SCIENCE NEWS®
A Science Service Publication
Volume 118/November 15, 1980/No. 20

THIS WEEK

RESEARCH NOTES

ARTICLES

DEPARTMENTS

COVER: Saturn's rings, once thought to number only 3, reveal a bewildering array of some 95 concentric features in this computer-enhanced photo taken by the Voyager 1 spacecraft from 8 million kilometers away. The tiny bright spot near upper left, just inside the narrow "F-ring," is Saturn's fourteenth known satellite, discovered from Voyager photos and believed to help sustain the F-ring by preventing its particles from drifting inward to the main ring system. For more on Voyager 1's Saturn sojourn, see p. 307. (Photo: JPL)

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231 West Center Street Marion, Ohio 43302

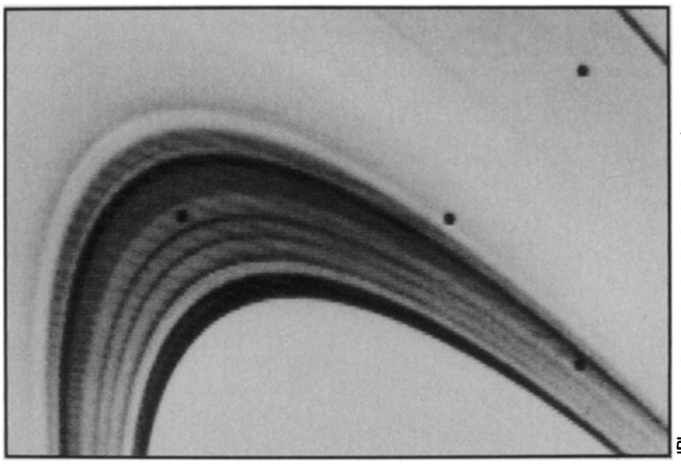
Subscription rate: 1 yr., $19.50; 2 yrs., $34.00; 3 yrs., $47.50 (Add $3 a year for Canada and Mexico, $4 for all other countries.) Change of address: Four to six weeks' notice is required. Please state exactly how magazine is to be addressed. Include zip code. For new subscriptions only call: (1) 800-247-2160.

Printed in U.S.A. Second class postage paid at Washington, D.C. Title registered as trademark U.S. and Canadian Patent Offices.

Published every Saturday by SCIENCE SERVICE, Inc. 1719 N St., N.W., Washington, D.C. 20036. (202-785-2255)
ISSN 0036-8423

SCIENCE NEWS OF THE WEEK

Saturn: More and more . . .



Several thin "ringlets" — the four brightest in this view are each about 500 kilometers wide — occupied the Cassini division. And as Voyager 1 neared, the number was growing.

JPL

The Voyager 1 spacecraft took its first photo of Saturn in the summer of 1979. Half a year later, it began picking up the planet's radio emissions, rapidly yielding the first reliable measurement of the length of a Saturnian day. Six months more, and it started monitoring hydrogen emissions from the vicinity. Yet this was no orbiter, fixedly studying its objective from a few hundred kilometers overhead, nor a landing craft, working literally from its target's backyard. Voyager 1 was a "flyby," bound on a 38-month, 2-billion-kilometer journey from earth that would climax in two frenetic days of intensive activity centered on the planet, its spectacular rings and its large family of virtually unexplored satellites. This week, Voyager 1 reached its goal.

For most of its months in the spacecraft's sights, Saturn itself showed only a near-featureless mask, hiding the details of its colorful clouds beneath a thick, chill haze and worrying scientists still elated from the probe's earlier photos of dramatic Jupiter. There had been hints — an oval feature in the southern hemisphere more than 10,000 kilometers long and evocative of Jupiter's Great Red Spot (though only about a third its size) had been noted since August — but it was not until the flyby's closing days that features other than axial stripes began to emerge with any clarity. The reddish oval, for example, appeared to be surrounded by a darker collar, suggesting from preliminary study that it might be an anti-cyclonic storm cell akin to similar-looking Jovian features. Other large ovals were spotted in the northern hemisphere, as were light-colored, smaller-scale convective cloud patterns and a wavy linear feature thousands of kilometers long.

