VOYAGER I VIEWS SATURN

by

Lisa A. Rossbacher

Amongst the thousands of photographs and other data beamed back to Earth from the unmanned spacecraft Voyager I as it swept through the Saturnian system in little more than 24 hours, are discoveries that are now making planetary geologists and astronomers adjust their thinking to include braided rings, dancing moons and liquid nitrogen oceans.

Close Encounter: Nov. 12, 1980

As Voyager I, launched on September 5, 1977,* approached Saturn, scheduled for a close encounter with the ringed planet on November 12, 1980, planetary geologists and other scientists expected several results. They hoped to learn more about Saturn's mysterious rings and atmosphere, to photograph and measure Saturn's moon, and in particular to study Titan, believed to be the largest satellite in the solar system. Now, as the spacecraft speeds toward interstellar space, scientists are being overwhelmed by the explosion of new information that Voyager I has sent back.

The Voyager Project is run for the National Aeronautics and Space Administration (NASA) by the Mission Control and Computing Center at the Jet Propulsion Laboratory (JPL) in Pasadena, California, U.S.A. JPL communicates with the spacecraft through a worldwide network of deep space tracking stations located in California, Australia, and Spain. Dr. Bradford Smith, astronomer at the University of Arizona and leader of the Voyager photo-interpretation team, has already expressed the view that Voyager's data will significantly alter previously held concepts and beliefs.

Saturn's Rings

Saturn's rings were first observed from earth-based telescopes in 1610 by the Italian astronomer Galileo, and later interpreted more accurately by Dutch astronomer Christian Huygens. Even as Voyager I was moving toward them, only five or six rings had been observed. On closer approach and with increased resolution, the photographs revealed an increasing number of subdivisions within the rings.

The total number of concentric ringlets, when finally counted, may exceed 1000. Even Cassini's Division - the break between rings A and B discovered in 1675 - appears to have as many as two dozen ringlets within it (Fig. 1), some with gaps only 20 km wide. Once thought to be the result of gravitational interaction between Saturn's moons and the orbit of ring particles, the complex system of rings now requires additional mechanisms to fully explain it.

Another surprising discovery was revealed through sequential photographs, which showed dark and light "spokes" in the rings as they emerged from behind the planet. The origin of these features may be related to magnetic or electrostatic forces, but the mechanism is not yet understood.

Photographs of the outermost F ring (Figs. 1 and 2) - a thin, uneven ring at the outside edge of the system, guarded by two small moons called S-13 and S-14, revealed a twisted, braided pattern. This feature is enigmatic, but preliminary interpretations by the imaging team at JPL indicate that electromagnetic fields may explain the phenomenon. Small nearby satellites may also be a contributing factor.

The initial scientific interpretation has been that the twists in the F ring defied the laws of orbital mechanics, but, as Dr. David C. Pieri of JPL has pointed out, "The laws of motion are still perfectly valid - we just do not understand the environment well enough yet to know exactly how the laws apply for Saturn's rings."

Figure 1. This mosaic of Saturn's rings was taken during Voyager I's approach toward the planet, at a range of 8×10^6 km. Before the encounter, only 5 or 6 rings were known. This photograph shows approximately 95 ringlets in addition to the rings within the Cassini Division. The bright spot just inside the outermost (F) ring, upper left, is Saturn's 14th satellite, which was discovered by Voyager I. It is less than 150 km in diameter. (Photo courtesy JPL/NASA)

Two other odd-shaped moons beyond the F-ring are performing an orbital "dance". Called S-10 and S-11, they are each less than 200 km long and share almost exactly the same orbit. It is believed that the co-orbital moons had once been a single body which had been struck by a large object, such as a comet, and broken in two. Complex gravitational interactions have prevented a collision between these moons.

Saturn itself is primarily composed of hydrogen and helium, and Voyager's photographs of its atmosphere reveal a convective structure similar to that of Jupiter. Its southern hemisphere, however, seems to have five or six times as many bands as similar regions on Jupiter, and the northern hemisphere is surprisingly bland. Saturn even has its own anticyclonic red spots.

Saturn's Satellites

Saturn's moons include a whole new class of small, icy satellites, ranging in diameter from 80 to 800 km, and appearing to be grayish-white in colour. Most are densely

*See EPISODES 1979, No. 2, p. 6 and No. 4, p. 29.

