Saturn: After the spacecraft, some time to think

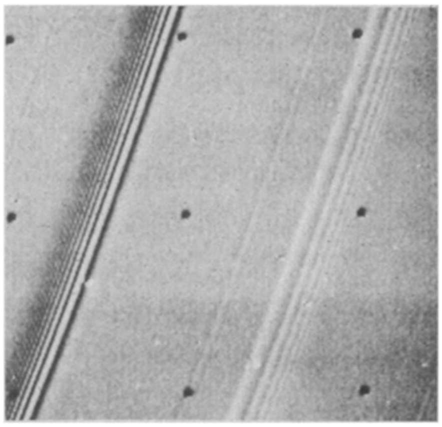
The last three planetary encounters by U.S. spacecraft have all been at the same place: Saturn. Pioneer 11 blazed the trail in 1979, followed in successive years by Voyagers 1 and 2, the three probes providing in just 24 months a flood of data whose implications kept evolving almost faster than scientists could look at it.

Now there is time to think. A return to Saturn is years in the future, and if the declining state of the U.S. planetary program does not depopulate the field of its researchers, the hiatus represents a chance to settle down and study the new questions, to seek order out of chaos.

The first broad-based attempt to summarize the knowledge of the new Saturn was held recently in Tucson, Ariz., where an international coterie of scientists met for five intensive days devoted to nothing else. The result will be a book, to be published by the University of Arizona as the latest word in Saturnology. But as the conference underscored, the state of the art so far is a combination of still-evolving consensus, totally new findings and intransigent bafflement — a mixture well-illustrated by the planet's remarkable rings.

One of the most surprising of the early Voyager findings, months before the spacecraft even reached the planet, was the discovery of radially aligned, spokelike features extending out across the rings. An early speculation was that the spokes might consist of fine particles, electrostatically levitated above the ring plane and moved around in some kind of synchronization with Saturn's magnetic field. Many other ideas were put forward, however, and the varied appearance of the spokes made it difficult to be sure. Recent studies, however, seem to be suggesting a pattern. At the Tucson conference, Richard J. Terrile of Jet Propulsion Laboratory reported that a comparison of the number of spokes observed in each 30° swath of longitude in Saturn's magnetic field indeed suggests there to be a favored (and least-favored) magnetic region. Similarly, Carolyn Porco of Caltech noted that the greatest "spoke activity" (the number of spokes and their optical density) seems to be concentrated in the same magnetic longitude that is also the source of the planet's strongest radio emissions.

(In the case of Jupiter, a number of phenomena have been tentatively linked with a possible magnetically "active sector," and several researchers now suggest a similar possibility for Saturn. An ongoing mystery, however, has been that magnetic-field measurements at Saturn have indicated neither such an active sector nor a tilt to the field's rotation axis, even though the planet's radio emissions show a periodic modulation of the sort that would presumably require such an asymmetry. The radio modulations have provided the first accurate determination of the length of a Saturnian day, but the reason for the existence of such a "signature" is still unknown.)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Portion of possible spiral "bending wave" (stripes at left) in Saturn's A-ring is indicated by an amplitude that decreases toward the planet (off upper left), in contrast with a spiral density wave (right), whose amplitude decreases outward.

Several scientists at the meeting joined in support of the idea that the spokes are formed by small, levitating particles, and various lines of evidence suggest that the particles would have to be a micron or less in size. One proposed source of such tiny particles was bombardment of the rings by micrometeoroids; others included ionization by solar ultraviolet radiation, and bombardment by charged particles trapped on Saturn's magnetic field lines. Roman Smoluchowski of the University of Texas suggested that even collisions at the low relative speeds between particles can do the job if the surfaces of the particles are weakened by "radiation-induced thermal fatigue." If the particles contain brittle "amorphous" ice rather than the more ductile, crystalline kind, he said, the task would be even easier.

One way to stretch the particles out into the spoke-shapes, said the University of Iowa's T.K. Goertz, could be electric currents aligned radially to the magnetic field and flowing through the particle-containing plasma through Saturn's ionosphere. Such currents, he said, could cause the plasma to move radially at speeds greater than 100 kilometers per second, "leaving behind radially aligned trails of dust like a car racing across a dusty plain." An alternative "driver" for the spokes, suggested earlier, has been electrostatic discharges, detected by the Voyagers and proposed by some researchers to have been produced in the rings themselves. Regardless of whether such bursts form the spokes, Joseph A. Burns of Cornell University proposed to the conference that the bursts might be formed not by some "exotic" process in the rings but by "mundane lightning," propagated up from Saturn's atmosphere.

An even more startling ring phenomenon discovered by Voyager, however, was the sometimes "braided" appearance of the thin F-ring, which also revealed unexpected clumps and kinks. The growing opinion seems to be that all these oddities are formed by gravitational effects of two tiny satellites that orbit just inside and outside the F-ring, but such effects are far from understood. Mark Showalter of Cornell showed a computer-generated drawing of the F-ring, indicating the possible effects of the two moonlets, and the results of the simplified analysis indeed suggested patterns like clumps and kinks in the ring. The intertwining "braids," however, were missing. They were perhaps Voyager 1's most surprising single discovery (they were absent in Voyager 2's photos), and more exhaustive study is sorely needed.

But the extraordinary rings seem to reveal new tricks at every turn. Photos and other Voyager data have shown patterns of alternating light and dark bands (or compressions and rarefactions of ring particles, in the case of stellar-occultation measurements) that are believed to represent spiral "density waves" due to gravitational resonances caused by Saturn's various moons. One characteristic of such waves, notes Jack J. Lissauer of the University of California at Berkeley, is that the wavelengths of successive bands become shorter as they move outward across the rings from the point of resonance. At the Tucson meeting, Lissauer reported the discovery of two spiral waves whose wavelengths get smaller *toward* Saturn rather than away from it. These, he said, may be a wholly different kind of wave — "bending waves," which result in a radially localized thickening of the ring rather than a radial compression.

They appear, he said, to be caused by the perturbing effect of the satellite Mimas, which has a strong (5:3) resonance in the A-ring, where the bending waves were seen. The orbit of Mimas is slightly inclined (less than 1.5°) from the plane of the rings, which causes the ring particles near the resonance to move up and down as much as 500 to 700 meters above and below the ring plane. The "self-gravity" of the ring, he says, causes the vertically moving particles to affect other particles nearby, producing a warping effect that propagates inward. The alternating light and dark bands visible in the photos, he said, result from the differing angles at which sunlight strikes the up and down sides of the wave. The idea, he says, grew out of work done by other researchers trying to explain the "warp" observed in some disk-shaped galaxies.

The conference dealt with more ring matters, as well as Saturn and its moons. More work remains on all of them.

—J. Eberhart