE BOOK IMAGES



Douglass made these drawings of Ganymede at Lowell Observatory in 1894 and 1895, as he observed through 12-, 18-, and 24-inch refractors. LOWELL OBSERVATORY ARCHIVES



These sketches of Ganymede and Callisto were made in 1983 by *Astronomy* columnist Stephen James O'Meara, using the 9-inch refractor at Harvard College Observatory. STEPHEN JAMES O'MEARA

moons that they made in 1894 and 1895.

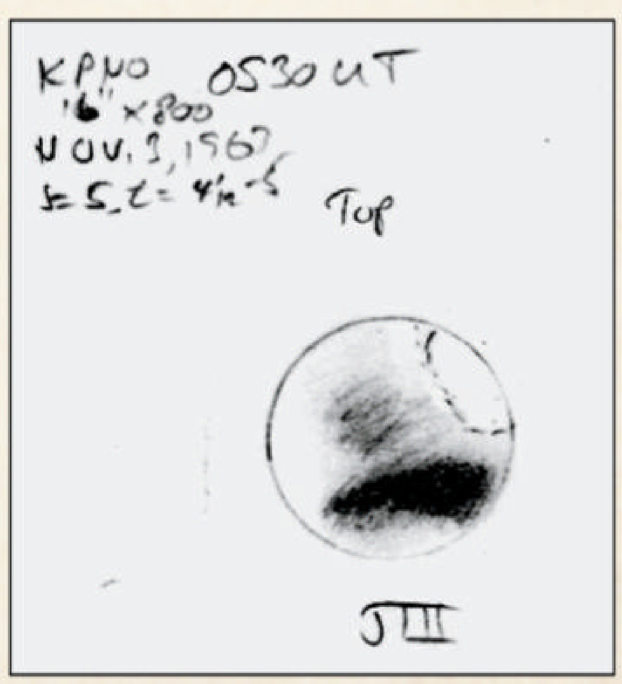
Working in Mexico and at Lowell Observatory in Flagstaff, Arizona, with two refractors — an 18-inch Brashear and a 12-inch Clark — mounted in tandem, the astronomers undertook an ambitious visual program. Their goal was to estimate the ellipticity, rotational periods, and surface features of what they called satellite I (Io), II (Europa), III (Ganymede), and IV (Callisto). The common names, originally assigned by Galileo's contemporary Simon Marius, did not become official until the 20th century.

Douglass subsequently undertook a more detailed study of Ganymede with the newly commissioned 24-inch Clark refractor at Flagstaff. He published the results in the prestigious journal *Astronomische Nachrichten* in 1897, including a map of the features he recorded.