Figure 2. Saturn's outermost ring, the F ring, has a braided structure with two bright, narrow bands and a broader, more diffuse band inside (approximately 35 km wide). Clumps of material appearing within these rings may be either local accumulation of material or tiny moons. This image was taken at a range of 7.5×10^5 km. (Photo courtesy JPL/NASA)

Figure 3. The Saturnian moon Dione is a heavily cratered body; the bright radiating patterns are probably debris rays scattered during impact cratering. Other bright areas may indicate topographic valleys and ridges. Some irregular valleys are also visible: these were probably created by the cratering of pre-existing fault troughs. The frame is centered at 26° S latitude on the Saturn-facing hemisphere and was taken at a range of about 2.4×10^5 km. (Photo courtesy JPL/NASA)

cratered (Fig. 3), but at least one (Enceladus) appears very smooth and uncratered. Curiously, the surface of Tethys seems to be only partly cratered. The current speculative explanation is that Tethys and Enceladus may be resurfaced by the melting of their incorporated ice, obliterating existing craters. Most of the craters have raised rims and central peaks similar to those on some planets and on Jupiter's Galilean satellites.

The cratering that occurred on these moons may have been dramatic. Mimas, which circles Saturn within the ring system and is closest to the planet, has an impact crater with a diameter over one-fourth the diameter of the moon itself (Fig. 4). The impacting body must have approached the maximum size that it could be without splitting the target in two.

The moon Titan was thought to be the largest satellite in our solar system, nearly the same size as Mercury, and the only one with an atmosphere. Its atmospheric composition was predicted to be mostly methane and ammonia, but Voyager has found that this accounts for only about 1%, with most of Titan's atmosphere appearing to be predominantly nitrogen, like the Earth's. Because the temperature is estimated to be around -200°C , Titan has been referred to as "the Earth in deep freeze". The methane and hydrogen cyanide in the atmosphere can convert to various organic molecules, which could then settle on the surface as organic rain.

One speculation suggests that as much as 300m of frozen hydrocarbons may exist on Titan's surface. The latter, however, is obscured by a photochemical haze - an extraterrestrial smog - caused by the molecular compounds in the atmosphere. The chemistry of Titan is similar to that inferred for the early Earth; because of the frigid temperatures, however, it is extremely unlikely that Titan could have life that evolved along paths similar to Earth's.

An alternative recent speculation is that if Titan's atmosphere is nitrogen all the way to its surface, estimates are that the pressure could be sufficiently high and the temperature sufficiently low that nitrogen could exist as a liquid; in fact, there could be lakes of liquid nitrogen at the poles which would look much like water, and rivers of liquid ammonia in the lower latitudes.

Preliminary findings also show that Titan is slightly smaller than Ganymede, one of Jupiter's icy moons, and may even be smaller than Triton, a large moon of Neptune which Voyager II will pass in 1986.

Saturn's other moons provide equally intriguing information. Rhea, for example, has a lacy, filamentous structure on its surface. Although their origin is not known, the surface patterns may be related to degassing of the body.

Voyager's Future

What is the future of Voyager I? The gravitational boost that it received from Saturn is sending it out of the plane of the solar system. Monitoring of the spacecraft will continue, and Voyager I is expected to enter the interstellar medium in 10-20 years' time. Images will not be returned to Earth, though other data concerning the spacecraft's environment will be.

Figure 4. Saturn's icy moon Mimas has a large impact structure on the face that leads its orbit. The crater is about 130 km in diameter, over one-fourth the diameter of the entire body. This may be the satellite with the largest ratio of crater diameter/satellite diameter in the solar system. Smaller craters, 15-45 km in diameter, are scattered across the remaining surface, and they are especially visible along the terminator. This photograph was taken at a range of about 6.6×10^5 km. (Photo courtesy JPL/NASA)

The radio-isotope thermal generator has a predicted life-span of 90 years, and Voyager I may eventually escape the influence of our Sun.

Voyager II is currently scheduled for an encounter with Saturn on August 27, 1981, passing much closer to its rings and two of the moons than its predecessor had; it will then continue on toward Uranus which it will reach in 1986, travel onward to Neptune in 1989 and possibly even get a distant glimpse of Pluto in the early 1990's. The information that it will send back to Earth should provide valuable insights into the dynamic processes operating in the Saturn system, including similarities and changes in the ring system, the braided F ring, and the atmospheric structure. Voyager II is also expected to take a time-lapse movie of ring motion.

Eventually, Voyager's look at Saturn should help clarify the origin of our solar system, but, as Dr. Smith has stressed, "we must understand the Saturn system itself before we can try to fit it into our understanding of the solar system as a whole." As the greatest exploratory mission to the moons of the giant planets continues, this could conceivably take planetary scientists several years to accomplish.

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