Voyager Bulletin

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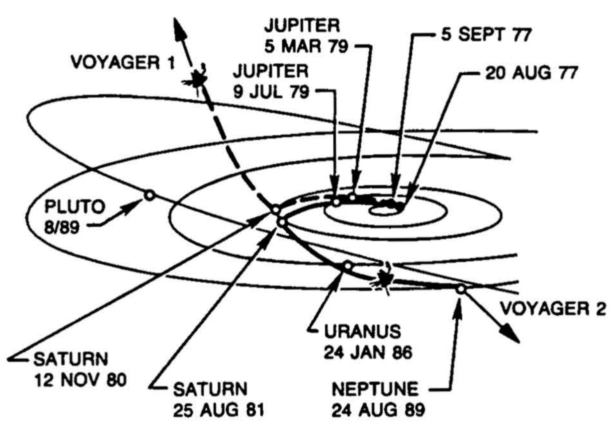


Introduction

In 1977, two one-ton spacecraft were launched toward Jupiter and Saturn on a journey of exploration. Today, 10-½ years after their launch, the Voyager spacecraft continue to expand our knowledge of the solar system.

This issue of the Voyager Bulletin summarizes Voyager 2's findings at Uranus in January 1986. Future issues will focus on preparations for the Neptune encounter in the summer of 1989, including the health of the spacecraft, science objectives for the encounter, and the Voyager flight team organization.

Uranus

The seventh planet from the Sun, Uranus, was discovered in 1781 by astronomer and musician William Herschel from the backyard of his home in Bath, England. Herschel called it the Georgian Star, after King George III. Astronomers provisionally called the planet Herschel, but it became known as Uranus, after the father of Saturn in Greek mythology.

Over the next 200 years, scientists could gather only the sketchiest of information about Uranus. They knew that it orbits the Sun at about 19 AU*, and that light takes 2 hours and 45 minutes to travel between Uranus and Earth. They knew that Uranus orbits the Sun once in 84 years, resulting in seasons that are about 21 years long at any particular spot on the planet, as different hemispheres face the Sun.

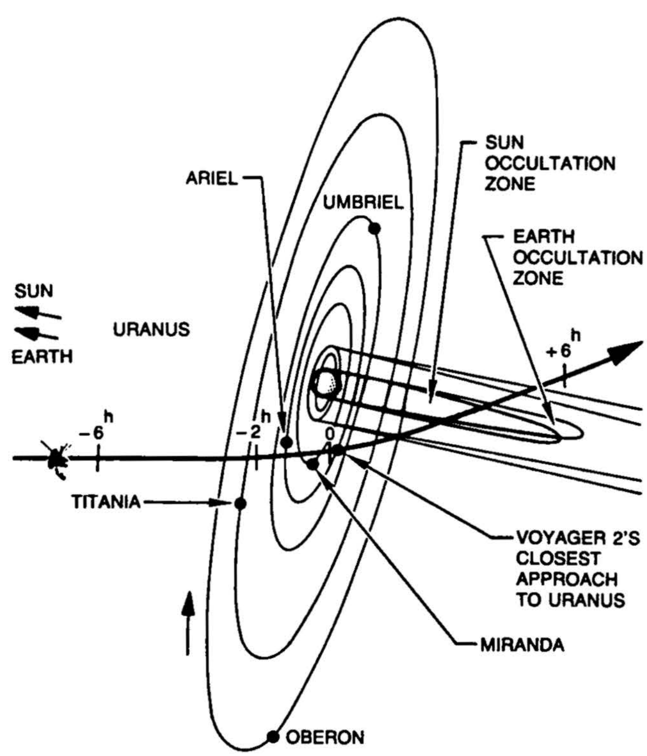
They estimated the diameter of Uranus to be about four times that of Earth, and the mass to be 14 to 17 times that of Earth. They knew that Uranus, like the other giant planets, Jupiter, Saturn, and Neptune, is composed primarily of hydrogen and helium.

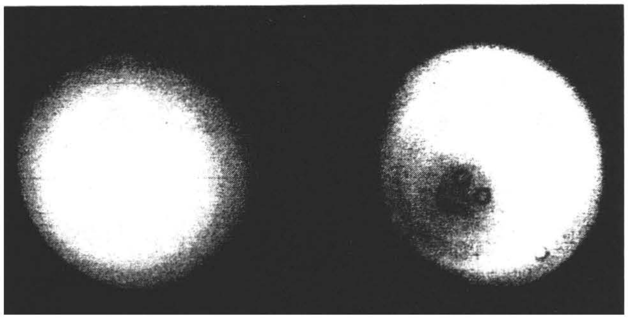
*One astronomical unit is the mean distance between Earth and the Sun, 150,000,000 kilometers (93,000,000 miles).