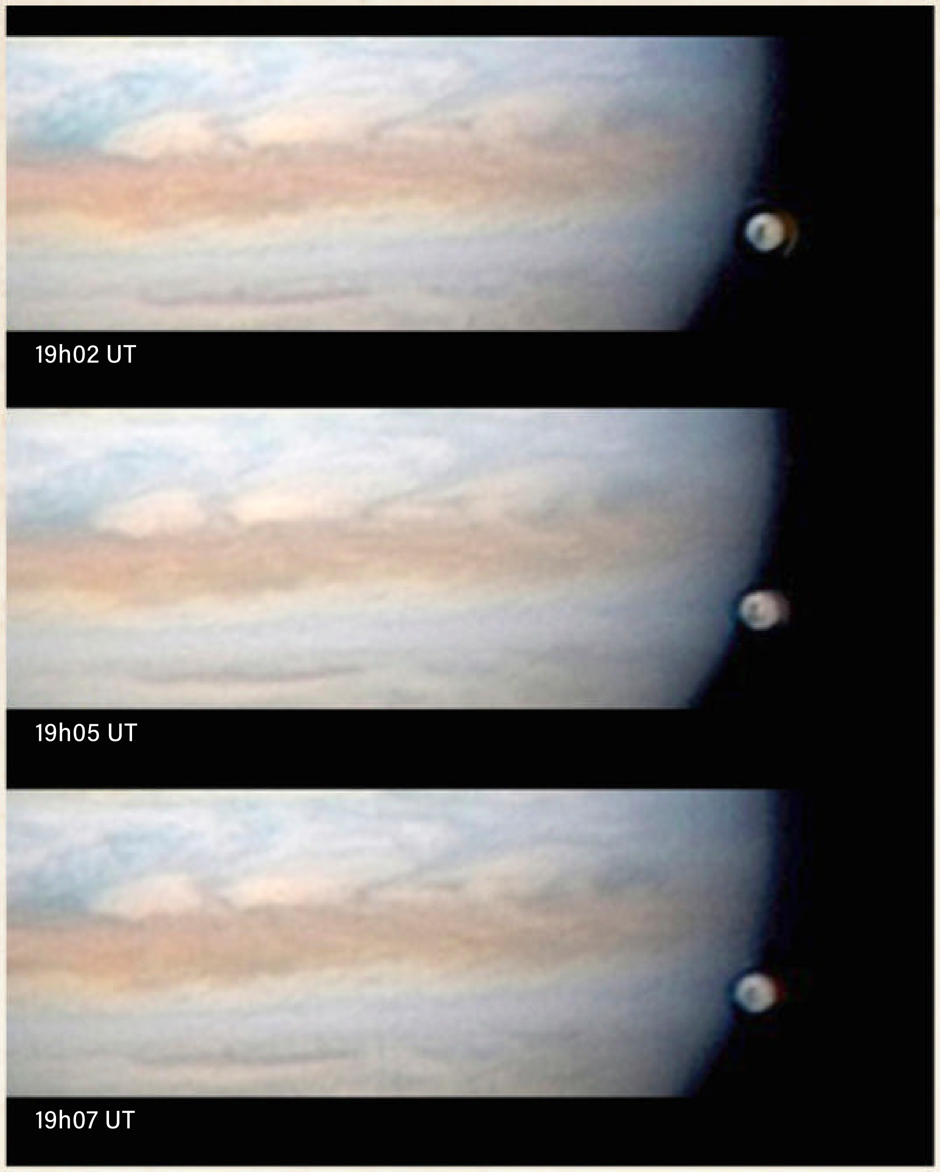
Pickering was a rather eccentric individual; among other extraordinary theories, he believed that Jupiter's moons were not solid bodies but low-density aggregates of dust and meteoric debris. That undoubtedly colored his impressions that they appeared elliptical through the telescope, as well as accounts for his obsession with measuring their "ellipticity." Other observers subsequently showed that the presumptive ellipticity of the moons reported by Pickering was illusory, likely due to contrast or astigmatic effects.

Douglass, a talented astronomer and botanist, was at that time strongly influenced by his boss, Percival Lowell, regarding his views of Mars and its putative network of canals. He was later dismissed by Lowell for doubting their reality. After moving to the University of Arizona in 1906, Douglass became head of Steward Observatory and founded the new science of dendrochronology, which dates historic events using the annual growth rings of trees.

At Lick Observatory, near San Jose, California, renowned astronomer Edward E. Barnard used the then-largest telescope in the world, the 36-inch Clark refractor, to undertake similar observations of Ganymede and Callisto from 1893 through 1895. His results were also published in *Astronomische Nachrichten* in 1897, in a paper



Dale P. Cruikshank reported seeing detail on Ganymede on November 3, 1963, while observing through a 16-inch reflector at 800x at Kitt Peak National Observatory. D.P. CRUIKSHANK



Compare the images of Ganymede above, taken May 5, 2016, to the one generated by JPL's Solar System Simulator (this page, top right). All were taken through a 14-inch Celestron with a 1.8x Barlow lens, and an ASI 120MM-S webcam. LEO AERTS

Co-author Aerts took the image of Ganymede on the left through a DMK webcam attached to a 14-inch Celestron with a 2.5x PowerMate, with the addition of a red filter. The comparative image of Ganymede on the right was generated using the Solar System Simulator provided by Jet Propulsion Laboratory (JPL). LEO AERTS

titled “On the Third and Fourth Satellites of Jupiter.”

