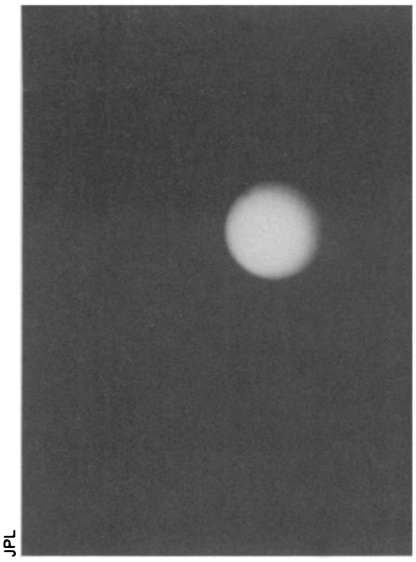
Uranus: Testing Voyager 2's IQ

On Jan. 24, the Voyager 2 spacecraft will pass about 50,600 miles from Uranus's cloud tops and directly through the planet's ring and moon systems. The long-awaited encounter is expected to provide more information in one day than has been gathered about the distant planet since it was discovered more than two centuries ago.



JPL

Uranus, imaged by Voyager 2 on Nov. 27.

By JONATHAN EBERHART

Long before the dawn of civilization, early human beings probably emerged from their caves into the perilous night, looked up at a skyful of mysterious lights, and unknowingly saw Mars. Jupiter, too, more than three times as distant from the sun, was within their view, as was Saturn, nearly twice again as far, though the notion of their planethood, including its association with the sun, was yet unimagined. But there the solar system ended. Not even Galileo, eons later in the early 17th century and abetted by the pioneering telescope that would show him the four major moons of Jupiter and the rings of Saturn, would extend the planetary horizon.

Nearly two more centuries passed. It was on a Tuesday, March 13, 1781, that a professional musician and amateur astronomer named William Herschel observed through his telescope what he described as "a curious either nebulous star or perhaps a comet." Determining that it was in fact neither took some time. Its motion across the sky suggested that it was not a star, but thinking it a comet was not an unreasonable speculation, given that no planet had ever before been discovered in all of recorded history. It was Uranus, invisible to the naked eye and so remote that awareness of its existence slightly more than doubled the size of the known solar system. Since then, five Uranian moons have been discovered (the first two by Herschel himself), as has a bizarre set of dark, improbably skinny rings. But little else.

Now closing in on the planet is the Voyager 2 spacecraft, which will pass about 50,600 miles from the cloud tops on Jan. 24. And so far away is Uranus from the scrutinizing instruments of earthbound astronomers — nearly 20 times earth's mean distance from the sun — that Voyager is likely to find out more about its present target, compared with what is already known, than has been learned from any other planetary flyby ever conducted to any world.

The probe's trek has been prodigious. Launched on Aug. 20, 1977, Voyager 2 will be more than 1.8 billion miles from earth when it zips past Uranus, a distance so great that its radio signals, moving at the speed of light, will take 2 hours 44 minutes 50 seconds to get home. And with its curving trajectory, which has also included flybys of Jupiter (in 1979) and Saturn (1981), the craft will have covered more than 3 billion miles on the way.

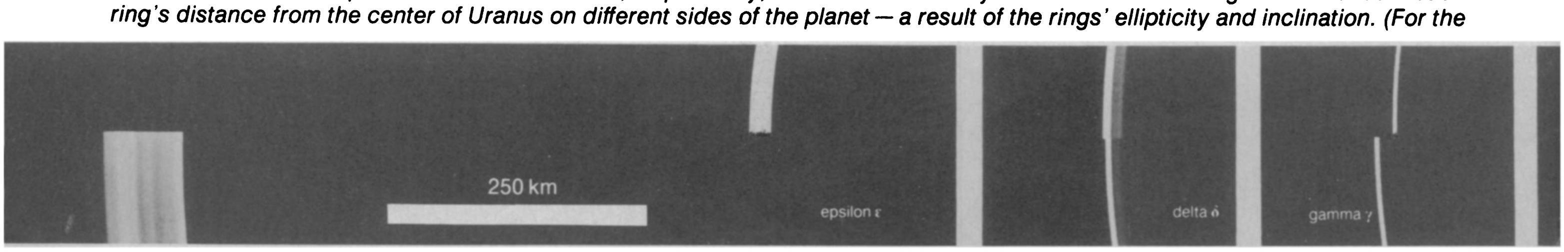
Yet after all of that, the encounter will be a quickie. One reason is that Voyager 2 is nearing Uranus at about 32,875 miles per hour, more than a third faster than its approach to Saturn and 91 percent faster than when it neared Jupiter. When it is closest to Uranus, in fact, it will be moving at more than 40,000 mph.