They also knew that perhaps the most unusual characteristic of the Uranian system is that it lies on its side—the planet's rotational axis is tilted below the plane of the ecliptic. Scientists believe a catastrophic collision with another large body may have been the cause for Uranus' strange tilt.

While each of its poles is effectively in sunlight and the other in complete darkness for 42 years at a time, scientists expected the pole that currently faces deep space to be essentially the same temperature as the pole facing the Sun, and they expected the equator to be a few degrees colder than the poles since it receives less light during a Uranian year than either of the poles. Surprisingly, Voyager 2 found that the atmospheric temperature—about −209°C (−344°F)—varies little from pole to equator to pole, indicating that heat received near the poles must be redistributed toward the equator. On Earth, heat received at the equator is redistributed toward the poles.

The other giant planets all give off about twice as much heat as they receive from the Sun, indicating that heat is generated in their interiors. Uranus, on the other hand, generates no more than about 12 percent more heat than it receives from the Sun.





As seen by human eyes (left), Uranus appears bland and featureless. By enhancing the color and contrast (right), scientists discovered a dark polar hood at the south pole.

Uranus is considerably larger than Earth (63 Earths would fit into the interior of Uranus), yet Uranus spins much faster on its axis—once every 17.24 hours. Using knowledge of a planet's rotation period, the composition of its atmosphere, and its gravity, scientists can estimate the distribution of its internal mass. Before Voyager 2's flyby, scientists believed that Uranus had a rocky core about the size of three Earths, overlain by an "ocean" of ice and a layer of molecular hydrogen. However, the planet's rotation period indicates that the heavier materials are not so centrally located. Scientists now believe that Uranus may have an interior in which rocky material, ammonia, water, and methane are almost uniformly mixed with hydrogen and helium. This uniform, dense fluid is extremely hot—10,500°C (18,900°F)—and under great pressure so that it is highly electrically conductive and gives rise to Uranus' magnetic field.

The outer atmosphere is about 16 percent helium and 83 percent hydrogen, which is very similar to the composition of the Sun. Uranus also has a large amount of methane, a gas composed of carbon and hydrogen. The amount of methane found at Uranus represents a surprising relative abundance of carbon—about 20 times as great as that of the Sun and 10 or 11 times that of Jupiter or Saturn. Uranus also receives its blue-green color from the methane, which selectively absorbs red light and reflects the blue-green shades.

By tracking cloud features in the atmosphere, Voyager scientists determined that winds at mid-latitudes on Uranus blow in the same direction as the planet rotates, at speeds from 0 to 200 meters per second (0 to 435 miles per hour). Near the equator, winds were measured at speeds up to 110 meters per seconds (240 miles per hour) and with a direction opposite that of planetary rotation . [On Earth, jet streams blow at about 50 meters per second (110 miles per hour) 9 kilometers above Earth's surface.]

Uranus also has an extended atmosphere composed mostly of neutral (un-ionized) hydrogen. This atmosphere, stretching about 6,000 kilometers (3,700 miles) above the cloudtops, can be seen only in ultraviolet light. When sunlight strikes it, the extended atmosphere glows, a phenomenon called "dayglow".

