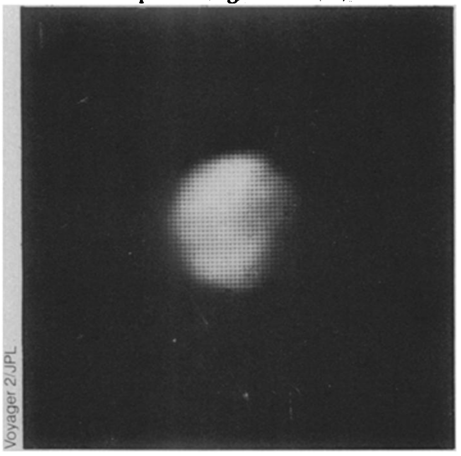
Saturn: Scanning the unseen scene

The spectacular rings, moons and wind-raked clouds of Saturn have been graphically captured in the thousands of photos taken in recent months by the two Voyager spacecraft. Yet there is another vital aspect of the Saturnian system to which the cameras are literally blind. Equally dramatic, constantly changing, alive with megawatt energies and vast on a scale dwarfing the planet itself, it is nonetheless invisible. It is Saturn's electromagnetic domain, an environment of magnetic fields, charged particles, radio signals, electrostatic discharges and more. And, like the more readily apparent phenomena in the photographs, it is displaying new surprises at every turn.

The radio emissions, for example, are so powerful that the Voyagers detected them from more than 600 million kilometers away. (Jupiter's still stronger signals have been known on earth since the early days of radio astronomy.) But as Voyager 2 was pulling away from Saturn late last month, heading for its 1986 rendezvous with Uranus, a totally unexpected thing happened. "For some reason," says Frederick L. Scarf of TRW, "Saturn turned off for four days."

Scarf is in charge of the spacecraft's plasma-wave sensor (PWS), which essentially measures the low-frequency end of the electromagnetic spectrum; the rest of the spectrum is monitored by a planetary radio astronomy instrument (PRA). One of the bands being recorded by the PWS was a 6-kilohertz emission that had been observed during both the inbound and outbound legs of Voyager 1's Saturn flyby last year, and (though at a somewhat reduced intensity) during Voyager 2's approach as well. Yet just after Voyager 2 passed the planet, the signal disappeared. "We don't know what happened," says Scarf. A similar dropout appeared to the PRA, which had also noted the reduced signal strength on the inbound pass. That was surprising enough, says Michael L. Kaiser of the NASA Goddard Space Flight Center, but "this dead silence [now ended] is just incredible."



Phoebe, Saturn's outermost known moon, only about 200 km across and unexpectedly round, was photographed Sept. 4.

Did Saturn indeed shut itself off? Not necessarily, though there is merely circumstantial evidence to suggest an alternative. Voyager 1 approached the planet from north of its equator, swooped down through the ring plane and back up again, departing also from the northern hemisphere. Voyager 2 also came in from the north, but only penetrated the ring plane once—leaving by the southern route. The earlier probe had already shown the northern hemisphere to be a stronger emitter than the south, but Voyager 2's view of the north was blocked for only a fraction of the four days of silence. One factor, though for reasons unknown, may be that it is summer in the Saturnian north, leaning that hemisphere about 8° toward the sun. There is also a slight tilt to the axis of the planet's magnetic field, but it poses a special quandary of its own.

The problem is that the tilt is so subtle —only about 0.7° in Voyager 1's data—that scientists are surprised that it can make any significant difference. Both Voyagers have been able to measure Saturn's rotational period by studying periodic modulations in the planet's radio emissions, and such modulations are almost surely due to some sort of longitudinal asymmetry in the magnetic field. But, says chief Voyager magnetometer experimenter Norman F. Ness of Goddard, "one is hard-pressed to understand how such a small tilt can have *any* effect in the modulation of the PRA signals." Instead, Ness was half-expecting Voyager 2's close-in pass through the field to reveal some sort of anomalous variation in the field strength —effectively an electromagnetic bulge— on one side of the planet. An early look at the data shows not a trace of such a bulge, though Ness this week was awaiting a detailed computer analysis of the spacecraft's positions during the flyby in hopes of refining his results. "It is," he says, "one of the real enigmas."

But not the only one. One of the most conspicuous parts of Saturn's invisible realm is the shock wave, or "bow shock," formed where the solar wind collides at supersonic speeds with the planet's magnetic field. The force of the solar wind pushes the sides of the bow shock back into a long, flaring skirt or tail, shaped roughly like a cone whose sharpness varies with changes in the solar wind's intensity. Voyager 2 followed a path that took it behind Saturn and around to the side. The shape of the skirt as derived from Voyager 1's penetrations of it prompted researchers to anticipate that Voyager 2 would emerge through the shock wave about 2 billion kilometers from the planet, or 35 times Saturn's radius (35 R_s). Such predictions are iffy at best, given the fickleness of the solar wind, but scientists waited as the spacecraft droned on and on inside the skirt, not passing out of the bow shock until it was some 77 R_s away. Twice the probe found itself back inside the shock and then out again (typical of the changing boundary) before finally leaving it for good at 87 R_s—two and a half times the expected distance from Saturn.

The presumed explanation is that the solar wind was simply "blowing" very weakly during that part of Voyager 2's journey, allowing the skirt to expand outward. But if so, says Ness, it was "the most expanded configuration yet studied by any spacecraft." In fact, says the Massachusetts Institute of Technology's James D. Sullivan, a member of Voyager's plasma science team, the solar wind drops to such a low pressure only about one percent of the time. Another factor, he adds, though presumably a lesser one, could be that the wind often changes direction somewhat, which could have the effect of swinging the whole bow shock around so that its skirts flare out along a different path.

Meanwhile, more is emerging about the mysterious "something" that affected the spacecraft just as it flew through the plane of Saturn's rings. Both the PWS and PRA instruments recorded sudden surges at the time, apparently of electrostatic rather than radio origin, leading to the speculation that Voyager had collided with a concentration of small particles in the ring plane. (This may also have been the time that the craft's instrument-laden "scan platform" stuck, as if jammed by a bit of loose material in its gears; the platform was still not back to normal by early this week.

A detailed look at the PRA data during the crossing, says Joseph Romig of Radiophysics, Inc., shows not only an intense peak centered right at the ring plane, but "at least five separate regions," with two lesser peaks above and two below the plane at similar spacing. Together, they represent a span extending from about 750 km above the plane to 750 km below it, almost as though Voyager 2 had encountered multiple rings arrayed like a stack of pancakes. This would be hard to swallow even for Voyager veterans of the anything-is-possible Saturn system, and the PRA team suggests that an alternative might be that the instrument was recording some sort of wave phenomenon, propagating outward through a cloud of particles to the north and south of the ring in the middle.

But what ring? The G-ring (discovered by Voyager 1) was thought to be inside the region penetrated by Voyager 2, and the wide, equally diffuse E-ring well outside. Voyager 2's photopolarimeter, tracking the flickering light of a star through the ring system, saw all manner of thin "ringlets" in supposedly empty regions. Perhaps a "phonograph record" analogy, connoting a continuous disk with circular thickenings and thinnings, is appropriate. Of course the grooves wouldn't be in the form of a continuous spiral. Of course not. □