SIGHTING IN ON SATURN

The Voyager 1 spacecraft is approaching a world that, far from being just a paler Jupiter, has surprises of its own

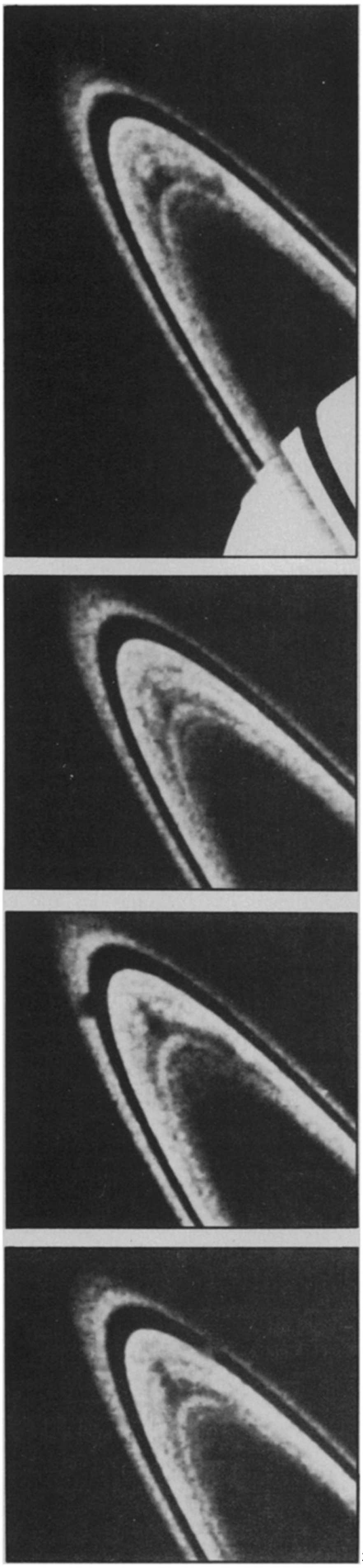
BY JONATHAN EBERHART

Saturn is a Cinderella world. Though it is one of the solar system's two supergiant planets, it is ever contrasted with Jupiter as the one with no Great Red Spot, the one lacking the vibrant color contrasts that make the larger body so spectacular. True, it has a large family of satellites, but so does Jupiter, and Jupiter's satellites include dramatic, volcanically active Io. Even the presence of rings, albeit ones so vast that they were seen by Galileo through his primitive telescope nearly four centuries ago, no longer uniquely identifies the planet.

Yet Saturn is no poor sister. The raging equatorial jetstream in the Jovian clouds is a quarter-speed crawl by comparison with Saturn's, Jupiter's ring system a relative trivium. The moons of Saturn include the only satellite known to have a substantial atmosphere, and others that may share or even swap orbits.

Now closing on Saturn at more than a million kilometers a day is the Voyager 1 spacecraft, directed there following its March 1979 encounter with Jupiter in hopes of shedding light on some of the distant world's mysteries. And, as has been true as long as space probes have been sent to explore other worlds, it is already raising new questions.

Launched from NASA's Kennedy Space Center in Florida on Sept. 5, 1977, Voyager 1 will make its closest approach to Saturn on Nov. 12. It will not be the first craft from earth to pass that way—Pioneer 11 earned that honor in September of last year, revealing new satellites, new structure to the rings, a puzzlingly well-ordered magnetic field and more (SN: 9/8/79, p. 163). More to the point, however, is the fact that those significant findings came from a probe that was built, relatively speaking, on a shoestring, using simple gyroscopic spinning for stabilization and embodying other economies. It was not even designed for the task, surviving the six-year, three-billion-kilometer trek in defiance of its formal specifications. Voyager 1 is not only a more ambitious design, with more power, higher data-transmission rates, more elaborate instruments and so on, but was built nearly half a decade later, benefiting from the rapid evolution of the technological state-of-the-art. At the Voyager control center at Jet Propulsion Laboratory in Pasadena, Calif., some 300 people are taking part in the mission, with more than 100 scientists plugged in from research facilities around the country and abroad.



Voyager 1/JPL

Radial features jutting across the general circumferential pattern of Saturn's widest ("B") ring were virtually unknown until they began showing up a few weeks ago in Voyager 1 photos such as these four, taken Oct. 4 and 5. An early interpretation was that the dark, short-lived features might be reduced ring-particle concentrations caused by gravitational resonances among the planet's satellites, but, said one project scientist not long afterward, "The ring structure now looks so complicated that we're having to throw out all our easy answers."

