Pioneer 11's New Saturn

The little Pioneer 11 spacecraft's new findings about Saturn and its environs reached the earth in the electronic equivalent of a slow trickle — 1,024 data bits per second down to as few as 128, compared to the expected torrent of as many as 44,800 each when the two Voyager probes get there in 1980 and 1981. But in that tiny stream flowed quantities of information — much of it simply inaccessible to earth-based observation — about wide-ranging aspects of the Saturnian system.

• **The planet:** The interior of Saturn had been modeled long before Pioneer 11, based on such "evidence" as comparisons with Jupiter and analyses of the planet's gravitational effects on its satellites' orbits. By plugging in the measured effects on the spacecraft's trajectory, along with magnetospheric and other data, John D. Anderson of Jet Propulsion Laboratory is now starting such guesstimates on the road to reality. An early look, he says, seems to support a rocky inner core about the size of the earth (about one-ninth of Saturn's diameter) but three times its mass, wrapped in a compressed blanket of such materials as water, methane and ammonia extending out to about 0.23 percent of Saturn's radius (0.23 R_S). From there out to about 0.58 R_S is the layer of electrically conductive, "metallic" hydrogen whose currents are the source of the planet's magnetic field. Most of the rest consists of somewhat less dense liquid hydrogen, atop which lies the comparatively minuscule layer that is the gaseous, cloudy atmosphere. Further work, Anderson says, should indicate the planet's precise shape or geoid (Saturn is extremely oblate due to its rapid rotation and low density, making it about 12,000 km shorter through the poles than through the equator) to within 60 or 70 meters.

Although Pioneer 11's images of the cloud tops will be greatly surpassed in sharpness and color accuracy by Voyager's, infrared measurements were able to show a sharp temperature drop within about 8° north and south of the equator, indicating that the faint, near-equatorial banding visible in the pictures could be due, as on Jupiter and earth, to a region of high, cool cloud. Also, according to Andrew Ingersoll of California Institute of Technology, the IR data seem to confirm that Saturn's internal heating causes it to emit about 2.5 times as much energy as it receives from the sun. High above the clouds, changes in the probe's radio signal as it passed through the atmosphere's outer fringes indicate an exospheric temperature of about 1,250°K (977°C), possibly higher than even Jupiter's, according to Arvydas J. Kliore of JPL and certainly too high to be due to solar heating alone. A possible explanation, according to chief project scientist John H. Wolfe of the NASA Ames Research Center, could be magnetic waves that propagate in from the outer part of the planet's magnetic field in response to varying solar wind conditions; the waves could "wiggle" the ions trapped in the inner field, which would in turn agitate neutral atoms and molecules in the upper atmosphere to cause the heating. Ultraviolet data have also raised the possibility of near-polar auroral regions.

• **The rings:** Pioneer 11 has added new detail to their complex structure, including an "F" ring about 3,500 km outside the clearly visible ring system, and an even fainter "G" ring (detected, says James H. Trainor of NASA's Goddard Space Flight Center, by its absorption of magnetospheric electrons and protons) that seems to occupy a region about 540,000 to 840,000 km above the equatorial clouds. This would put it about 460,000 km outside the rest of the rings, except for a possible wide "E" ring so rarified that Pioneer 11 didn't detect it at all, but which has been inferred from earth-based measurements to possibly extend from the main rings outward for a distance of nearly 3 million kilometers.

Many researchers have assumed that the ring particles are composed largely of water ice, and the new data seem supportive. Ultraviolet scans indicate a cloud of glowing hydrogen enclosing the ring region (and more faintly permeating the whole Saturnian system), probably due to photodissociation of the water, according to Darrell L. Judge of the University of Southern California, and gravitational data suggest that the rings have a low overall mass, as they would if mostly ice. Structurally, says Ingersoll, the temperature difference between the ring system's shadowed and sunlit sides is great enough to suggest that the rings are more than a single layer of particles thick, as some models had proposed. (Good chances for earth-based observers to study the ring thickness may come around Oct. 27, as well as March 12 and July 23 of next year, when the ring plane will be edge-on to earth. Greatly improved instruments have been developed since the last opportunity in 1966 — which yielded some of the E-ring data as well as possible evidence for an eleventh satellite — and the next chance after 1980 will not come until 1995. Intensive observations are being planned.)