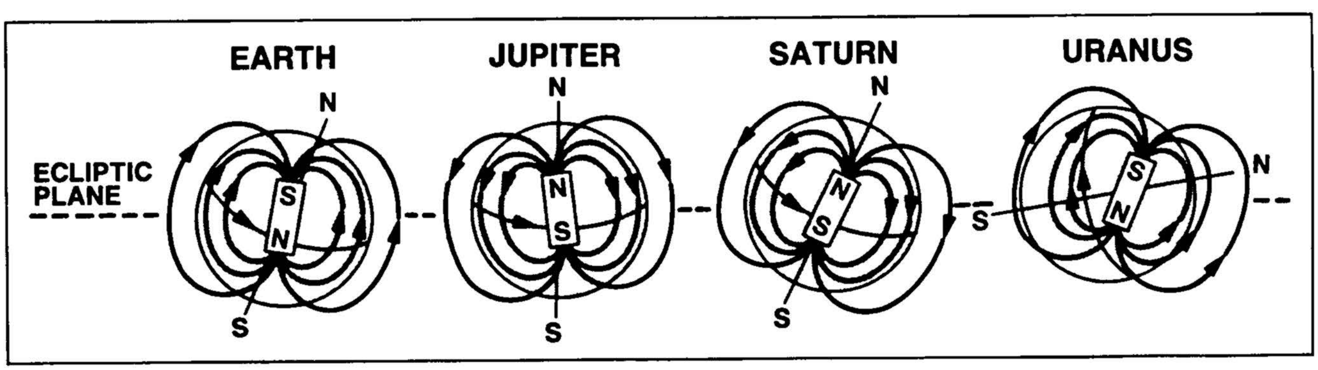
Voyager 2's ultraviolet spectrometer also detected an aurora on the dark side of the planet, centered near the planet's magnetic pole. (On Earth, aurorae at the poles are caused by ionization of particles spiraling into the atmosphere along Earth's magnetic field lines, and are called the Northern or Southern Lights.)

Magnetosphere

Of the nine planets, Mercury, Earth, Jupiter, Saturn, and Uranus have magnetic fields. The magnetic field of Uranus is unusual in several ways. It is tilted almost 60 degrees from the rotational axis, so that the magnetic poles are closer to the equator than to the poles. The field is also offset from the center of the planet by about one-third of the planet's radius. Neither of these phenomena have been adequately explained. Some scientists speculate that Uranus may be undergoing a magnetic field reversal (there is geologic evidence for numerous field reversals on Earth). Or, it may be that the dynamo region from which the field arises is just closer to the surface on Uranus than at other planets.

The magnetic field of a planet extends some distance into space, encircling the planet in a "cage" (the "magnetosphere") that captures charged particles and rotates with the planet. All of Uranus' rings and satellites are within its magnetosphere, which extends to about 590,000 kilometers on the sunward side of the planet and to about six million kilometers on the night side.

When the solar wind (a stream of charged particles from the Sun) meets a planet's magnetic field, the field is compressed on the sunward-side of the planet and drawn into a long "magnetotail" behind the planet as the solar wind rushes past. (One might envision a windsock as an analogy for the shape.) Due to Uranus' tilt on its axis and its offset magnetic field, the rotation of the magnetosphere with the planet imparts a corkscrew twist to the magnetotail.



Within the Uranian magnetosphere there are positively charged particles including a large number of protons. The source of the protons may be the extended hydrogen atmosphere, the ionosphere, or the solar wind. High energy protons (28,000 electronvolts) may be absorbed by methane in the satellite surfaces, freeing hydrogen and leaving a dark, carbon residue on the satellites.

Rings

Nine dark, narrow rings were discovered at Uranus in 1977 from a NASA research aircraft flying above the Indian Ocean. Scientists onboard the plane noticed that the light of a star blinked on and off as they watched Uranus pass in front of the star, and the blinking pattern repeated itself as the star emerged from behind the planet. These rings are known (in order of increasing distance from the planet) as 6, 5, 4, alpha, beta, eta, gamma, delta, and epsilon. Voyager 2 discovered two new rings, for a total of 11. Other ring structures composed of dust-sized particles exist between the classical rings.

Uranus' rings probably did not form at the same time as the planet. They are not all circular, nor are they all precisely in the plane of Uranus' equator as we have come to expect. They range in width from 2 to 100 kilometers, in comparison to Saturn's rings, which span 60,000 kilometers (37,000 miles). Some of them broaden and then narrow, and some are incomplete. They are some of the darkest objects ever studied, as the ring particles reflect only about 5 percent of the sunlight shining on them. (In contrast, Saturn's ring particles are made of water ice and reflect nearly all sunlight.)

The narrowness of the Uranian rings may be due to gravitational interactions with nearby satellites. As orbiting ring particles tend to try either to escape to space or to fall inward toward the planet, scientists believe they are "shepherded" back into their orbits by small satellites. Two such "shepherding" satellites, Cordelia and Ophelia, flank the epsilon ring, but other such satellites were not found because they are probably too small or too dark to have been detected by Voyager 2.