Though the mission is only a "flyby"—it will not land, probe the atmosphere or go into orbit — the spacecraft has been monitoring Saturn for the past 10 months, taking increasingly sharper photos and listening to radio emissions that could not even be clearly detected from earth.

The craft hit paydirt almost as soon as it began its scrutiny. The length of a day on Saturn had previously been calculated by earth-based astronomers tracking individual features across the planet's cloud tops, but few such features are visible from earth, possibly because Saturn is so cold that a high-altitude haze overlies the top of the atmosphere. The ones that have been seen, like those on Jupiter, move at different speeds at different latitudes, leaving Saturn's real, "internal" rotation period uncertain. Voyager 1, however (together with Voyager 2, following nine months behind), was able to record variations in the planet's radio emissions as it turned, pinning down the internal period at 10 hours 39.4 minutes.

This promptly raised another question: Pioneer 11 had showed the axis of Saturn's magnetic field, important in producing the emissions, to be almost exactly aligned with the planet's rotation axis (unlike the other planets with known intrinsic fields whose axes are tilted). A tilt could have modulated the emissions in a way that yielded a radio "signature" characteristic of the speed of rotation. With no tilt, what is causing the variations detected by Voyager 1? Local differences in the field, such as those in the earth's field, would do the job, but earth is a hardrock world with compositional and density variations "frozen" in place, not a gasball in presumed hydrostatic equilibrium.

And why is the field axis straight up in the first place? The one published hypothesis (SN: 6/21/80, p. 393) depends on a particular idea about how Saturn's hydrogen and helium combine in the planet's interior, but to survive it must also deal with another Saturnian oddity: It's too hot.

Jupiter gives off about 1.7 times more heat than it receives from the sun, roughly what one would expect if the giant planet is simply cooling down from its initial formation temperature, and Saturn, says Andrew Ingersoll of Caltech, ought to follow about the same ratio. Instead, Saturn seems to be emitting more than three times its solar input, implying some additional heat source. One idea is that the heat is caused by the gravitational separation of Saturn's helium from its lighter hydrogen. But some researchers say this should show as a reduced helium percent-

Voyager I Closest Approaches

Target	Time (PST) at Voyager	Distance (km) from surface
NOVEMBER 11		
Titan	9:41 p.m.	4,000**
ring plane	11:22 p.m.	1,184,575*
NOVEMBER 12		
Tethys	2:16 p.m.	415,320
Saturn	3:45 p.m.	124,200**
Mimas	5:42 p.m.	88,820
Enceladus	5:50 p.m.	202,521
Dione	7:39 p.m.	161,131
ring plane	9:45 p.m.	377,900*
Rhea	10:21 p.m.	72,000
NOVEMBER 13		
Hyperion	8:44 a.m.	879,127
Iapetus	11:25 p.m.	2,474,000

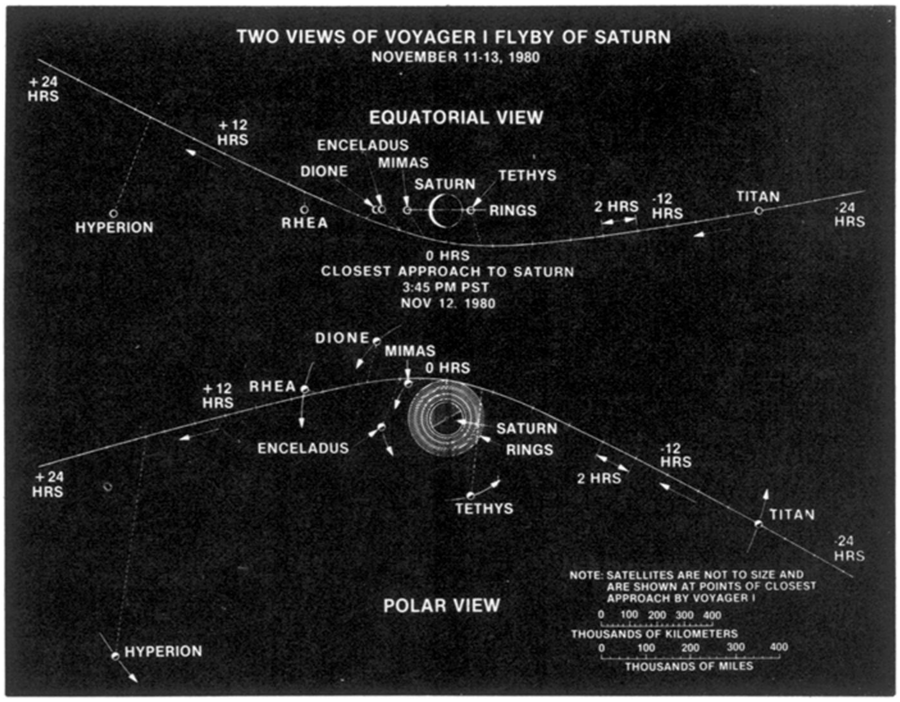
*ring plane crossing in km from center of Saturn