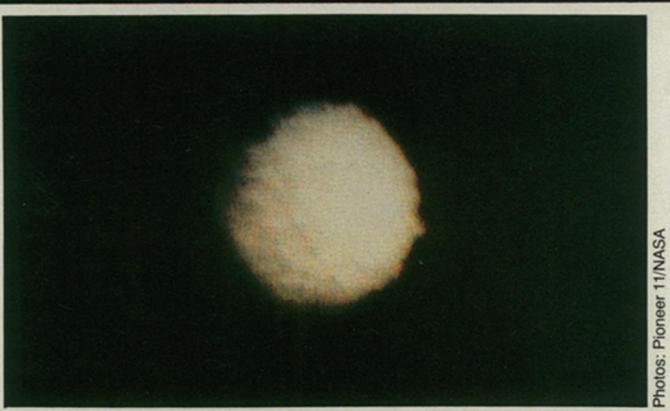
• **The satellites:** Although Voyager 1 discovered Jupiter's ring system, no spacecraft has yet been credited with finding a new individual planetary satellite (Mariner 10 was briefly but erroneously thought to have found one orbiting Mercury in 1974). Pioneer 11, however, has spotted not one but two objects that have at least not been readily matched with Saturn's known moons. The problem is that one of the already-listed satellites — Janus — has an imperfectly known orbit, and the limited observations of another — known only as S-11 — have enabled no orbital analysis at all; thus it will take detailed studies of the data to find out whether Saturn can now be said to have 10 moons, or 11, or 12, or 13. One of Pioneer 11's finds can actually be faintly seen in one of the spacecraft's photos, though it was first detected by instruments that noted its "wake" through particles trapped in Saturn's magnetic field. The other, informally christened "Pioneer Rock," showed only in particle-absorption and magnetic-field data, but the University of Chicago's John Simpson was able to tentatively conclude that it is 200 to 600 km across, and was detected about 90,000 km from the planet's cloud tops. The upcoming edge-on ring observations from earth may provide a chance for such faint satellites to be seen.

Analysis of the gravitational data should yield improved mass measurements for several of the moons (Rhea, Iapetus and Titan), Anderson reports, and there are signs of a possible hydrogen cloud (though not a complete, Io-style torus) associated with Titan. Unfortunately, although interference from a Soviet satellite turned out not to have drowned out much-anticipated infrared measurements of Titan's day-night temperature difference (relating to the thickness of the satellite's atmosphere), solar interference did the job instead. "There's not a prayer," says Ingersoll. But Voyager 1 is coming.