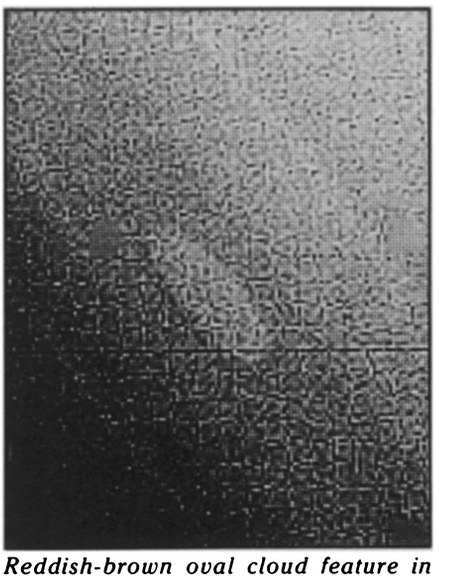
More would emerge during Voyager 1's 125,000-kilometer closest approach to the planet (the day after SN's deadline) but there were already signs that Saturn's cloud patterns would not be mere pale miniatures of Jupiter's. Features typically found along the turbulent boundaries between the larger planet's stripey belts and zones, pointed out imaging team leader Bradford Smith, were showing up in the *middle* of similar zones on Saturn. Raging, mid-zone winds seemed to taper off to nothing at the belt-zone boundaries, which on Jupiter are often the sites of strong wind shear. "The differences," said Smith, "are greater than I would have expected."

The clear center of attention in the final pre-encounter days, however, was Saturn's vast ring system, which revealed such a succession of surprises and bizarre structural details that Smith called the matter of the rings "a bottomless pit." Long thought to consist of three main rings (known simply, from the outside in, as A, B and C), the array has been found in recent years to include two and possibly three more: a narrow F-ring outside A, a wide but extremely tenuous E-ring outside that, and a tentatively identified (though initially unconfirmed by Voyager 1) D-ring closest to the planet. Even with some 8 million kilometers to go, however, Voyager's photos revealed a pattern of so many rings, sub-rings and ringlets — one image showed about 95 — that reporters and scientists alike compared it to the grooves of a phonograph record.

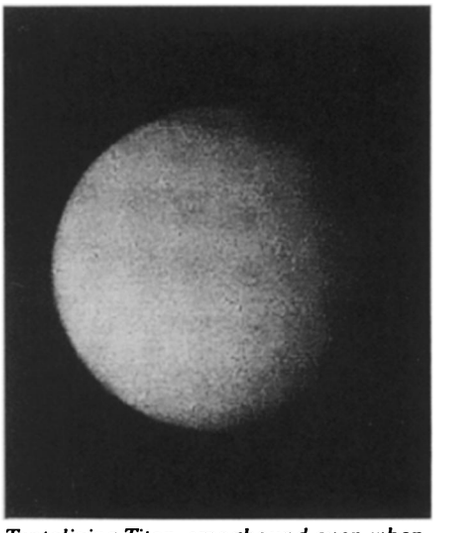
Even the Cassini division, a nearly 4,000-km-wide gap between the A and B rings, became part of the embellished picture. Once thought to be empty, it was revealed by the Pioneer 11 spacecraft in September of 1979 to contain some material, but nothing approaching Voyager 1's findings. A Nov. 8 image showed half a dozen rings filling the space; after looking at higher-resolution images four days later, Smith announced he had counted 20.

Photos: JPL

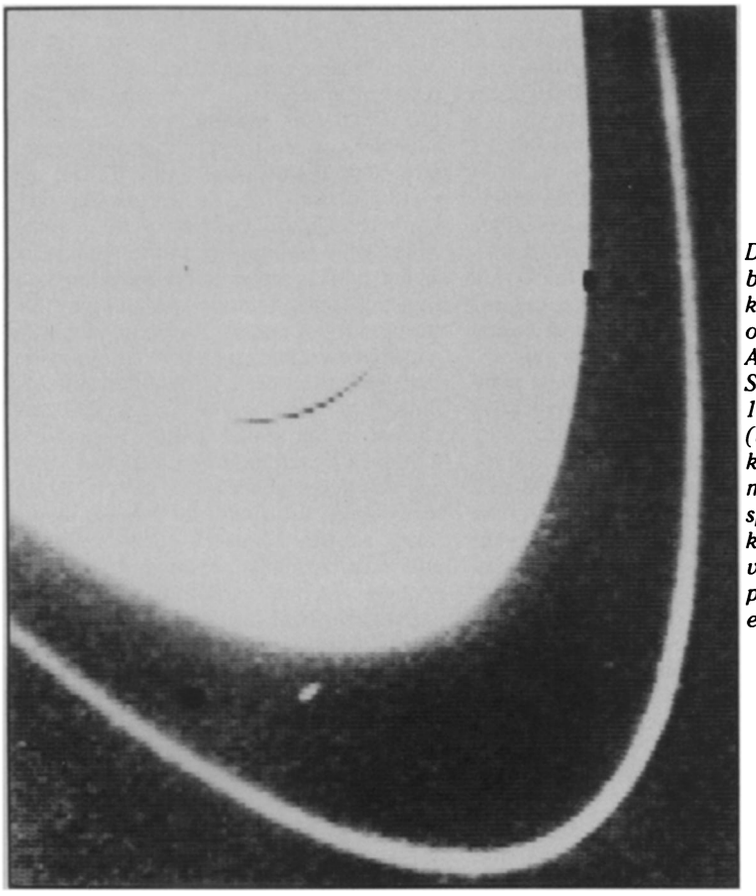
Near-featureless from a distance, Saturn's atmosphere reveals distinct convective cloud features (though smaller than Jupiter's) in Voyager 1's close-ups.