Differences arise

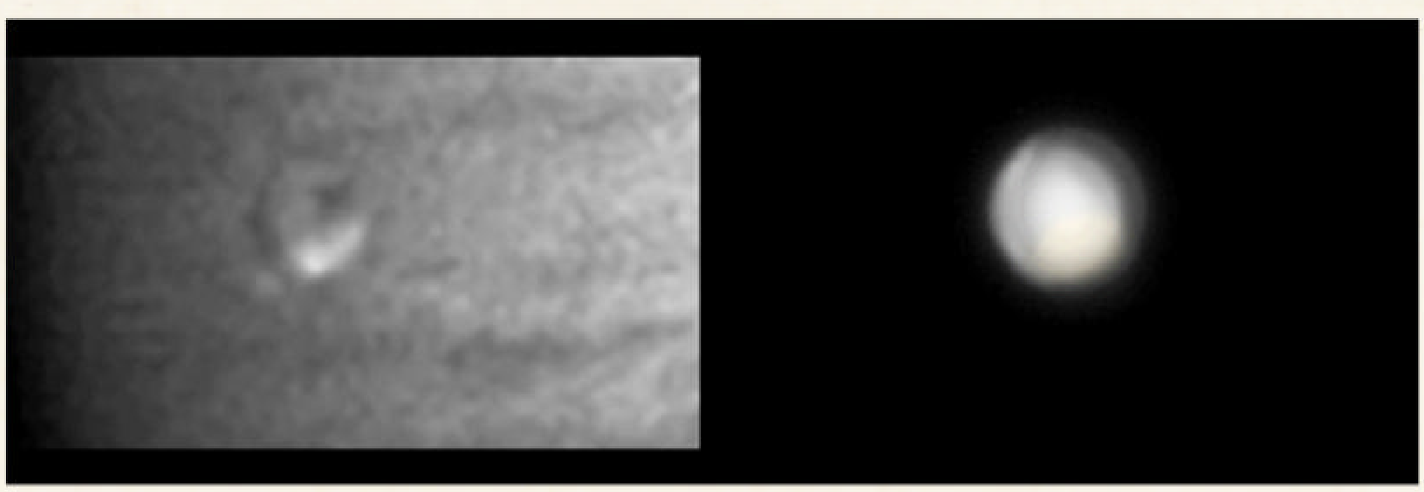
The Lowell observations show predominantly banded and crossed streaks on all four satellites, and also provide detailed descriptions of each. Ganymede is summarized as: “The third satellite was observed with much greater ease and gave more satisfactory results. The detail is conspicuous, and consists of northern and southern belts parallel to the equator, and other markings. The northern belt becomes visible 2.2 [days] after superior conjunction. Its position is easily determined, and between 1894 and 1895 gives a means for measuring very exactly the rotation period. It shows that the rotation of detail agrees with revolution about Jupiter within 15 minutes. The north polar cap seen by some observers is immediately north of this conspicuous northern belt and is probably caused by contrast.”

Other astronomers later showed that Jupiter's main moons are tidally locked and rotate synchronously with their planet like our Moon. In his subsequent 1897 paper, Douglass appears more certain of the key markings he described: “On February 20th … an interval of extremely good seeing revealed the Great Northern Belt in longitude 260° to 20°, with perfect distinctiveness and definition.”