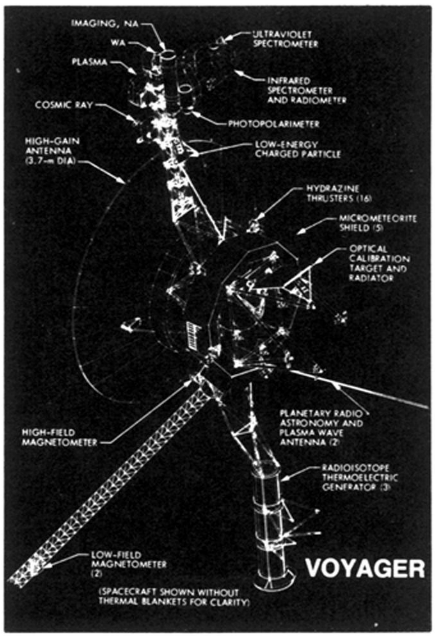
**km from visible top of atmosphere

age at the top of the atmosphere (compared to the solar abundance with which the planet formed), and Pioneer 11 showed no such reduction. Does convection keep the gases mixed in defiance of gravity? There is no easy answer, but the Voyagers are in a position to help.

As for the bland, presumably hazed-over cloud patterns, they held up through more than half a year of Voyager 1's ever-closer photos. In early October, however, the images began revealing increasing numbers of bright and dark spots and other turbulence features. They are smaller than many of Jupiter's, possibly because Saturn's lower absolute heat output produces less convection. But they are at least energetic enough to reach up into the haze, giving scientists clues to the dynamics of the planet's atmosphere.

As for Saturn's rings, the previously recognized pattern of three main rings and two or three lesser ones has shown itself to be vastly more complex, with dozens of circumferential stripes distinguishable by color and brightness differences. By early October, a ring of material was clearly visible *in* the wide Cassini division, with signs





pointing to a possible mini-division within that ring. Unexpected dark radial features in the "B" ring — not permanent yet strangely long-lived — so excited scientists that they reprogramed the spacecraft to take photos that could be combined into a "movie" of the rings' rotation. Voyager 1's cameras have not been expected to resolve individual ring particles smaller than about a kilometer, but radio-occultation data will help.

The moons of Saturn offer a host of tantalizing targets. Huge Titan is believed to have substantial atmosphere (but so poorly understood that surface pressure estimates range from 20 to 2,000 millibars), possibly generating a rain of organic materials and making Titan, to some scientists, a more important objective even than Saturn itself. High-altitude winds could be dramatic if particles absorb the sun's heat in the upper atmosphere; unfortunately, project researchers hold out little hope of seeing the surface, except possibly in small patches. Another satellite, Iapetus, is noteworthy because one side of it is six times brighter than the other; it has been suggested that one side of Iapetus may receive a continuous dusting of material carried in from Phoebe, the next satellite out, much as the sulfurous cast of Jupiter's moon Amalthea has been tentatively attributed to material brought in from Io.

The currently favored explanation for Io's volcanism — tidal stress caused by Jupiter's varying gravitational pull as the satellite follows an orbit kept out-of-round by the attraction of another moon — may also affect the Saturnian satellite Enceladus, caught in a tug-of-war between Saturn and its moon Dione. It was recently suggested that Enceladus might be the source of Saturn's E-ring, if the satellite has a water mantle kept liquid by the tidal heating and occasionally spurted out by meteorite impacts, but the idea is far from proven.

Earth-based observations, supported by Voyager photos, have indicated yet another oddity, previously unknown in the solar system: two moons in the same orbit — Dione and one so far dubbed "Dione B." Two other satellites, closer in to the planet, may come so close together in their near-identical orbits that every few years they swap positions, with the inner one becoming the outer. Many of Saturn's satellites also represent a class never before studied by spacecraft — smaller than earth's moon and Jupiter's Galilean satellites, but larger than the Martian moons Phobos and Deimos or Jupiter's Amalthea.

Voyager 1 could be the Cinderella world's glass slipper. □