The other factor that will compress the experience, however, is perhaps the strangest aspect of Uranus itself: Rather than spinning on an axis like the spindle of a phonograph, Uranus spins almost lying on its side, with its axis just 8 degrees out of the plane of its orbit. The planet's satellites and rings orbit around the same tilted axis, and because that axis is now pointed almost directly at the sun, Voyager is heading for the Uranian system like an arrow seeking the concentric circles of an archery target. Some researchers have speculated that Uranus may owe its strange tilt to having been struck by another object, which knocked it askew. But whatever the reason, the spacecraft will be hurtling *through* the plane of moons, rings and all (passing outside the rings, and inside the orbit of the innermost known satellite, Miranda), rather than moving almost parallel to it as was the case at Jupiter and Saturn.

The result will be an intensive, action-packed encounter with most of its key scientific observations squeezed into less than a day.

Though relatively little is known about the Uranian system, the limited information has been sufficient to generate excited anticipation among scientists about every aspect of the encounter:

The nine known rings of Uranus are shown here not in a photo but as synthesized in a computer that "rotated" the single, flickering line formed by tracking a star as the rings passed in front of it on May 24, 1985. The upper and lower halves of each image represent the inbound and outbound portions of the occultation, respectively, with the fact that they do not match indicating the difference in each ring's distance from the center of Uranus on different sides of the planet — a result of the rings' ellipticity and inclination. (For the

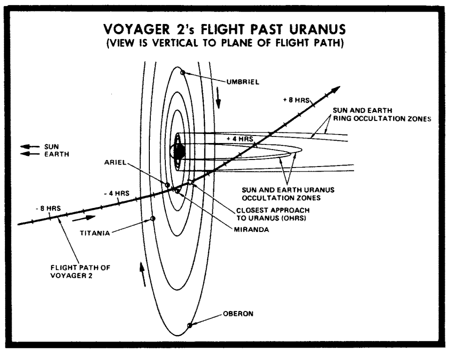


• *The rings:* Perhaps the most bizarre Uranian feature to be found since the planet's discovery, they were detected by accident in 1977, less than six months before the launching of Voyager 2. Revealed when they unexpectedly caused blinks in the light of a star that was about to be occulted—blocked out—by Uranus itself, they are so narrow and dark that they have yet to be "seen" from earth except in extremely diffuse images of their infrared emissions. As recently as last month, the widest of the nine known rings, which strangely ranges in width from 60 down to about 12 miles, was just becoming visible to Voyager's cameras (SN: 12/14/85, p. 373). On the other hand, there have been more than a dozen stellar occultations by all or part of the ring system, indicating many of the rings to be either elliptical or differently inclined — or both — and extremely sharp-edged. One hypothetical suggestion to explain their unusual structure has been that their edges may be shepherded by 10 or more tiny moonlets, potentially more grist for Voyager 2's mill.

Besides taking pictures, the spacecraft will be set on two occasions to track the light of a star with one of its instruments, called a photopolarimeter, to provide "occultation tracks" across the rings. The photopolarimeter is mounted on the spacecraft's movable "scan platform," which also carries the cameras, so while it is tracking a star, photography must stop. But the technique was used so successfully with the rings of Saturn that it is being tried twice at Uranus — first for about four hours, when the star Sigma Sagittarii (Nunki) will be occulted by the two outermost rings, and later by the star Beta Persei (Algol), whose track will encompass all nine.

There may also turn out to be considerably more than nine. Even from earth there have been subtle hints of possible additional details in the ring structure, and at Saturn, the thin "ringlets" revealed by Voyagers 1 and 2 turned out to number in the thousands.

• *The moons:* Voyager 2's head-on path through the Uranian system will mean that the spacecraft's closest approaches to all five known moons, when some of the best photography is expected, will take place in less than six hours. (The longer of the two stellar occultations by the rings will happen before that time, while the shorter — though it is the one that takes in the whole ring system — nestles in a fortuitous gap between the closest approaches to Uranus itself and the outermost moon, Oberon.) All five show signs of water-ice on their surfaces, but there are indications of something else as well, something dark. And there is more at stake in the question of what the dark material is than just learning the satellites' surface compositions. Exposed, rocky material is a possible candidate, but there are theoretical studies suggesting that some of the moons may still be so warm inside — possibly even from volcanism — that rock would have sunk to lower depths. Other candidate explanations have been offered, but important for any of them may be close-up photos showing where and how widely spread the dark stuff lies, and whether there are smooth areas that appear to have been "resurfaced."

