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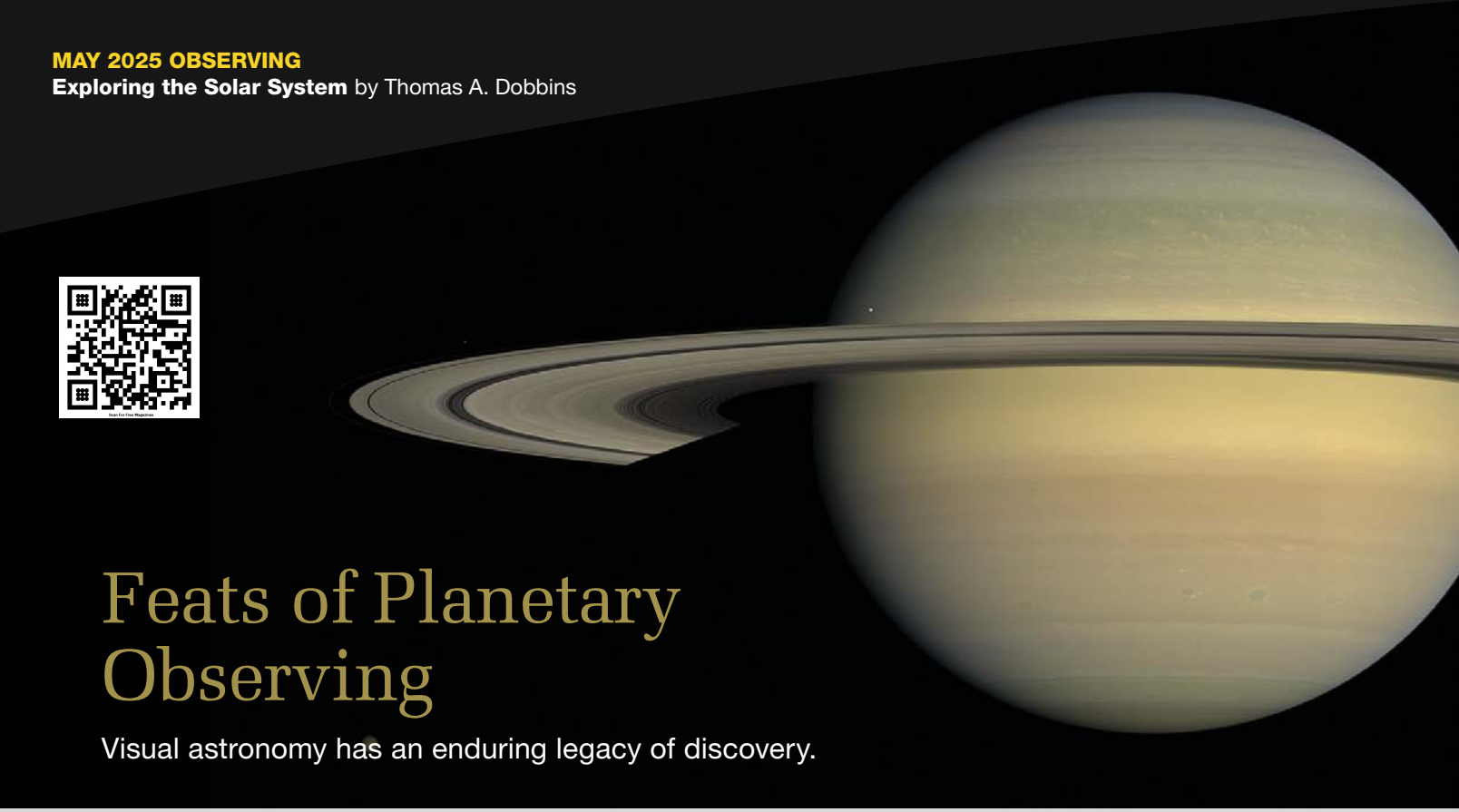

Feats of Planetary Observing

Visual astronomy has an enduring legacy of discovery.

