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Suspense at Saturn II

Do recent observations herald the return of ring spokes?

During the late 1970s the eagle-eyed observer Stephen James O'Meara repeatedly glimpsed dusky, ephemeral streaks crossing Saturn's B ring through the 9-inch Clark refractor at Harvard College Observatory in Cambridge, Massachusetts. Although it would prove to be one of the last great planetary discoveries made by a visual observer, O'Meara's description of ghostly linear features rotating like rigid bodies was initially greeted with skepticism (*S&T:* Aug. 2022, p. 28).

Kepler's third law of planetary motion dictates that objects in the inner regions of the ring should have shorter orbital periods than those in its outer regions. Particles at the inner edge of ring B revolve around Saturn every 7.9 hours, while those at its outer edge circle the planet every 11.4 hours. Radial features that mimic a rotating lighthouse beacon or the spokes of a bicycle wheel just didn't seem possible, so O'Meara's reports were written off as optical illusions.

When NASA's twin Voyager spacecraft flew past Saturn in 1980 and 1981, they captured hundreds of images of faint, shadowy fingers radiating across ring B. In movies assembled from these images, "spokes" 6,000 kilometers (3,730 miles) long are seen to form in as little as 5 minutes. Once these structures coalesce, they initially orbit Saturn at the same rate as the axial rotation of the planet's magnetic field, indicating that they are electrically charged. They persist for several hours before gradually shearing out, with their broad ends facing Saturn, as their constituent particles gradually begin to move in trajectories controlled by gravitational rather than electromagnetic forces. Confined primarily to the central regions of ring B at distances of 43,000 to 57,000 km above Saturn's cloudtops, spokes are absent in the A and C rings.

▲ On September 22, 2022, the Hubble Space Telescope recorded a pair of dusky smudges in ring B resembling the "baby spokes" imaged by the Cassini spacecraft in 2005.

The fact that coherent, linear structures thousands of kilometers long could revolve around Saturn without being torn apart by differential rotation initially baffled the Voyager project scientists. When the spacecraft's cameras recorded images of the rings backlit by the Sun, the dark spokes seen during approach suddenly appeared bright. This optical behavior, known as *forward scattering*, is exhibited by minute particles that are approximately equal in diameter to the wavelength of the light that illuminates them, like motes of cigarette smoke in a sunbeam. The spokes are composed of exceed-

NASA / ESA / AMY SIMON (NASA / GSFC), IMAGE PROCESSING: ALYSSA PAGAN (STSCI)

ingly fine grains of icy dust measuring only a few millionths of an inch across levitating above the ring plane due to electrostatic repulsion.

During the 1990s, the Hubble Space Telescope and several ground-based telescopes routinely imaged spokes. The spokes abruptly and mysteriously vanished in 1998 and were still absent when the Cassini spacecraft swung into orbit around Saturn in July 2004. In September 2005, the spacecraft's cameras recorded the sudden appearance of "baby spokes" in the form of small, diffuse patches in ring B. Full-fledged linear spokes like those the Voyager spacecraft imaged developed during 2007, persisting until 2013.

The mechanism responsible for generating spokes is still not well understood. But the most popular model holds that random collisions between meteoroids and ring particles generate transient clouds of dense plasma that impart an electrical charge to the resulting debris. According to University of Colorado physicist Mihály Horányi and Carolyn Porco, leader of the Imaging Team for the Cassini-Huygens mission, the background plasma environment surrounding the rings plays a vital role in determining whether impact ejecta stay aloft long enough for spokes to form.

When the background plasma density is high, electrical charges on particles lofted above the plane of the rings rapidly dissipate, causing the particles to quickly fall back into the rings. Charges are more persistent when plasma density is low, so the levitated grains continue to be repelled and follow trajectories aligned with Saturn's magnetic field until their charges are slowly depleted.