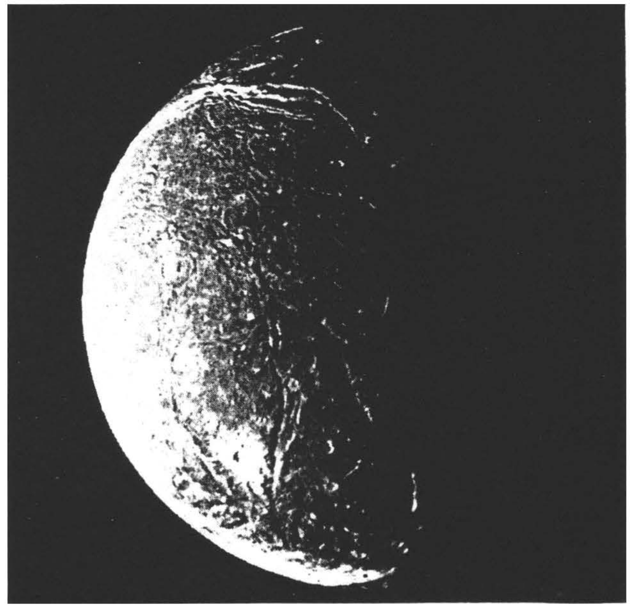
The particles in the previously known rings range in size between baseballs and automobiles, and there is a surprising lack of dust in the main rings. Particles in the newly discovered rings are much smaller, like dust particles.

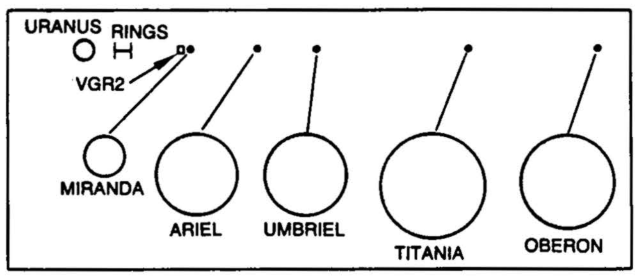
Satellites

Uranus has at least 15 satellites, ten of them discovered by Voyager 2. They all orbit near the plane of the planet's equator, and thus their orbits are nearly perpendicular to the plane of the ecliptic. The Uranian system presented a bull's-eye target for Voyager 2, and thus only the sunlit southern hemispheres of the satellites were imaged.

One would expect to find more ice as one moves away from the Sun, but the larger Uranian satellites may be composed of 50 to 60 percent rocky matter, in contrast to Saturn's more icy satellites. They are also dark, and most scientists agree that the darkness must be caused by carbon-rich surfaces.