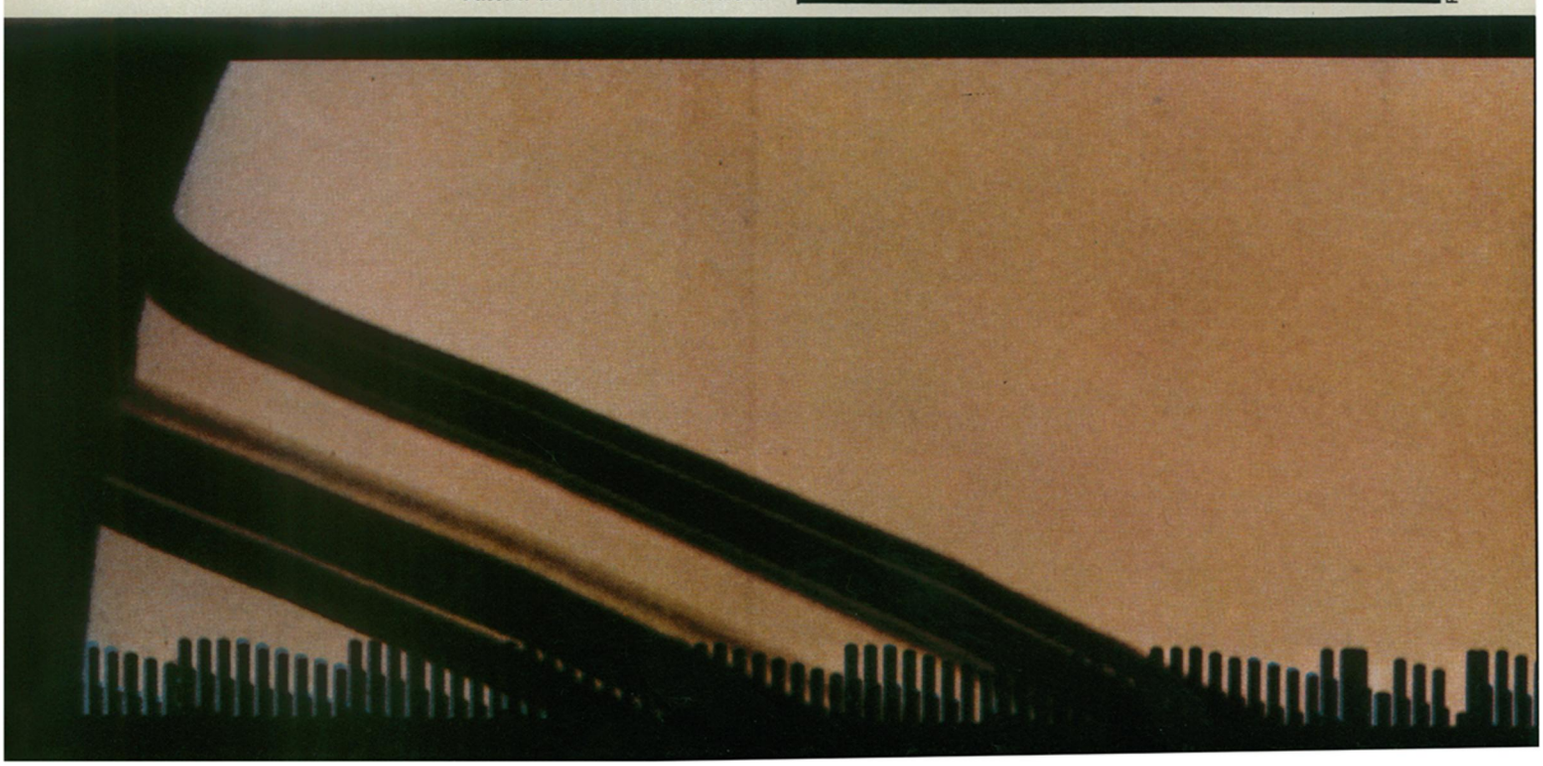
• **The magnetic field:** Besides being the only intrinsic planetary field yet measured that is apparently not tilted at all relative to its planet's rotation axis, Saturn's field is three to five times weaker than expected, according to Edward J. Smith of JPL. Sustained by a source region occupying a comparatively small proportion of the big planet's radius, the field at the equatorial cloud tops is even weaker than earth's — about 0.22 gauss versus about 0.3. At the north and south poles (relative to the ecliptic, since Saturn's magnetic polarity is the reverse of earth's, with magnetic "north" in the southern hemisphere), however, the field strengths are a more earthlike 0.69 and 0.53 gauss, respectively, Smith says, due to Saturn's greater polar flattening.