Observing the planets is often comparable to watching a movie in which the projector is out of focus except for a few occasional sharp frames thrown in at random intervals. During most of the 20th century, recording the planets using photographic film required exposures lasting appreciable fractions of a second to several seconds. Even in that seemingly brief span, atmospheric turbulence invariably effaces the finest details. As recently as the 1980s, the sharpest photographs of the planets taken through the world's largest telescopes failed to record details beyond the grasp of visual observers equipped with 8- or 10-inch telescopes.

While the human eye isn't quite an instantaneous sensor, it requires less than one-fifteenth of a second to register an image. Experienced visual observers learn to retain the fleeting impressions of clarity and disregard the blurry intervals. The supremacy of the human eye was only brought to a close at the dawn of the 21st century when photographic film's inefficient grains of silver salts were supplanted by far more sensitive silicon chips combined with image-processing software capable of automatically selecting and combining the sharpest frames.

By keeping a patient vigil at the eyepiece, observers enjoy those magical moments that Percival Lowell called "revelation peeps." Here are three discoveries by visual observers that are still difficult to record using today's finest imaging technology.

Cassini's Thin Division

Saturn's bright A and B rings are separated by a dark, 4,700-kilometer-wide (2,900-mile-wide) gap known as the Cassini Division. Although it's comparable in width to the continental United States, the Cassini Division subtends only 0.7 arcsecond for Earth-bound observers when Saturn is at its closest, corresponding to the apparent width of a penny as seen from a distance of a bit more than 5 kilometers.

High-resolution images as well as radio and stellar occultation data obtained during NASA's Voyager spacecraft flybys in the early 1980s revealed that, rather than an empty void, the Cassini Division contains narrow ringlets with particle densities about one-fifth those of the adjacent A and B rings.

▲ In this 2008 image captured by the Cassini spacecraft, the jet-black shadow cast by Saturn's globe across the rings contrasts with the pale reflection of material in the Cassini Division. In 1852 William Stephen Jacob cited this disparity as proof that the Cassini Division is not an empty void.

Although the Voyager spacecraft are widely credited for discovering the presence of material in the Cassini Division 45 years ago, the real credit should go to British astronomer William Stephen Jacob. In 1852 Jacob reported that the Cassini Division didn't appear black but had the color of slate when seen through the 6.2-inch refractor at the Madras Observatory in India. Four years later he reported that the shadow cast by Saturn's globe across the rings "could also be seen across the dark space between the two bright rings, which therefore cannot be a mere opening but must be filled with matter of some kind."

Other visual observers soon confirmed Jacob's eyepiece impressions. Thomas Gwyn Elger, a keen-eyed British amateur who is remembered today chiefly for his lunar studies, commented in the *Monthly Notices of the Royal Astronomical Society* in 1888 that

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the Cassini Division ". . . has never impressed me as being perfectly black" through his 8.5-inch reflector. In 1899 the French astronomer Camille Flammarion described the appearance of the Cassini Division through his 9.6-inch refractor as "dark grey, not black" and inferred that "there is probably some matter in it." Fifteen years later his countrymen Georges and Valentin Fournier reported that on the steadiest nights, the 19.7-inch refractor of the Jarry-Desloges Observatory in Algeria showed that the Cassini Division was "not devoid of particles."

Discovery of Titan's Atmosphere

Saturn's largest moon, Titan, is surrounded by a dense, hazy atmosphere laden with orange photochemical smog. The discovery of Titan's atmosphere is usually attributed to the Dutch-American astronomer Gerard Kuiper, who used the 82-inch reflector at McDonald Observatory in 1944 to photographically record prominent absorption bands of methane gas in the giant satellite's spectrum.

Remarkably, a visual observer beat Kuiper to the punch 37 years earlier. During the first decade of the 20th century, the Catalan astronomer Josep Comas i Solà made an intensive study of Jupiter's Galilean satellites as well as Titan using the 15-inch refractor at the Fabra Observatory in Barcelona. Remote Titan's apparent diameter is a mere 0.8 arcsecond at opposition, only slightly greater than the width of the Cassini Division and almost identical to the maximum apparent diameter of the asteroid Ceres.