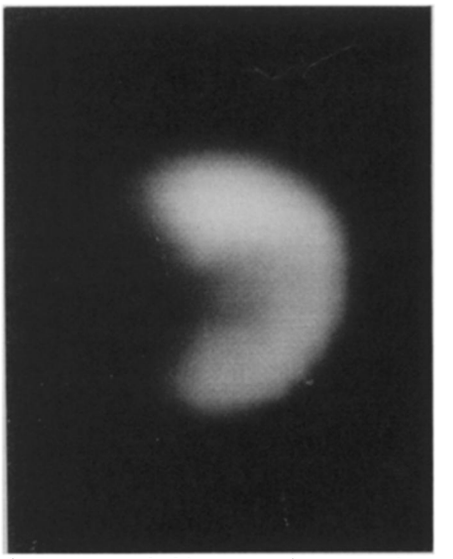
Reddish-brown oval cloud feature in Saturn's southern hemisphere is about 10,000 kilometers long, a third the size of Jupiter's famous Great Red Spot.



Tantalizing Titan, smogbound even when seen from close-up.



Discovered barely 800 kilometers outside the A-ring, Saturn's tiny 15th satellite (barely 100 km across) may be responsible for keeping the vast ring's particles from escaping.



Iapetus revealed its strangely contrasting faces even from 8 million kilometers.

(Ironically, Pioneer 11 project officials once considered aiming the craft to fly *through* the supposedly empty division, though the decision was later made to send it outside the rings as a path finder for Voyager.)

What could produce such a complex structure? The pre-Voyager assumption had been that the main rings and their then-known gaps were held in place by gravitational resonances with some of Saturn's moons, and it is quite possible that such forces do play a significant role. But, commented one project researcher, "There's no way resonances can explain all of this." Alternative hypotheses were proposed, though none found immediate acceptance. Could occasional larger chunks of ring material create wakes or pressure waves or gravitational effects? The answer was unclear, though Voyager scientists did go to the trouble of calculating that the rings could hold as many as a thousand 100-km chunks without exceeding the total mass of the ring system as determined from Pioneer 11 measurements.

But there was more to Voyager 1's ring riddles. The strange radial streaks, or "spokes," discovered months ago in the photos (SN: 11/1/80, p. 282), continued to appear amid a staggering number of proffered explanations, but none seemed to fill the bill: gravitational effects, charged-particle annealing, temperature changes as the particles emerged from Saturn's shadow, magnetically caused clumping.... Exasperated, Smith labeled the spokes "quite clearly the most baffling surprise that we've come up with so far in this mission."

Running a close second, however, was the finding that, while most of the rings are concentric, a few are not. A ring occupying a 250-km-wide gap in the broad C-ring was found to be 85 km across on one side of the planet and 35 on the other, differing in radius at the two extremes by about 60 km. The thin, innermost ringlet in the Cassini division also turned up out-of-round or eccentric, as did the outlying F-ring. Gravitational effects from known or unknown satellites were proposed as a possible category of explanation, but nevertheless the finding, said Smith, was "*most* unexpected."

Some of Saturn's moons were also apparently having their gravitational will with the rings in other ways. A few weeks ago, the planet's 13th and 14th satellites were discovered in Voyager 1 photos (SN: 11/1/80, p. 277), orbiting just outside and inside, respectively, of the skinny F-ring, less than 100 km wide. And apparently, Smith reported, it is the moons that keep it that way, sharp-edged and confined. Because #13 circles Saturn more slowly than the ring particles orbiting inside its path, any particles tending to drift outward will be slowed down by the satellite's gravitational influence and move back in. Conversely, S-14, inside the ring, moves more quickly and adds restorative energy to particles that would otherwise drift inward. The same kind of "gravitational focusing" by satellites (in this case yet-undiscovered ones) has been suggested by Peter Goldreich of Caltech as an explanation for the nine or more strange rings of Uranus, *all* of which are thin and sharp-edged, and of which some are circular and others apparently elliptical (SN: 2/11/79, p. 88).