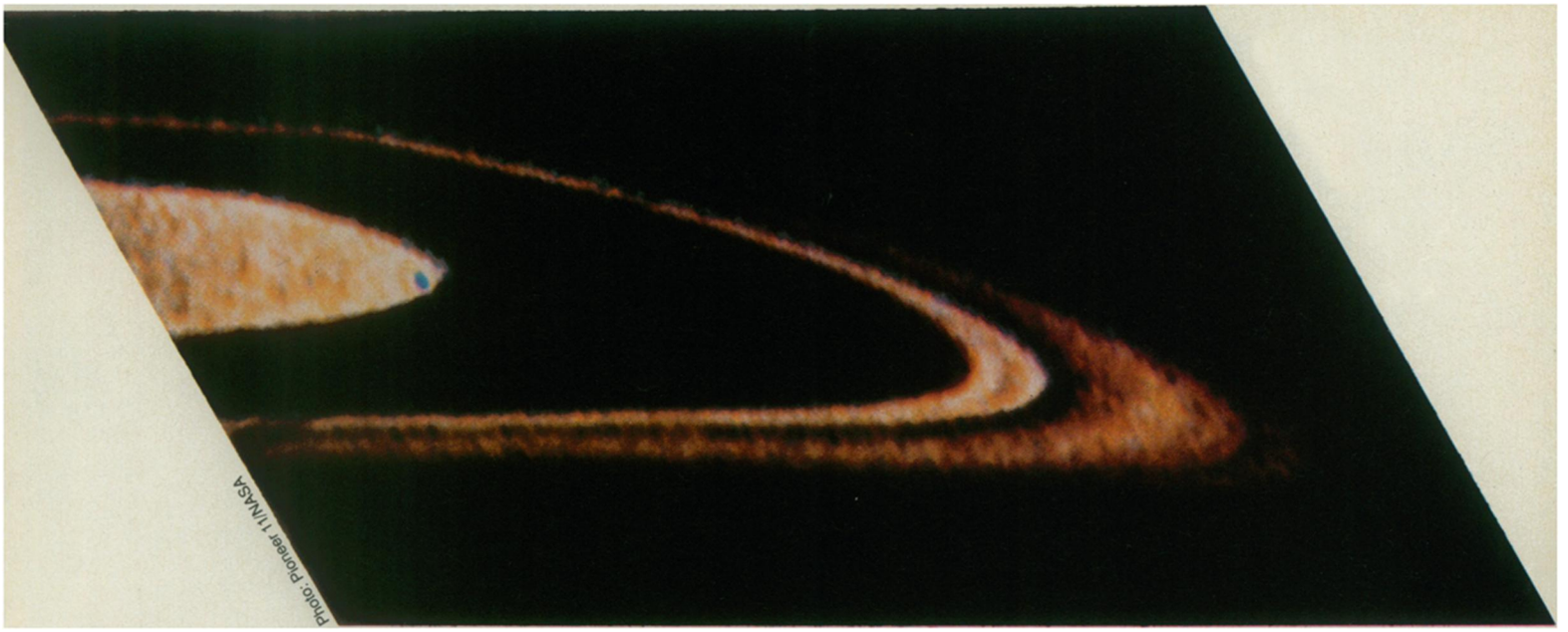
The weak field, combined with the presence of the rings and satellites that absorb magnetically trapped particles, gives Saturn a benign radiation environment relative to Jupiter's. During the entire Saturn encounter, Pioneer 11 received a total dose of about 9 billion electrons per square centimeter with energies above 3 million electron volts. "For comparison," says Simpson, "the spacecraft received approximately the same dose in only two minutes in the radiation belts of Jupiter." □

Saturn (above), showing the side of its rings away from the sun, was here photographed by Pioneer 11 on Aug. 29 from 2,846,000 kilometers away. Unlike Jupiter, many of whose features are visible from earth, Saturn here reveals only faint banding in its polar and equatorial regions, weakened perhaps by overlying haze. The huge satellite Titan is above the planet. Closer view of Titan (right), taken Sept. 2 from 370,150 km away, shows some limb-darkening probably related to its atmosphere, though the color as shown is considered unreliable, and the apparent mottling is largely an artifact of the imaging system. Swath of Saturn's north-equatorial region (below), differently color-balanced than the portion of it shown on the cover, shows a bland face even in relative close-up, together with rings (lower stripes) and their shadows. Light streaks in rings and shadows represent the Cassini and "French" Divisions.



Photos: Pioneer 11/NASA





Portion of the "dark" side of Saturn's rings appears unlike earth-based telescopic images because sunlight is reaching Pioneer 11's camera after being scattered through the ring particles, rather than reflected back from them as in the sunside view.

