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PRELIMINARY SCIENCE RESULTS OF VOYAGER 1 SATURN ENCOUNTER

Voyager 1's encounter with Saturn began Aug. 22, 1980, when the spacecraft was 109 million kilometers (68 million miles) from Saturn. Closest approach to Saturn took place at 3:46 p.m. (PDT) Nov. 12, when the spacecraft passed 126,000 km (78,000 mi.) from the cloud tops. The encounter ended Dec. 15, 1980. The spacecraft took more than 17,500 photographs of Saturn and its satellites.

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Scientific results of the encounter are as follows:

Saturn

From the spacecraft, as from Earth, Saturn's atmosphere appears grossly similar to Jupiter's, with alternating dark belts and light zones, circulating storm regions and other discrete dark and light cloud markings. Unlike Jupiter, however, Saturn's markings are strongly muted by a thick haze layer above the visible cloud tops. (Jupiter has a similar haze layer, but it is not as optically thick as Saturn's.) Because Saturn is colder, the cloud layers are deeper in the atmosphere than at Jupiter and appear blander.

Wind speeds in the atmosphere of Saturn are substantially higher than on Jupiter, and do not appear closely tied to the belt-zone boundaries. Highest winds (about 1,770 km or 1,100 mi. an hour) blow eastward at the equator and are four times stronger than on Jupiter. The velocity decreases smoothly to near zero at about 40 degrees latitude north and south.

The bulk of Saturn's atmosphere is composed of hydrogen. Helium accounts for only about 11 percent of the mass of the atmosphere above the clouds, compared to an abundance of about 19 percent at Jupiter. The difference is consistent with gravitational separation of helium and hydrogen in Saturn's interior and could generate the excess energy radiated by Saturn over that received from the Sun.

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Voyager 1 found aurora-like emissions near the illuminated limbs of the planet, and auroras in ultraviolet light were found in a ring near 80 degrees south latitude. Scientists faced a difficult and unexpected problem in attempts to detect lightning on the dark side of Saturn, since the rings reflected too much light onto the night side. Although lightning has not been detected in images of Saturn's dark face, radio emissions typical of electric discharges have been observed. Those discharges originated in the rings.

Radio emissions, primarily from the north polar region and near 90 degrees longitude, indicated that the body of Saturn and its magnetosphere rotate with a period of 10 hours, 39 minutes and 26 seconds.

The Rings

Voyager 1 found that the classically observed A-, B- and C-rings consist of hundreds of small ringlets, a few of which are elliptical in shape. Even the classical gaps were seen to contain ringlets; the Cassini Division appears to contain at least five, each of which shows finer detail. The F-ring, discovered by Pioneer 11 in 1979, is composed of three separate ringlets that appear to be intertwined. The inner and outer limits of the F-ring are controlled by two shepherd satellites, 1980S26 on the outside and 1980S27 on the inside. The intertwining or "braiding" phenomenon is unexplained -- although it may be related to electrostatic charging of the dust-size particles comprising the ring.

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Near the outer edge of the A-ring orbits the newly discovered satellite 1980S28. All three of those satellites (1980S26, 1980S27 and 1980S28) were discovered by Voyager 1.

Voyager 1 also photographed the D- and E-rings, during passage through Saturn's shadow, and confirmed a new ring near 2.8 Saturn radii from the center of the planet. The existence of that ring had been postulated on the basis of Pioneer 11 fields and particles data.

Measurements show that the E- and F-rings have large populations of particles smaller than about 2/10,000th of an inch in diameter. Radio measurements of the C-ring indicate that it has an effective particle size of about 2 m (6 ft.), and, at the same time, suggest a wide distribution of particle sizes. Effective particle sizes for the A-ring and the Cassini Division are 10 and 8 m (33 and 26 ft.), respectively.

On its inbound leg, Voyager 1 discovered a series of transient, spoke-like features that radiate outward across the B-ring; they first appear as the ring emerges from darkness and seem to dissipate within a few hours. In photos taken during the inbound portion of the flight, the spoke-like features appeared darker than the surrounding ring material.

After it passed Saturn, Voyager 1 took photographs of the spoke-like features that showed they were brighter than surrounding material. The material in the spokes forward-scatters sunlight effectively, implying extremely small particles.

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It is possible that the fine material is levitated above the rings. The electric discharges in the rings may be associated with the spokes.

New Satellites

Photographs of the new satellites were used to measure their size. The innermost satellite, temporarily designated 1980S28, is about 30 km (19 mi.) in diameter. The next satellite, 1980S27, which shepherds the inner edge of the F-ring, is about 220 km (137 mi.) in diameter. Next is 1980S26, outer shepherd of the F-ring, about 200 km (124 mi.) in diameter. 1980S3 and 1980S1, which share an orbit 91,120 km (56,620 mi.) from the clouds, are 90 by 40 km (56 by 25 mi.) and 100 by 90 km (62 by 56 mi.), respectively. And 1980S6, the new satellite that occupies the same orbit as Dione (about 60 degrees ahead) is about 160 km (100 mi.) in diameter. Other satellites may be discovered as Voyager scientists sift through the mountains of data returned from the spacecraft's encounter -- or from photos to be returned in the summer of 1981 by Voyager 2.

Other Satellites

Voyager 1 observed all Saturn's known satellites except Phoebe. Mimas, Enceladus, Tethys, Dione and Rhea are approximately spherical in shape and appear to be composed mostly of water ice.

Tethys in particular seems to be almost pure ice, while Dione has a density that indicates it is 40 percent rock. All five are of sizes not previously explored by spacecraft. Their measured diameters, accurate to about 20 km (12 mi.), are: Mimas, 390 km (240 mi.); Enceladus, 500 km (310 mi.); Tethys, 1,050 km (650 mi.); Dione, 1,120 km (700 mi.); and Rhea, 1,530 km (950 mi.).