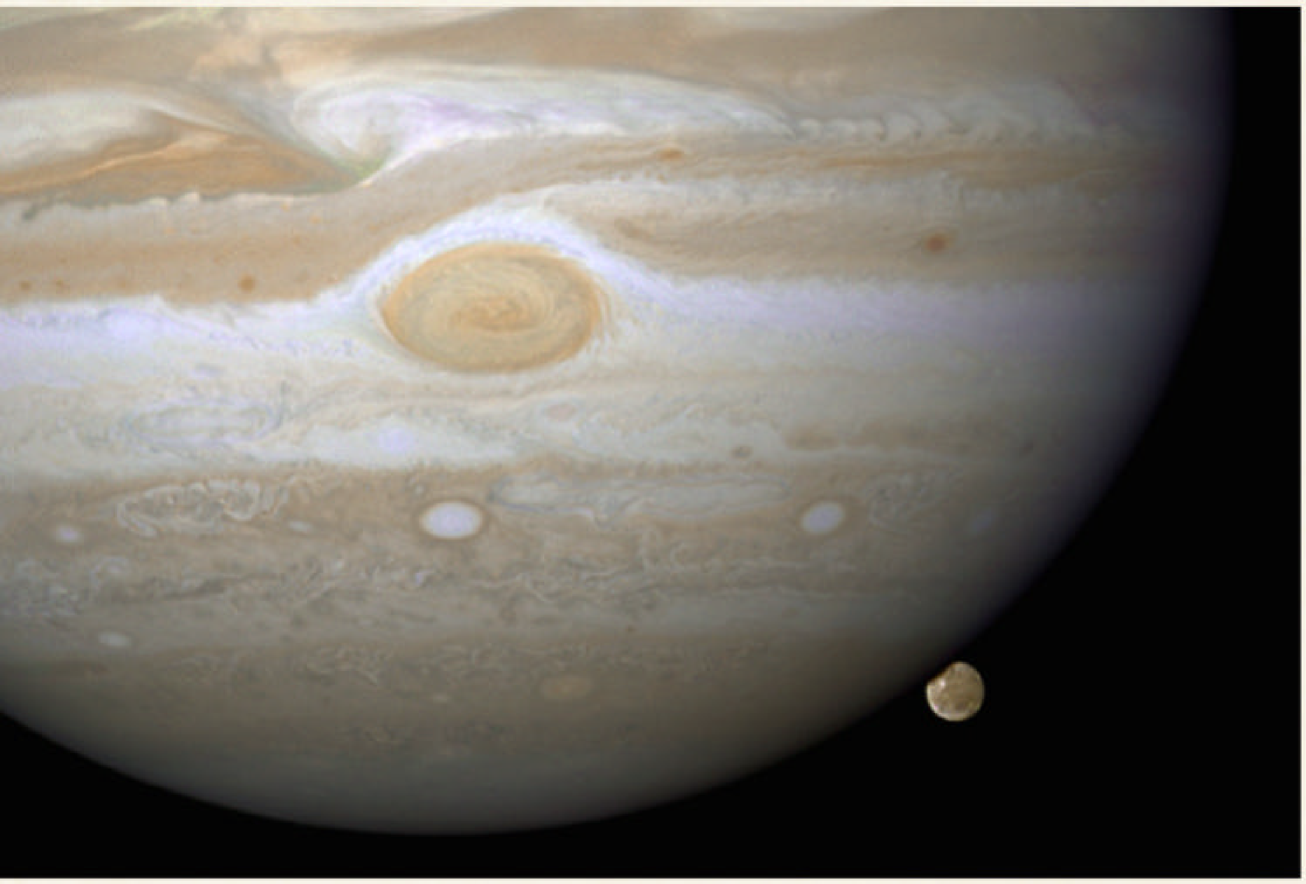
In sharp contrast to Douglass and Pickering, Barnard's drawings of Ganymede and Callisto show far more diffuse features: “Though conspicuous enough, they were so vague in form that at no two times was it possible to say definitely that the same marking was under observation.” He goes on to say, “I have been very much interested in Mr. Douglass' paper on the third and fourth satellites of Jupiter.” After Barnard mentioned that he used the much larger 36-inch Lick refractor to make his observations, he wryly added, “According to Mr. Douglass' drawings and statements, he finds these satellites covered by a series of fine dark lines, the maximum width being estimated at less than 0.1" or 200 miles. In appearance, from the drawings, these markings very much resemble those seen at the same observatory upon Mars, Venus and Mercury.”

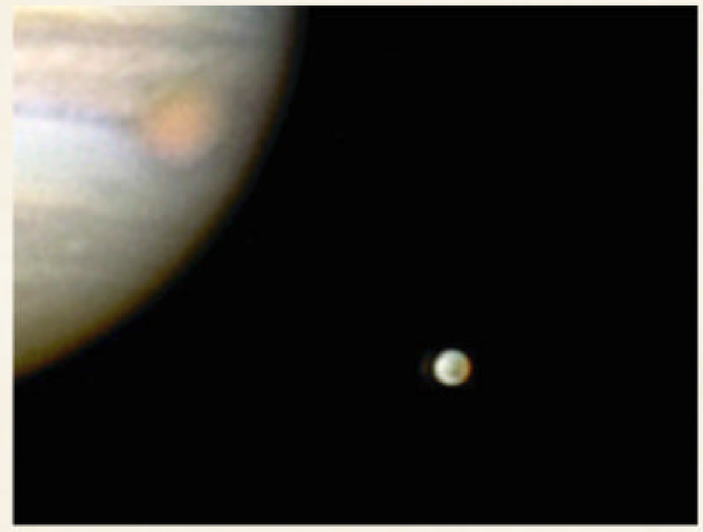
These strident comments, well documented in William Sheehan's memorable biography of Barnard, *The Immortal Fire Within*, point to the rivalry and disagreements between the two observatories. They were most glaring with respect to the putative martian canals and similar features as depicted by Percival Lowell and others. Much of the divergence hinged on Lowell's claims that while his telescopes were of smaller aperture, seeing conditions at the high and dry elevation of Mars Hill were unequaled.