On a night of excellent seeing in August 1907, Comas i Solà was able to examine Titan at a magnification of 750×. The miniscule nail's head appeared almost one-third the diameter of the Moon as seen with the naked eye, but much dimmer because the intensity of sunlight is reduced 90-fold at Saturn's orbital distance. He was struck by an appearance that was always lacking whenever he had observed Jupiter's Galilean satellites. Titan displayed pronounced limb darkening which signified the presence of a substantial envelope of gases surrounding the satellite. The following year Comas i Solà announced his discovery in *Astronomische Nachrichten*, the era's leading astronomical journal:

> *. . . I saw Titan with a very dusky edge that trailed off into the darkness of the sky (something similar to what one observes on the disk of Neptune), while towards the central part, much more clearly, one saw two whitish patches that gave me the impression of a diffuse double star. We can justifiably suppose that the pronounced obscurity of the limb demonstrates the existence of a very absorbent atmosphere surrounding Titan.*

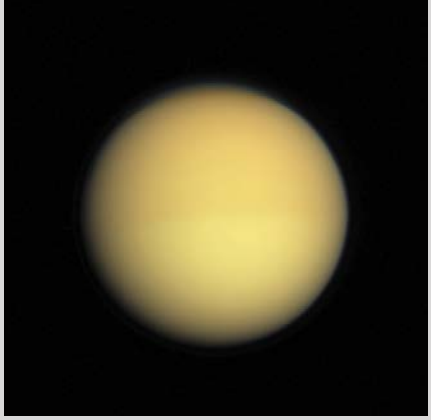
Saturn's Spokes

During the late 1970s, the eagle-eyed observer Stephen James O'Meara repeatedly glimpsed faint dusky streaks crossing Saturn's B ring through the 9-inch Clark refractor at Harvard College Observatory. O'Meara's detailed accounts of ghostly linear features rotating like a lighthouse beacon were greeted with skepticism until NASA's twin Voyager spacecraft flew past Saturn in 1980 and 1981. Voyager cameras captured hundreds of images of faint, shadowy fingers radiating across Ring B. In movies assembled from these images, spokes up to 6,000 kilometers long were seen to form in as little as 5 minutes.

Low-contrast features that are only 10% darker than their surroundings, the spokes are composed of exceedingly fine grains of icy dust levitated above the ring plane by electrostatic repulsion. After these structures coalesce, they orbit Saturn at the same rate as the planet's magnetic field. The spokes gradually shear out as their constituent particles begin to move in trajectories controlled by gravitational, rather than electromagnetic, forces.

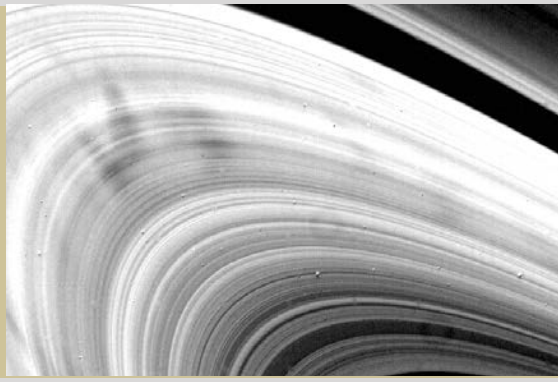
In the next installment I'll recount more remarkable discoveries by visual planet observers.

■ Contributing Editor **TOM DOBBINS** is co-author of *Epic Moon, A History of Lunar Exploration in the Age of the Telescope*, available at **shopatsky.com**.



◀ In 2013, the Cassini spacecraft imaged Titan's pronounced limb darkening — a feature first discerned by the keen-eyed Spanish astronomer Josep Comas i Solà in 1907.

TITAN: NASA / JPL / SPACE SCIENCE INSTITUTE; VOYAGER PHOTO: NASA / JPL



Right: S&T Contributing Editor Stephen James O'Meara's 1976 drawing is one of the first sketches to show the spokes in Saturn's rings. *Far right:* Five years later, the Voyager 2 spacecraft captured spokes in this image recorded on August 22, 1981.