Ariel

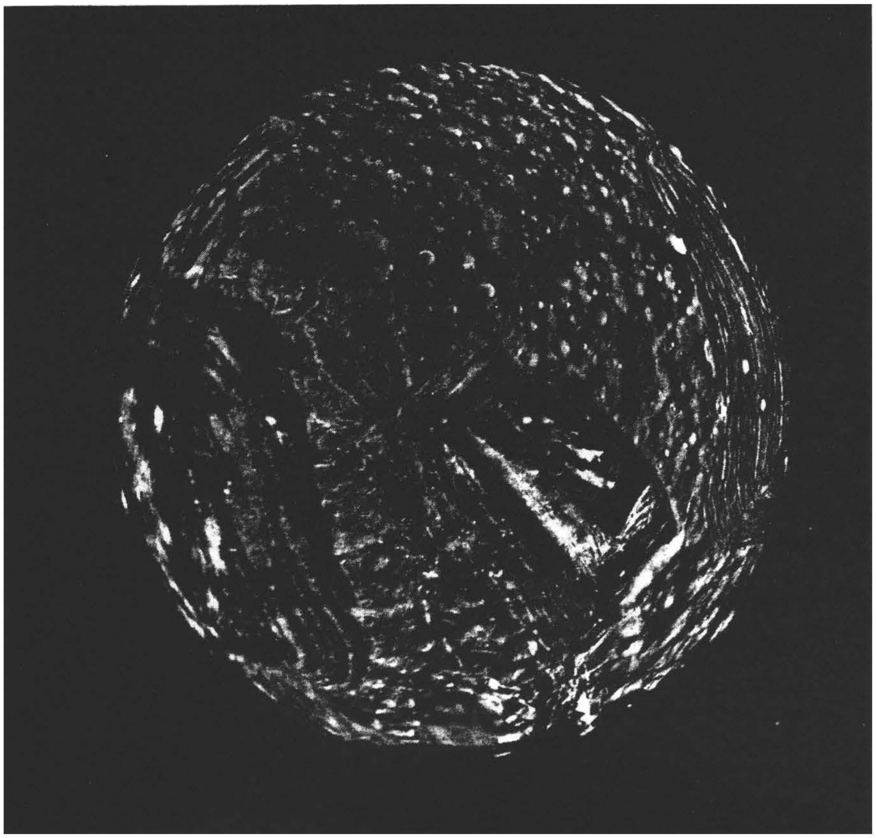




Uranus Bodies

	RING WIDTH (km)	BODY RADIUS (km)	ORBITAL DISTANCE* (km)
URANUS		25,600	
1986U2R	2,500		38,500
RING 6	1 to 3		41,837
RING 5	2 to 3		42,235
RING 4	2 to 3		42,571
alpha ring	7 to 12		44,718
beta ring	7 to 12		45,661
eta ring	0 to 2		47,176
gamma ring	1 to 4		47,627
delta ring	3 to 9		48,299
Cordelia		~20	49,752
1986U1R	1 to 2		50,024
epsilon ring	22 to 93		51,149
Ophelia		~25	53,764
Bianca		~25	59,165
Juliet		~30	61,767
Desdemona		~30	62,658
Rosalind		~40	64,358
Portia		~40	66,097
Cressida		~30	69,927
Belinda		~30	75,255
Puck		~85	86,004
Miranda		236	129,850
Ariel		579	190,950
Umbriel		586	266,010
Titania		790	436,340
Oberon		762	583,510

*From center of Uranus.



Miranda

About one-sixth the diameter of Earth's moon, Miranda is the most surprising of the Uranian satellites, for its geologic diversity. Most of its terrain consists of old, heavily cratered and rolling plains. Overlying this older terrain are three very large, younger, oval features which bear little resemblance to any other real estate in the solar system. These "ovoids" are basically rectangular and between 200 and 300 kilometers (120 to 180 miles) in diameter. They are cut by deep, parallel ridges, grooves, and scarps. Large cliffs cut through both the ancient terrain and the ovoids. Some of these cliffs are as high as 20 kilometers (12 miles).

Some scientists suggest that Miranda's ovoids formed when Miranda may have melted early in its history, allowing the heavier rocky materials to sink toward its center. During this process, called differentiation, Miranda may have been fragmented several times by larger bodies, and then gravitationally reassembled, with the former core material now near the surface. The ovoids could be the scars left as the heavier material again sank through the viscous ice surface of the satellite. On the other hand, the ovoids could have been caused by rising masses of ice that broke through the surface. In either case, the process of differentiation was probably never completed: Miranda appears frozen at an early stage of its development.

Oberon's surface probably has not been reworked since the satellite formed. There is a large number of craters with diameters between 50 and 100 kilometers (30 to 60 miles). Bright material on the satellite's surface may be material ejected during the impacts that formed the craters. Oberon has at least one enormous mountain, at least 20 kilometers (12 miles) high that may be the central peak of a large impact crater.

Titania is the largest of the Uranian satellites, and its surface shows evidence of internal activity at one time. It has far fewer craters of the size found on Oberon, indicating that the larger, older craters have been erased by later cratering and global tectonics. Titania has many smaller craters and its surface is more heavily fractured than Oberon's. As the moon cooled and began to freeze, its watery interior froze and expanded, stretching the crust and producing the faults and graben we see in Voyager images. Titania has probably been relatively quiet for about three billion years.

Umbriel is the darkest of the major Uranian satellites, reflecting only about 19 percent of the sunlight it receives. Most of Umbriel is dark and bland, but it does have two large bright features near the equator: a ring 80 kilometers in diameter that covers the floor of an impact crater, and a spot on the central peak of another large crater. The bright material probably came from below the surface.

Ariel, as its name evokes, is the brightest of the Uranian satellites. Its surface is probably also the youngest (i.e, the most recently resurfaced, in geologic time). After a period of tectonic activity resulting in deep crustal faults, Ariel was probably resurfaced by volcanic activity. The volcanic material was probably a warm, plastic mixture of ice and rock with a glacier-like flow.

In late 1985, about a month before Voyager 2's closest approach to Uranus, the first of ten new satellites was discovered. The Voyager flight team was able to reprogram the spacecraft to capture an image of this satellite, now whimsically known as Puck. Puck is remarkably round for its size, and very dark. Puck is about 170 kilometers (100 miles) in diameter.

The remaining nine new satellites range in size from about 20 to 40 kilometers (12 to 24 miles) in diameter, and lie between the rings and Puck.

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