VOYAGER 2

All eyes and ears for Saturn

The last spaceflight to Saturn in who-knows-how-long has its work cut out for it

BY JONATHAN EBERHART

The flight of Voyager 2 past Saturn on Tuesday, Aug. 25, will be the last visit to another world by a U.S. spacecraft until 1986 (when the same probe gets to Uranus) — but it'll be a lulu.

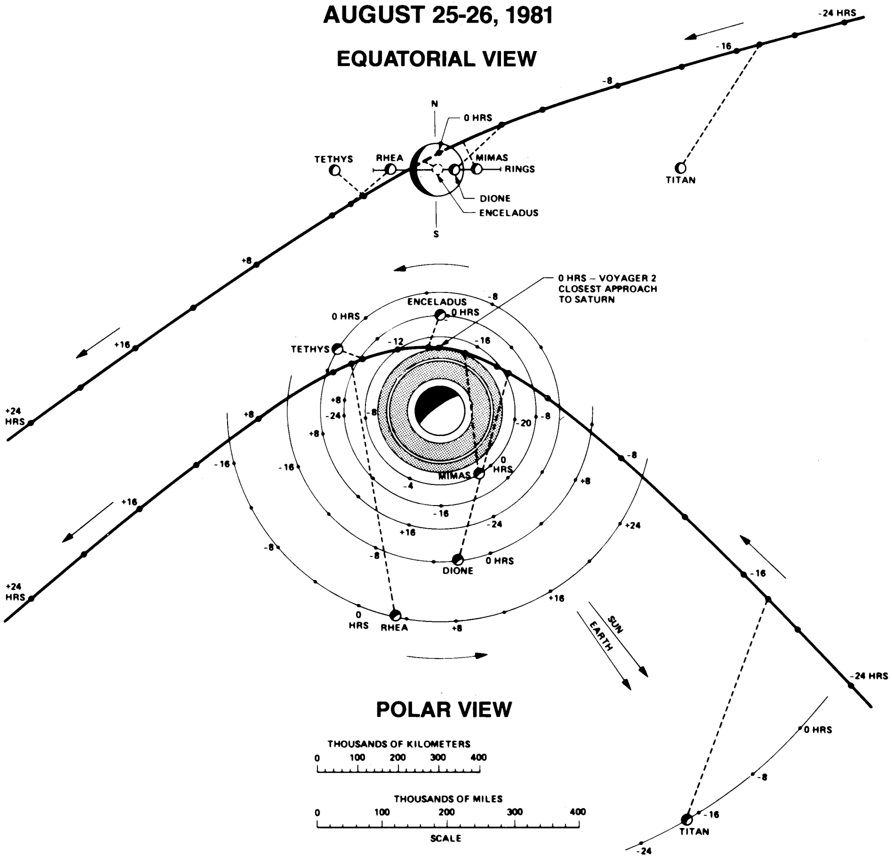
Less than 10 months ago, as Voyager 1 neared the climax of its own Saturn trek, scientists were expecting to encounter a planet with perhaps half a dozen distinct rings and 14 satellites. But the rings turned out to consist of hundreds of individual ringlets, and the list of moons grew to at least 17 — among other surprises. So many bizarre findings confronted Voyager 1's cameras and other sensors during its flyby that, before it was even past the planet, one observer at the Voyager control center at Jet Propulsion Laboratory in Pasadena proposed a T-shirt reading, "Whaddya mean impossible? This is Saturn!"

At that time, Voyager 2 was already hot on its predecessor's heels, and the complex series of computer commands that would guide its scientific observations had already been prepared, the result of two years of careful planning to accommodate the needs of the project's 11 diverse research teams. The need for a few changes had been anticipated, but this was to be no mere repeat mission. Altering the command sequence is a difficult, time-consuming process, both because each of the interwoven instructions affects others, and because Voyager 2's original observing plan was already filled to the brim, so that each addition must be made at the expense of something else. Yet so much was new that changes were a necessity. In the part of the plan covering the 20 hours before and after the closest approach to Saturn, in fact, fully half of the old commands were modified, of which two out of every five were thrown out completely and replaced.

