New Outer Rings for Saturn?

At the recent meeting held in Toulouse on planetary rings,* a group of researchers suggested that two or more rings far outside the known rings of Saturn may have left their mark in the charged-particle observations of all three spacecraft that visited that planet.

Massachusetts Institute of Technology (MIT) researchers Alan Lazarus, Tomo Hasegawa, and Fran Bagenal used what has been called "particle-beam astronomy" to build a case for possible outer rings. Last spring, Lazarus was preparing a talk when he noticed that certain decreases in the density of low-energy plasma ions along the path of Voyager 1's encounter with Saturn coincided with decreases in the Voyager 2 record. The MIT researchers had noticed a single set of coincident dips before, but attributed it to chance. When they checked the record of Pioneer Saturn's previous encounter, they found similar dips in the same two locations relative to the magnetic field of Saturn. The two most prominent dips are nearly 60,000 kilometers wide and fall about 14 and 19 Saturn radii from the planet (one Saturn radius equals 60,000 kilometers). That places them in the broad gap between the satellites Rhea and Titan, more than 12 Saturn radii from the main rings and 4 Saturn radii beyond the known edge of the diffuse E ring.

Magnetospheric researchers have inferred the presence of unseen satellites and rings from similar spacecraft observations of Saturn—some of these predictions have been confirmed, others not. Such predictions depend on solid particles intercepting and absorbing plasma ions as they bounce back and forth between the planet's polar regions along magnetic field lines. No matter where a spacecraft penetrates the magnetosphere, such absorption at the equatorial plane will reveal itself as a dip in plasma ion density. Too wide to result from absorption by a few satellites, the dips may be caused by ring particles, the MIT group decided.

"It's speculative," says Lazarus, "We're excited about it, but we're not entirely sure if it's real." There are several possible problems, the MIT group points out. Data from the outbound legs of spacecraft encounters do not always have similar dips, and initial analyses of those data by the MIT group do not reveal any obvious coincident dips. Also, some coincident dips are no longer so if recently proposed, more complex models of Saturn's magnetosphere are used to determine the dips' relative positions.

Whatever the ambiguities of the spacecraft plasma data, the reality of outer rings will stand or fall on optical, Earth-based observations. A telescopic search by James Elliot and his group at MIT and a stellar occultation search by Jay Goguen at the University of Hawaii failed to detect faint outer rings, but better observing opportunities will occur in the spring of 1983.

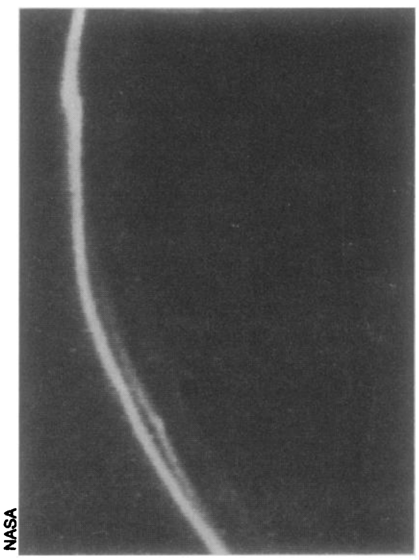
This is not the first suggestion that there might be something in the gap between Rhea and Titan. In 1978, before any spacecraft flybys, Giuseppe Colombo of the Smithsonian Astrophysical Observatory pointed out that if Saturn had an analog of the solar system's asteroid belt, it should fall between Rhea and Titan. In 1979, a single dip in Pioneer Saturn charged-particle data was taken as evidence of a ring in that same gap (*Science*, 5 October 1979, p. 38). The new ring was dubbed the G ring, but it was a short-lived ring. Without other confirming data, it was abandoned, and its letter designation was given to a more substantial candidate. The MIT group has not been so bold as to give letter designations to their possible rings.

*Planetary Rings, colloquium number 75 of the International Astronomical Union, held 30 August to 2 September 1982 in Toulouse, France; André Brahic, chairman. See also *Science*, 8 October, p. 141.

The F Ring Becomes a Little Less Baffling

When first observed by the Voyager spacecraft, the narrow F ring of Saturn was mysterious, even mind-boggling. It snaked across images made by the Voyager 1 spacecraft, split into multiple strands and rejoined, had a faint ghostlike companion ring, and was bunched into clumps like beads on a string. Planetary ring particles were supposed to know their physics better than that.

Some aspects of F-ring behavior are not so mysterious now, and it appears that nothing more exotic than gravity may be needed to understand other F-ring oddities. The most encouraging progress has been made in understanding the clumps and kinks. Mark Showalter and Joseph Burns of Cornell University have used a computer model to simulate the gravitational interactions between ring particles and the two satellites that herd particles into a narrow ring in the first place. They started with a uniform, simplified ring of particles, but ended after numerous satellite passes with particle concentrations and offsets in the ring reminiscent of the clumps and kinks seen in Voyager images.



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The F ring

Showalter had less luck simulating the F ring's "braiding," which probably more closely resembles the end result of several inebriated road painters trying to put white lines down the center of the same curving road. In a meeting abstract S. Synnott of the Jet Propulsion Laboratory (JPL) reported, on the basis of the limited number of suitable Voyager images, that there may be an association between braiding and shepherding satellite conjunctions. Conjunctions are the close passage of the two satellites as the inner overtakes the outer shepherd. But Showalter's simulations of shepherd conjunctions produced only 100- to 200-meter offsets in the ring, not the tens of kilometers observed by the Voyagers.