To that, Barnard countered that it was his belief that no existing telescope, except the 40-inch Yerkes refractor, “is so capable of showing the surface features of these satellites



In 2015, co-author Aerts captured the webcam image at left of Ganymede transiting Jupiter with a 14-inch Celestron Schmidt-Cassegrain telescope. He also made a simultaneous sketch of the satellite, at right. LEO AERTS





A Hubble Space Telescope image of Ganymede emerging behind Jupiter is shown at left. Co-author Aerts took the comparable image at right through a 14-inch Celestron Schmidt-Cassegrain telescope. LEO AERTS

as the Lick 36-inch. I also believe there are brief intervals of good seeing at the Lick Observatory which are not excelled if indeed they are equaled at any other observatory."

Well over a century later, what can we conclude as to who was right and what in fact can be observed of the jovian moons' features using earthbound telescopes? Both authors of this piece have spotted vague detail on Ganymede through a 14-inch Schmidt-Cassegrain telescope on rare occasions of outstanding seeing. And one of us, Brasch, even saw ruddy patches on Io while observing with Lowell Observatory's 4.3-meter Discovery Channel Telescope. Well-known planetary scientist Dale P. Cruikshank likewise observed details as a student with the 82-inch Otto Struve telescope at McDonald Observatory, as well as with smaller instruments at Kitt Peak National Observatory (KPNO) and elsewhere.

In addition, in the 1940s, French astronomer Bernard Lyot and others reported visible details on all four Galilean moons. They were observing with a 24-inch refractor at Pic du Midi Observatory in France, known for its legendary steady seeing and clear skies.

Current observations

One can argue that jovian moon detail should be well within visual reach of large, professional telescopes, but what about smaller, more typical amateur instruments? Clearly, it depends on a number of factors: the quality of the optics, the seeing, the magnification, and perhaps most importantly, the observer's experience and visual acuity.

Before the Voyager spacecraft flybys of Saturn in 1980 and 1981, *Astronomy* magazine's eagle-eyed Stephen James O'Meara (then a student) spotted the spokes in the planet's B ring. He also accurately determined the rotation period of Uranus with the 9-inch Clark refractor at Harvard College Observatory. In 1983, O'Meara went on to spot mottled markings on Ganymede and Callisto with this same telescope. Regarding the latter, he advises, "Seeing detail on the jovian moons requires exceptional seeing, and the best views are [obtained] through astronomical twilight. Spend a minimum of 30 minutes looking, waiting for moments of perfect seeing, and confirm and reconfirm any initially suspected structure at least three times."

Likewise, during his student days, Cruikshank reported detail on Ganymede with his 12-inch reflector, a 16-inch reflector at KPNO, and the 40-inch refractor at Yerkes Observatory. More recently, co-author Aerts sketched and simultaneously imaged details on Ganymede with a 14-inch Schmidt-Cassegrain telescope.

These results once again raise questions as to the reliability of visual reports. In an effort to answer them, we undertook a side-by-side comparison of visual observations from several sources, with modern digital images of the Galilean moons. Making allowances for stylistic differences among observers, as well as instrumental and atmospheric variances, it seems clear that visual reports of features on Jupiter's largest moon, Ganymede, must be taken with considerable skepticism. While there is general agreement that the satellite exhibits diffuse dark and light regions, and there are references by several of the early observers to "bright polar caps," the notes of Barnard, O'Meara, and Cruikshank all urge caution in their accompanying notes: "extremely difficult"; "probably unreliable"; "seemed real, but …"; and so on.

On the other hand, today, thanks to the tremendous advances in digital imaging and processing, amateur astronomers with just medium-size telescopes can capture outstanding images of Jupiter and its moons, unheard of just a decade ago. It is indeed a golden age of amateur astronomy.

Klaus Brasch *is a retired bioscientist and volunteer at Lowell Observatory in Flagstaff, Arizona.* **Leo Aerts** *is a Belgian amateur astronomer specializing in solar system imaging.*