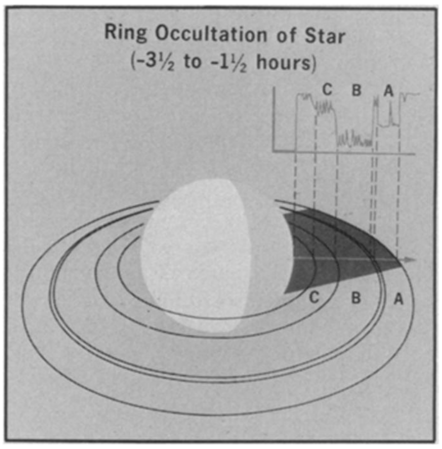
Voyager 1's most baffling find, for example, was the clumpy, multi-stranded nature of the thin F-ring, described by imaging team leader Bradford Smith of the University of Arizona as "braided." The braiding may be a satellite gravitational effect, but Voyager 1, caught unawares, showed it clearly in only two of its more than 17,500 frames. Voyager 2 has thus been reprogramed to photograph it in exhaustive detail — from above and below, at different radial positions, in stereo and in timed-sequence "movies." These and other changes have required such trade-offs as the elimination of all photos of Saturn's moons that would not offer sharper resolution than Voyager 1 imagery of the same targets.

Another ring puzzle has been the strange features dubbed "spokes," which extend out across the wide B-ring in a roughly radial direction, clashing with the ring's emphatically concentric patterning. Study of Voyager's photos suggests that however the spokes are formed, they become progressively less radial as they move around the ring, presumably because particles orbiting close to Saturn have a higher angular velocity than those farther away. The initial radial alignment, notes Voyager project scientist Edward Stone of Caltech, could come from the electric field that is normal to the axis of the planet's magnetic field — in other

TWO VIEWS OF VOYAGER 2 FLIGHT PATH PAST SATURN AUGUST 25-26, 1981



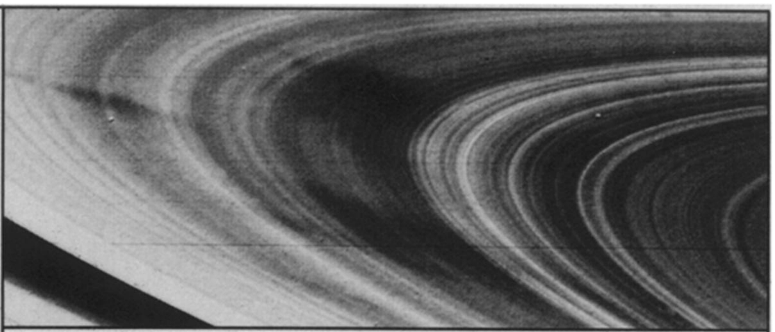
NOTE: SATELLITES (NOT TO SCALE) ARE SHOWN IN POSITIONS WHEN VOYAGER 2 IS CLOSEST TO THEM. ALSO SHOWN ARE SATELLITE POSITIONS RELATIVE TO HOURS BEFORE AND AFTER VOYAGER'S CLOSEST APPROACH TO SATURN

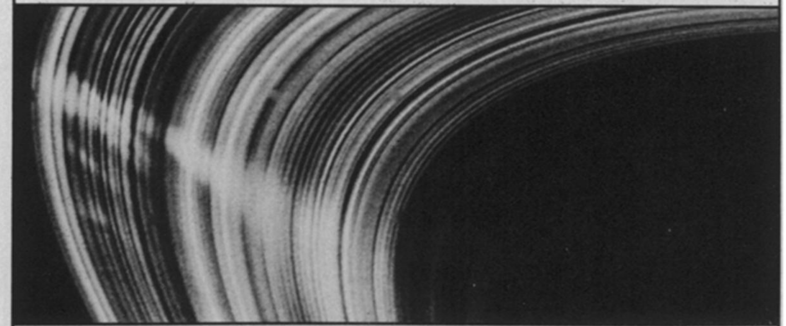


Looking through Saturn's rings as it flies, Voyager 2's photopolarimeter will record changes in the light of the star Delta Scorpii, revealing the number, densities, widths and intervening gaps of the numerous ringlets to 100-meter accuracy.