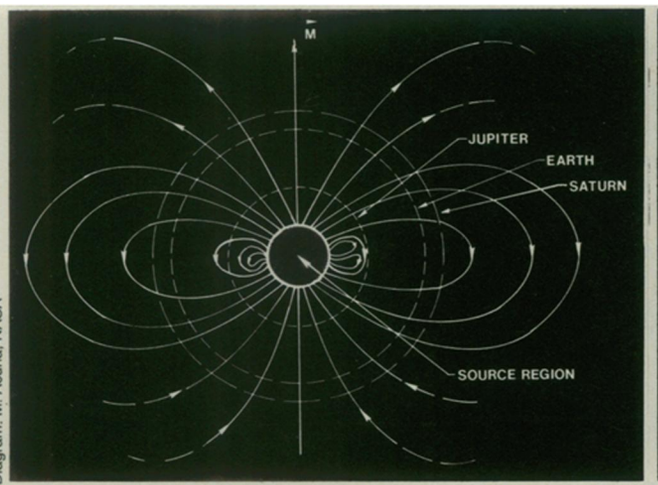


Diagram: M. Acuna, NASA

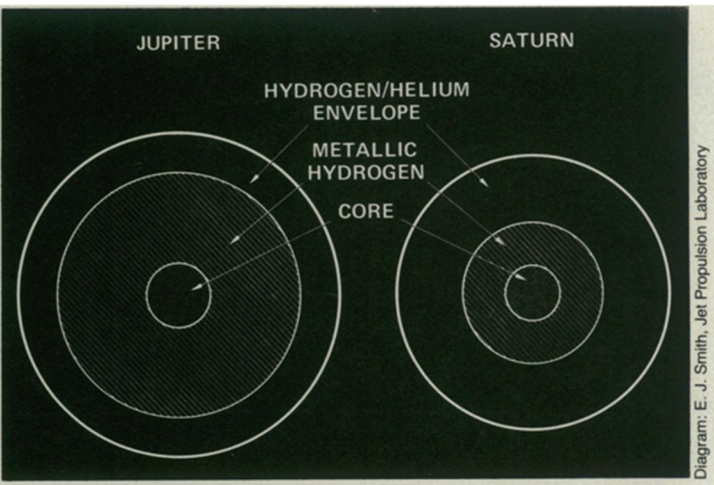
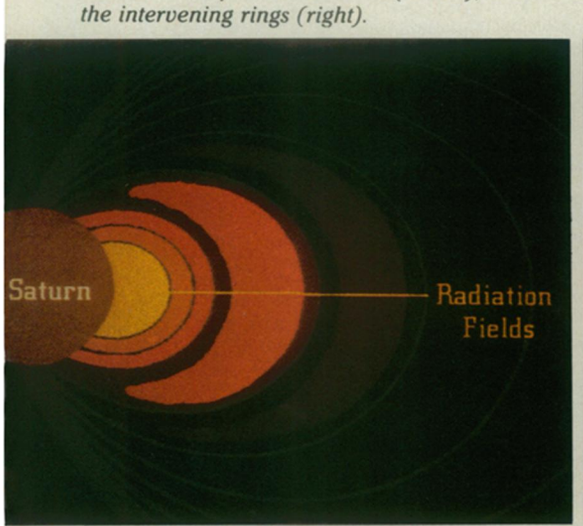
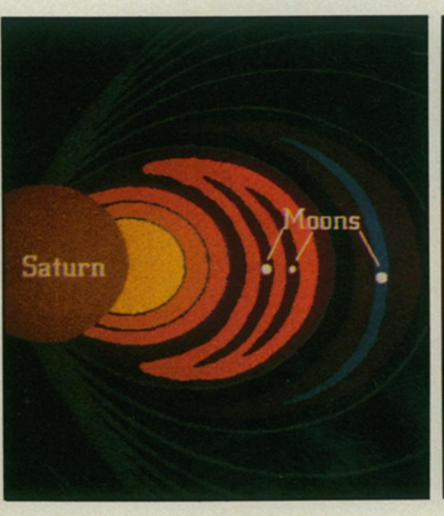
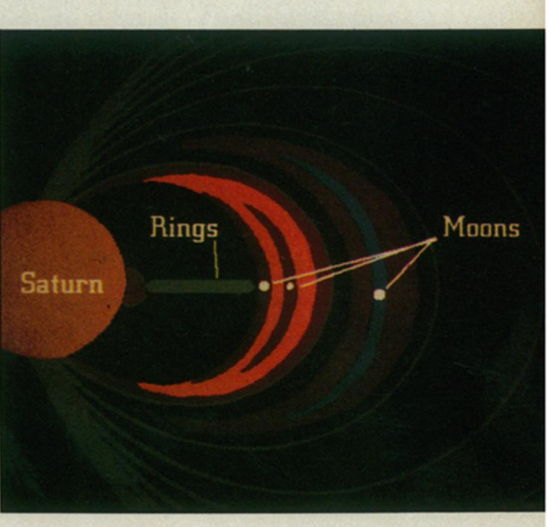


Diagram: E. J. Smith, Jet Propulsion Laboratory

Saturn's surprisingly orderly magnetic field may be due to the fact that the electrically conductive metallic hydrogen that is the field's source region occupies a relatively small portion of the planet's radius compared with the source regions of the earth or even mighty Jupiter. Diagram (upper left) shows the three planets with estimated source regions scaled to the same size, suggesting that only the regular dipole portion of Saturn's field extends outside the gasball. Jupiter and Saturn are compared at upper right. Charged particles trapped by the field would give Saturn intense radiation belts (diagram below left), except that many of the particles are absorbed by several of the planet's satellites (center), and the strongest portion of the field, closest to the planet, is swept virtually free of particles by the intervening rings (right).







Diagrams: Damon Rarey/Xerox color graphics system