Another and more dramatic example seemed to involve yet another Saturnian moon — the 15th — also discovered from Voyager 1's photos. Initially estimated to be barely 100 km across, the little satellite orbits about 800 km outside the vast A-ring, seemingly an unequal contest in such gravitational tug-of-wars. Because the moon is so close to the ring's outer edge, however, said Smith, its speed relative to the outer ring particles is only about 100 meters per second, giving it a long "gravitational influence time." The apparent result? In a situation reminiscent of David and Goliath, the tiny body manages to contain the ring's vast particle population, preventing it from escaping outward and depleting the ring to oblivion.

(Also conspicuously sharp-edged is the overall ring system's visible inner boundary, the inner edge of the C-ring. Might still another satellite be responsible for that? "I think," said Smith the day after S-15's discovery, "we ought to bet on it right now.")

The skinny F-ring revealed another oddity in the photos—a distinct "clumpiness" in which segments of the ring as much as 200 km long appear substantially more densely packed with particles than do adjacent portions. Perhaps, suggested NASA's James Pollack, the clumping and other asymmetries are providing a look at the processes by which small particles accrete into larger bodies. And then the fast-closing spacecraft provided a photo showing the F-ring to apparently include three individual rings — with two of them seemingly braided.

Yet all was not rings with Voyager 1's encounter. Well outside the ring system, the spacecraft's ultraviolet spectrometer was taking the measure of a cloud of neutral hydrogen gas so huge that it had been in the instrument's view since July. Apparently originating in the atmosphere of the satellite Titan (bigger even than Mercury) the hydrogen was expected to exist in a doughnut-shaped torus following Titan's orbit, much like the sulfur ring along the path of Jupiter's volcanically active moon Io. Close to the planet, the spectrometer indeed showed a torus of sorts—but with a difference. Instead of being a simple doughnut the size of Titan's orbit, about 20 times the radius of Saturn, it turned out to be a vast, flattened affair, extending all the way from the orbit of Rhea at about 8 Saturn radii to well beyond Titan at 25. Analysis indicated a hydrogen Lyman-alpha brightness of about 100 Rayleighs, a density for the cloud of about 10 atoms per cubic centimeter and a total mass of 1.6 x 10^{34} atoms, or 25,000 tons.

One of the flyby's major goals was to take the first close looks at Saturn's family of satellites, which were largely missed by Pioneer 11. Key among them was Titan, the only satellite known to have a substantial atmosphere, and at press time dramatic closeups of other moons (together with long-sought measurements of Titan's atmospheric surface pressure and temperature) were just being collected.

Next week: moons and more. □

Major quake hits northern California

A major earthquake, registering approximately 7 on the Richter scale, struck northern California at 2:27 a.m. on Nov. 9. Only light damage was reported because the quake's epicenter was located some 10 miles offshore in the Pacific Ocean, near a sparsely populated part of the state. This was the largest earthquake in northern California since 1923, and Robert E. Wallace, chief scientist at the U.S. Geological Survey's Office of Earthquake Studies in Menlo Park, Calif., said it may mark the beginning of a new cycle of seismic activity in the state. He noted that prior to the Great San Francisco Earthquake in 1906 there had been a period of increased magnitude 7 quakes (SN: 6/7/80, p. 363).

The Nov. 9 quake occurred along a stretch of the Humboldt County coast where the San Andreas fault intersects the Gorda Basin, part of a tectonic plate pushing eastward against the North American continent. The area is one of the most earthquake prone in California and seismologists will have to study the records of the latest quake before they can say precisely what its magnitude was or just which fault was responsible.

The town nearest to the quake was Eureka, some 20 to 30 miles away, with a population of less than 30,000 people. Some houses there were shifted on their foundations, but the only major injuries occurred when a section of a highway overpass collapsed and two vehicles plunged 30 feet to the ground. The fallen span blocked the only railroad access to Eureka, but automobile traffic was easily rerouted.

Despite light damage in the area, a magnitude 7 earthquake is capable of causing severe destruction. The latest quake was at least as powerful as the San Fernando Valley quake in 1971 that killed 65 people, and again it raised concern over a nuclear power plant in Humboldt County. The plant had already been shut down because of a study that revealed a possible hazard from earthquakes, but nuclear fuel is still present. Pacific Gas and Electric Co., which owns the plant, reported that the reactor was not damaged by the recent quake. □