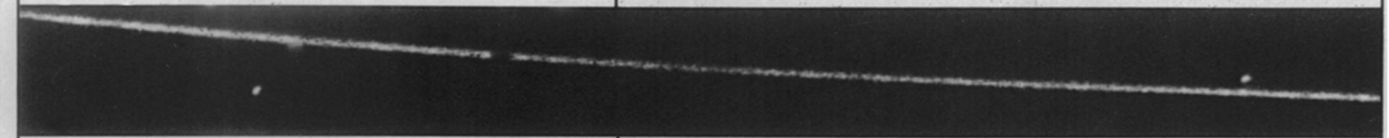
VOYAGER 2 CLOSEST APPROACHES

TARGET	TIME (PDT) AT VOYAGER	DISTANCE (KM) FROM CENTER	CHANGE (KM) FROM VOYAGER 1
August 22			
Iapetus	6:27 p.m.	909,070	1.560,930 closer
August 24			
Hyperion	6:25 p.m.	470,840	409,600 closer
August 25			
Titan	2:37 a.m.	665,960	659,470 farther
1980 S6	3:58 p.m.	313,200	88,200 farther
Dione	6:05 p.m.	502,250	340,730 farther
1980 S13	7:22 p.m.	153,520	278,777 closer
Mimas	7:34 p.m.	309,990	221,550 farther
1980 S28	8:08 p.m.	287,170	68,170 farther
1980 S26	8:19 p.m.	107,000	163,000 closer
Saturn	8:24 p.m.	161,094	23,047 closer
1980 S27	8:33 p.m.	246,590	53,410 closer
Enceladus	8:45 p.m.	87,140	114,900 closer
1980 S1	8:50 p.m.	222,760	74,240 closer
1980 S3	9:06 p.m.	147,010	26,010 farther
ring plane	9:18 p.m.	172,109	204,309 closer
1980 S25	11:03 p.m.	284,400	47,068 farther
Tethys	11:12 p.m.	93,000	322,670 closer
Rhea	11:29 p.m.	645,280	571,300 farther
September 4			
Phoebe	6:23 p.m.	2,075,640	11,461,360 closer



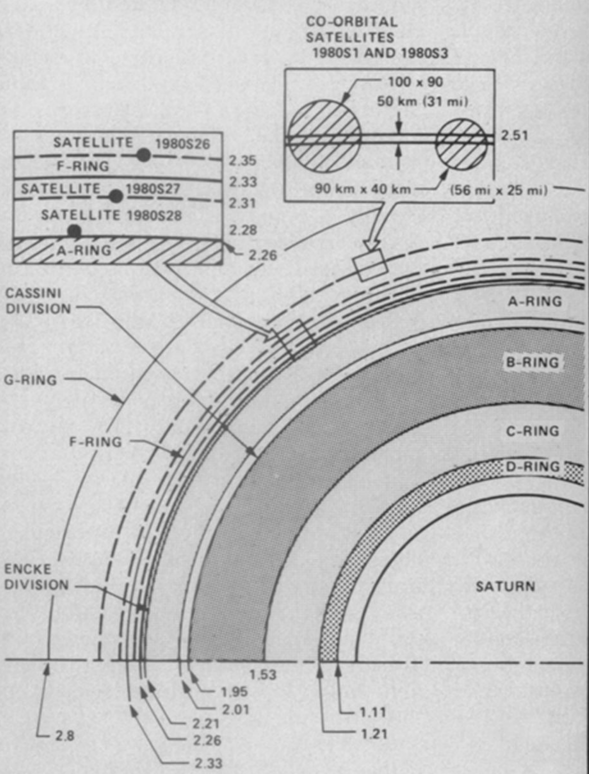


Voyager 1 discovered strange, spoke-like features in the B-ring, looking dark by backscattered light (top) and bright (above) in forward scattering, possibly generated by magnetic and electrostatic forces.



Two tiny moons apparently confine the F-ring (above) to a thin ribbon.