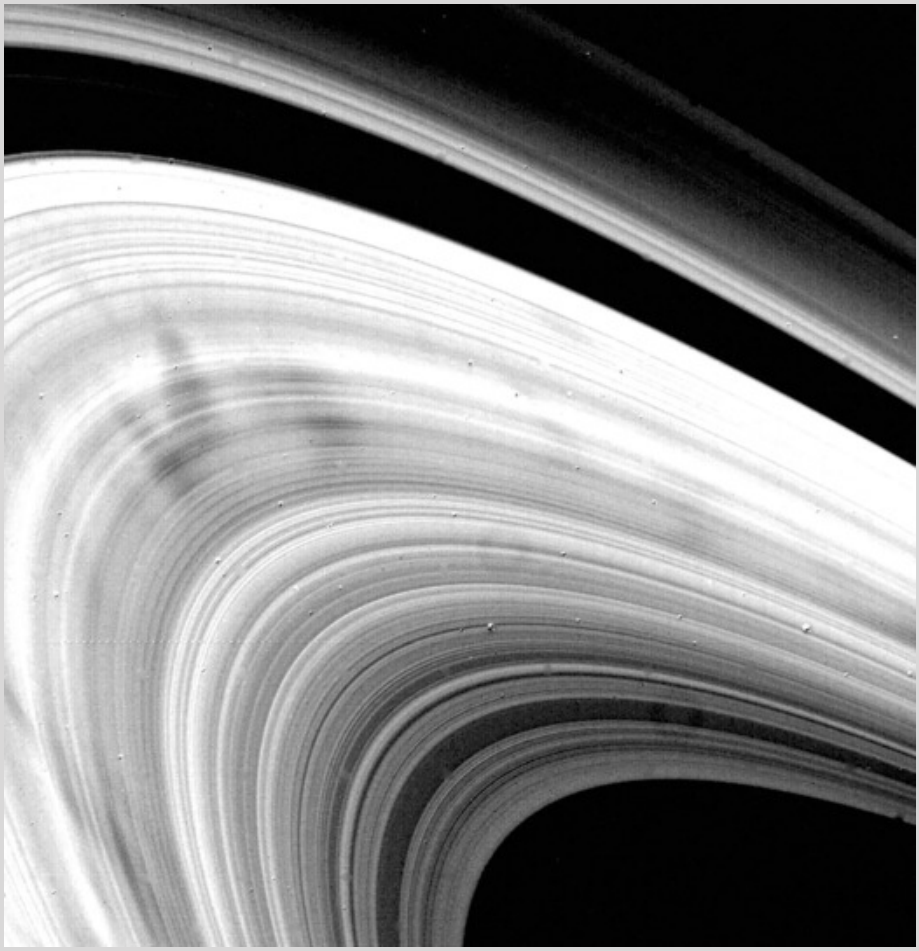
The density of the plasma surrounding the rings depends largely on the angle between the Sun and the rings. Photoelectrons generated by the interaction of incident solar radiation and ring particles seem to turn off spoke formation when the angle between the Sun and the rings exceeds 17°. Spokes appear to be a seasonal phenomenon, disappearing near Saturn's summer and winter solstices and gradually reappearing as the planet approaches its equinox, when the angle between the Sun and the ring plane is relatively low and fewer photons strike ring particles.

Saturn ponderously circles the Sun once every 29.4 years, so each season lasts more than seven Earth years. Summer solstice in Saturn's northern hemisphere occurred in May 2017, and the autumnal equinox is coming up in May 2025. According to NASA planetary scientist Amy Simon, "the precise beginning and duration of the spoke season is still unpredictable, rather like predicting the first storm during hurricane season."

Last September, renowned British planetary imager Damian Peach, veteran Austrian observer Martin Stangl, and the Hubble Space Telescope independently recorded small, dusky smudges in ring B resembling the "baby spokes" that Cassini imaged in 2005. In February of this year, NASA issued a press release announcing that the appearance of these features heralded the advent of "spoke season."

The "baby spokes" are at the very limit of visibility in large backyard telescopes, but in coming months we can expect much larger linear spokes to develop. These low-contrast, faint fingers will still be among the most challenging targets for visual observers and imagers alike. Careful monitoring of ring B on nights of very steady seeing may reward you with glimpses of these fleeting trophies.

■ Contributing Editors **TOM DOBBINS** and **BILL SHEEHAN** will both be watching Saturn this year with great anticipation.



▲ The Voyager 2 spacecraft captured this high-resolution image of spokes on August 22, 1981, from a distance of 4 million kilometers. The contrast of these ghostly features was greatly exaggerated to make them more visible — they are only about 10% darker than their surroundings.

NASA / JPL