Mimas, Tethys, Dione and Rhea are all cratered; Enceladus appears smooth. One very prominent crater on Mimas is so large it covers about one-third the diameter of the satellite. Stretching for 750 km (465 mi.) across the surface of Tethys is a valley that is 60 km (37 mi.) wide. The valley appears to be a great fracture in the crust of the satellite. Several sinuous valleys, some of which appear to branch, are visible on Dione's surface, as are smooth plains, suggestive of internal processes and renewal of portions of the surface.

Both Dione and Rhea have bright, wispy streaks that stand out against an already-bright surface. The streaks are probably the result of relatively fresh ice that has migrated from the interior fairly recently (on a geologic time scale).

Enceladus shows no evidence, at 12 km (7 mi.) resolution, of any impact craters. Because the maximum intensity of the E-ring occurs at the orbit of Enceladus, it has been speculated that the satellite is the source of particles for that ring; it also may be that tidal stresses cause a surface renewal similar to Jupiter's satellite Europa.

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Enceladus was not a prime target for Voyager 1; Voyager 2 will fly closer and return higher-resolution pictures of that satellite.

Hyperion's and Iapetus' masses are poorly known, so their densities are uncertain. It is, however, likely that they too are mostly water ice, although Iapetus is peculiar because it has one bright and one dark hemisphere. The dark side, which faces forward as Iapetus orbits Saturn, reflects only one-fifth as much light as the bright, trailing side. Hyperion, which also has a somewhat darker surface, has a diameter of about 290 km (180 mi.), and Iapetus has a diameter of about 1,440 km (895 mi.).

Titan

Because of its unique atmosphere, Titan may turn out to be the most important and interesting body, from a terrestrial perspective, in the solar system.

For almost two decades, space scientists have searched for clues to the primeval Earth. At Titan, they found an atmosphere similar to the one that would have evolved on Earth, had Earth formed at Titan's distance from the Sun.

Titan was thought from Earth-based observations to be the largest satellite in the solar system. Voyager's close approach and diametric occultation show it to have a diameter of 5,140 km (3,194 mi.) -- slightly smaller than Ganymede, Jupiter's largest satellite. Both are larger than the planet Mercury.

Titan's density thus appears to be about twice that of water ice, requiring Titan to be composed of nearly equal amounts of rock and ice, as is Ganymede.

Titan's surface cannot be seen in photos from Voyager 1; it is hidden by a dense, optically thick haze. Several distinct, detached haze layers can be seen above the visibly opaque haze layer. The layers merge into a darkened hood over the north pole of Titan. The southern hemisphere is slightly brighter than the northern, possibly the result of seasonal effects. When Voyager 1 flew past, the season on Titan was the equivalent of early April on Earth, or early spring in the northern hemisphere and early fall in the south.

The atmospheric pressure near Titan's surface is about 1.6 bars, 60 percent greater than Earth's. The atmosphere is composed mainly of nitrogen, the major constituent of Earth's atmosphere.

The surface temperature appears to be about 93 degrees Kelvin (-294 degrees F), close to the triple-point temperature of methane. Methane, therefore, probably plays the same role on Titan as water does on Earth -- as rain, snow, ice and vapor. Rivers of methane may cut through glaciers of methane under a nitrogen sky. Clouds may drop liquid-methane rain on the surface.

Titan's methane, through continuing organic chemistry, is converted to ethane, acetylene, ethylene and (when combined with nitrogen) hydrogen cyanide.

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The last is an especially important molecule, since it is a building block of amino acids. However, Titan's low temperature undoubtedly inhibits more complex organic chemistry.

Titan has no intrinsic magnetic field; therefore it has no electrically conducting liquid core. Its interaction with Saturn's magnetosphere does create an induced dipolar field in Titan's wake, however. The big satellite also serves as a source for neutral and charged particles in Saturn's magnetosphere.

The Magnetosphere

While Saturn's magnetosphere is only about one-third the size of Jupiter's, it is still a huge stucture, extending nearly a million miles from the planet toward the Sun before the flow of charged particles in the solar wind overcomes the effects of Saturn's magnetic field. As at Jupiter, charged particles in Saturn's magnetic field are dragged along by the magnetic field and circle the planet once in 10 hours, 39 minutes, 26 seconds.

At Titan's orbit, those particles pass the satellite at a relative speed of 200 km (124 mi.) per second. The size of Saturn's magnetic field fluctuates as the solar wind pressure increases and decreases. As a result, Titan is generally inside but sometimes outside the magnetosphere.

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Titan was inside Saturn's magnetosphere as Voyager 1 flew past and observed the wake resulting from the flow past Titan of the electrically charged ions carried around by Saturn's rotating magnetic field. Radio emissions were also observed emanating from the wake region.

Surrounding Titan and its orbit, and extending to Rhea's orbit, is a cloud of uncharged hydrogen atoms forming an enormous hydrogen torus. A disk of plasma, composed of hydrogen and possibly oxygen ions, extends from outside the orbit of Tethys almost to the orbit of Titan. The plasma is in nearly full corotation with Saturn's magnet field.

Voyager 1 is now headed out of the solar system. Its scan-platform instruments were turned off Dec. 19, 1980. Most fields and particles instruments continue to operate, monitoring the solar wind and its changes with distance and time. Although the exact location of the heliopause (the outer edge of the solar wind) is unknown, it is possible Voyager 1 will reach it sometime around 1990. Even before that time, however, Voyager may detect low-energy cosmic rays penetrating into the outer reaches of the solar system from nearby supernova remnants.

Voyager 2, meanwhile, will make its closest approach to Saturn Aug. 25, 1981, and then continue on a trajectory toward Uranus.

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