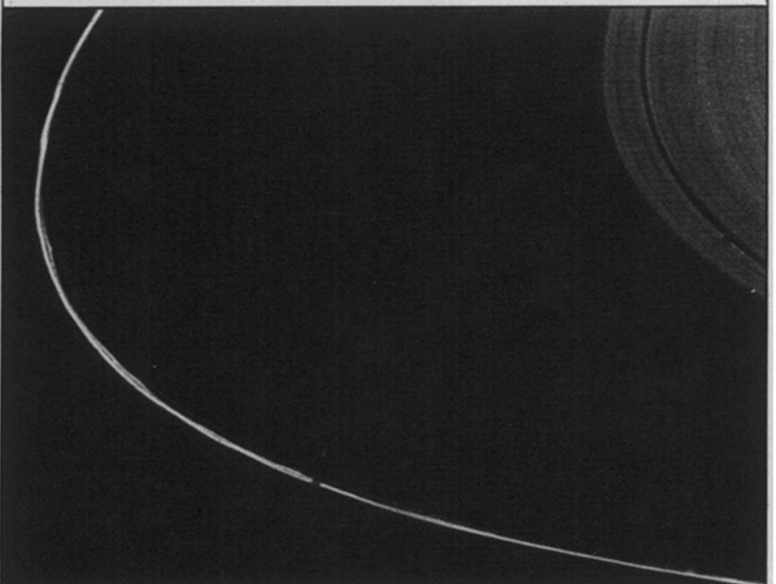
ORBIT LOCATIONS OF SATELLITES NEAR SATURN'S A RING AND F RING



NOTE: SATURN RADIUS IS 60,330 km (37,489 mi)
SATELLITE ORBIT AND RING DISTANCES
ARE GIVEN IN SATURN RADII

Photos, illustrations and charts: NASA

An even smaller moonlet orbits just outside the A-ring's sharp edge.

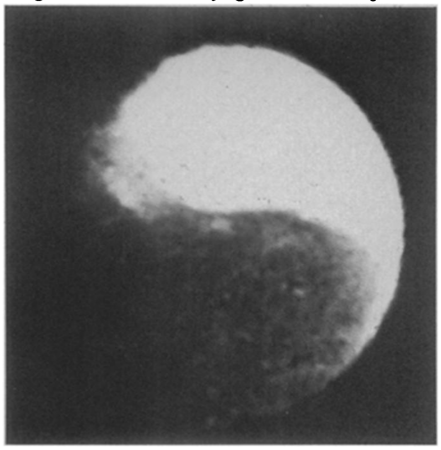


The kinked, possibly intertwined multiple strands of the F-ring, Voyager 1's most startling find, are still unexplained and will be a major target for carefully planned Voyager 2 photo sequences.

words, radial. It is unclear what generates the spokes in the first place, but Voyager 1's radio-astronomy instrument did record what seem to be electrostatic discharges originating in the rings. With no atmosphere to glow, the discharges may not take the form of giant sparks, but the spokes could be their visible manifestation. One early idea was that the spokes might take their shape from the near-radial edge of Saturn's shadow across the rings, but careful analysis indicated that the spokes were not parallel to the shadow edge when they emerged from it. Still, Voyager 2 will take sequence "movies" of successive spokes as they appear, also following individual spokes around the B-ring. Their light-scattering properties suggest that they consist of small particles, possibly levitated slightly out of the ring plane, and the spacecraft has been programed to try photographing the ring edge-on in search of such a particle haze. There will be time for only three of the edge-on images — one each slightly above, at, and slightly below the plane — in Voyager 2's single plane crossing.

(The two previous spacecraft to visit Saturn—Pioneer 11 in September 1979 and Voyager 1 last year—each penetrated the ring plane twice, always outboard of known concentrations of ring material, and obviously survived the trips without being obliterated by a stray chunk of ice or rock. Voyager 2 will flash through at a much closer distance than did Voyager 1, perhaps 3,000 kilometers outside the G-ring, but Pioneer 11 made a similarly close-in run with impunity. Thus the upcoming crossing is expected to be a safe one.)

Possibly the best data of all on the number of ringlets, their densities and widths, and the widths of the gaps between them could result from an experiment in which Voyager 2's photopolarimeter is aimed through the rings at the bright star Delta Scorpii. To the speeding spacecraft, the star will appear to move behind the rings, dimming or winking out completely as the ringlets successively get in its way. The



Voyager 2 will take the closest look yet at Iapetus, one of whose faces is several times brighter than the other.

changes in the star's apparent brightness should provide a record of the blockages and gaps across a single radial sample of the rings, extending from Saturn's limb all the way out to the F-ring, with an accuracy as precise as 100 meters. An indication of the experiment's importance to the Voyager scientists is that it requires data to be collected in a mode that allows no photos to be taken, yet it has been allotted 2 hours 20 minutes in the busiest part of the mission.