A way out of this quandary may be found in the apparent wide range of particle sizes in the F ring. Voyager observations show that the F ring has a narrow core of marble-size particles embedded in a broader ring of fine material. Some of the particles may be considerably larger than marbles. Richard Terrile of JPL pointed out that the images of some ring clumps are consistent with point sources below the limit of resolution. One particular clump could be a 10-kilometer satellite if it were a point source, he noted. Moonlets would also help explain some features of Voyager charged-particle data.

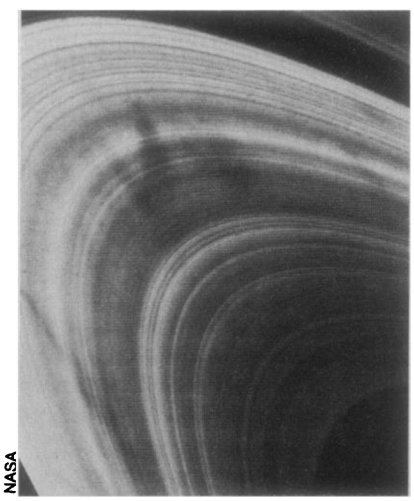
Peter Goldreich, a theoretician from the California Institute of Technology, noted that such huge ring particles would behave differently than small particles after being perturbed by shepherding satellites. The differences arise because the small ones tend to damp their perturbations through collisions with other particles. This difference might allow the moonlets to "act like a zipper to open up the ring," he said, and produce some of the as yet unexplained structure.

Spokes, SKR, and SED: A Connection?

Two of the stranger phenomena at Saturn may be linked by an apparent anomaly in the planet's magnetic field. Carolyn Porco and Edward Danielson of the California Institute of Technology reported at the ring meeting in Toulouse that both ring spokes, the radial finger-like markings on the rings, and Saturn kilometric radiation (SKR), Saturn's natural long-wave radio emission, may tend to be associated with the same sector of the magnetic field.

Porco and Danielson found that the amount of spoke activity on the rings at the morning ansa (where ring particles first emerge from Saturn's shadow) tends to peak every 640.6 minutes ± 3.5 minutes, the same period that SKR has (639.4 minutes). The latter is also taken as the rotation period of the planet's magnetic field, which had previously been linked to SKR. In addition, the Caltech researchers reported that the same sector of the magnetic field that points toward the sun when SKR is most intense is likely to be at the morning ansa when spokes appear there. Thus, the common element that links both phenomena to Saturn's rotation seems to be a particular part of the magnetic field. Spoke activity at the morning ansa may also exhibit a weaker tendency to come and go with the 609-minute period of Saturn Electrostatic Discharges (SED), Porco noted. SED are powerful bursts of radio-frequency noise that may originate in atmospheric electrical storms or in the rings (*Science*, 11 June, p. 1211).

Although most listeners seemed willing to accept the SKR-spokes-magnetic field correlation, the mechanics of any physical linkage remains mysterious. Peter Goldreich of Caltech suggested that the crucial unknown is the electrical conductivity of the magnetosphere. Most theorizing



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Ring spokes

about spokes requires some electrical phenomenon in the rings to create spokes. The magnetosphere, micrometer-size ring particles, and the ionosphere could form a huge electrical circuit whose current would be driven by plasma as it is dragged across the rings by the magnetic field. Whether enough current could be driven through the circuit to precipitate spoke formation—another mysterious process—depends on the largely unknown conductivity of the magnetosphere, Goldreich pointed out. One possible conclusion is that the sector of the magnetic field identified by Porco and Danielson's correlations modifies the circuit to increase the likelihood of spoke formation.

The Uranian Rings Get Stranger and Stranger

Six years ago, planetary rings were fairly ordinary things: they were all broad, circular, uniform disks of icy particles orbiting Saturn in its equatorial plane. Then came the rings of Uranus. They broke most of the rules: they are narrow, elliptical ribbons of varying width composed of pitch-black rock. Now, it seems that some of the rings around Uranus are inclined and warped too.

Richard French and James Elliot of the Massachusetts Institute of Technology (MIT) reported at Toulouse and in a recent paper* that at least seven of the nine known rings are inclined to the equatorial plane of Uranus, where all well-behaved ring particles were thought to reside. The maximum inclination is several hundredths of a degree. That sort of inclination produces a 50-kilometer departure from the equatorial plane in the case of ring 6, which is 42,000 kilometers from Uranus. Detecting this kind of irregularity in a ring system almost 3 billion kilometers away was made possible by the increasing number of occultations of stars by the rings that have been observed by the MIT group and by others.

Traditional ring theory has no place for inclined rings, but they do seem to fit nicely into an explanation of the Uranian rings offered by Peter Goldreich of the California Institute of Technology and Scott Tremaine of MIT. They proposed in 1978 that tiny, unseen satellites orbiting on either side of each ring gravitationally herd particles into the ring. At Toulouse, Nicole Borderies of Caltech, Goldreich, and Tremaine showed that shepherd satellites in inclined orbits can keep ring particles in inclined orbits also, contrary to the particles' tendency to fall into the planet's equatorial plane. The group also predicted that inclined rings must be slightly warped, perhaps a maximum of 1 kilometer of distortion from a perfectly flat plane. That is just below present, but probably not future, occultation resolution. No one will be surprised if inclined rings are eventually found at Saturn too.

Nature (London), 26 August 1982, p. 827

—Richard A. Kerr