The experiment will end about an hour and a half before the spacecraft's closest pass by Saturn. A second occultation will be recorded about nine hours after closest approach as Voyager 2 looks back at the planet, this time aiming the photopolarimeter at the star Beta Taurii. The repeat run will take only 40 minutes, generating a light-curve from the F-ring to the outer A-ring, but even this short span should help scientists determine whether the ringlets are differently spaced at different positions around Saturn. Voyager 1 found signs of one or more eccentric or elliptical ringlets among the concentric, round ones, and its successor will photograph them at different points around the planet in an effort to determine their rates of precession.

A major influence on the elaborate structure of Saturn's rings is the existence of its satellites, and not merely because they produce gravitational "resonances" that account for the locations of the main rings and their gaps. The F-ring, for example, is bordered by two tiny moonlets (1980 S26 and S27), which are apparently responsible for the ring's narrowness. It has also been suggested that the F-ring's "braided" appearance may result from gravitational perturbations created when the two satellites are directly across the ring from each other. An even smaller moonlet (1980 S28) has been suspected of keeping the huge A-ring from diffusing out into space, but the satellite's mass is so minuscule, says Stone, that one of the F-ring duo is now a preferred candidate.

But there are still more oddities among Saturn's gallery of miniature moons. Just outside the F-ring pair are two more (1980 S1 and S3) that essentially share one orbit, taking turns in the leading position—yet without ever passing. Every few years, astronomers believe, the trailing object catches up with the leader, whereupon the two exchange energy, sending the leader speeding off to catch up from behind with the former trailer, which has obligingly slowed down to wait. Elsewhere in the system, 1980 S6 moves ahead of the satellite Dione, oscillating around a gravitational balance between Dione and Saturn, while Tethys apparently shares its orbit with *two* librating companions, 1980 S13 ahead and 1980 S25 behind.

Saturn's major satellite, Titan, revealed its most long-sought secret to the probing radio beam of Voyager 1—a methane-rich atmosphere with a surface pressure half again greater than earth's. Voyager 2 will not be in a position for another radio occultation, but it does have Voyager 1's experience to help set more accurate camera exposures for photographing possible cloud features as keys to atmospheric circulation. The only additions will be some polarization measurements in hopes of establishing the sizes of the organic particles believed to form at the top of the atmosphere and settle out in a sludgy layer at the bottom.

For Voyager 2, the most exotic satellite target by far will be Enceladus, to which it will come nearly 115,000 km closer — about 57 percent — than did last year's probe. Voyager 1 showed it to be perhaps Saturn's smoothest satellite (Tethys, photographed from nearly twice as far away, revealed a wealth of surface relief), possibly because tidal-dissipation heating from a 2:1 orbital resonance with Dione softens its icy crust. Also, two researchers have suggested that Enceladus may be the source of Saturn's diffuse E-ring, generated when meteorite impacts puncture the crust and toss icy particles out into orbit.

Iapetus is another unusual moon for which Voyager 2 stands to greatly improve the picture. The side of Iapetus that faces forward as it circles Saturn is five to six times brighter than the trailing hemisphere, which has prompted some researchers to speculate that an otherwise ice-clad satellite was darkened from behind by material that caught up with it after being cast off from Phoebe, the next moon out. Voyager 1's limited-resolution view of irregularities in the bright-dark boundary, however, suggests to deputy imaging team leader Laurence Soderblom of the U. S. Geological Survey that the difference may be due to the internal upheavals of Iapetus itself. It is unclear why such eruptions would concentrate so sharply in only one hemisphere, but diffuse, "wispy" features were photographed by Voyager 1 on similarly limited portions of Dione and Rhea.

Several other satellites will also be part of the show, as will, of course, Saturn itself, with its 1,800-kph winds and muted coloration. Equally intriguing is its magnetic field, which is tilted only 0.7° from the planet's axis of rotation, yet somehow manages to impress its rotational "signature" so strongly on Saturn's radio emissions that Voyager 1 could use them to determine the length of a Saturnian day from hundreds of millions of kilometers away. And finally, there is the yet-untested possibility that Voyager 2 may find Saturn immersed in a "filament" of the vast magnetic tail of Jupiter, perhaps blocking out the solar wind and changing the nature of Saturn's radiation belts. Voyager 1 flew by at the wrong time to study the effect, since Jupiter's tail was then far away.

And there will be more surprises. Whaddya mean impossible? This is Saturn! □