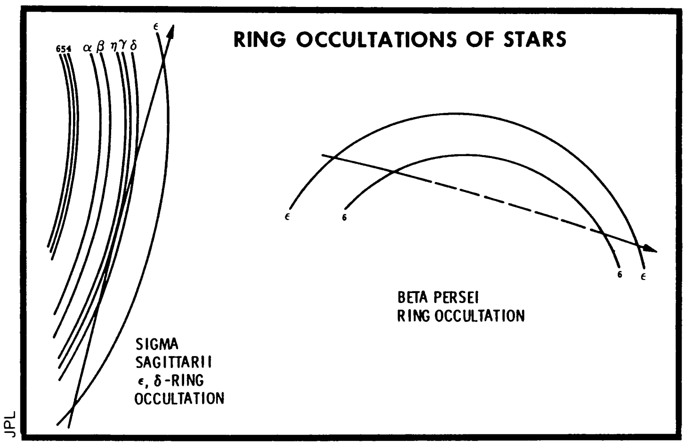


The spacecraft's curving trajectory will penetrate the Uranian ring plane at an angle of 67°. Also shown are zones where the rings will occult the sun and earth (for ring-particle studies), and where Uranus itself occults the earth (for "profiling" the Uranian atmosphere and ionosphere) and sun (to seek lightning and auroras on the planet's night side).

Getting sharp close-ups of the moons of Uranus will be a difficult matter, however, at Voyager 2's flashing speed. Because the Uranian system is twice as far from the sun as is Saturn, there is only one-fourth as much light for photography, which requires longer exposures, which in turn increase the chances of getting blurred pictures. To correct for this, Voyager engineers at Jet Propulsion Laboratory (JPL) in Pasadena, Calif., the mission's control center, have developed a technique called "image-motion compensation," which involves turning the spacecraft itself. Tested a few times at Saturn, it will be used during most of the close approaches to the Uranian rings and moons.

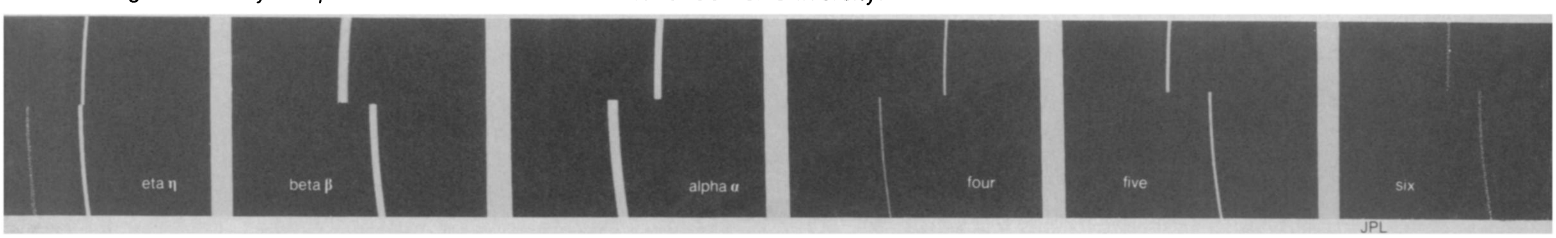
The most challenging attempt will occur in the case of Miranda, innermost and smallest of the planet's known moons, past which Voyager 2 will sweep at a distance of only 18,000 miles. The rapidly changing geometry of the Miranda encounter will require the spacecraft to turn at a rate faster than its onboard computers would normally permit. Faced with that quandary, the engineers have worked out and tested a way of getting Voyager to "override the override" they had originally built into it.

• *The planet:* Uranus itself appears virtually featureless in earth-based photos, and has continued to look the same to Voyager's cameras well into December. None of the spectacular, multicolored bands and swirls of Jupiter, or even the paler versions seen at Saturn. Nothing



Voyager 2's photopolarimeter will track two stars across the Uranian rings, recording dips in the stars' light to "map" fine details of the rings' structure.

epsilon ring, the difference shown is 603 km; at most it is 844 km.) The epsilon, delta, beta and alpha rings also show marked variations in radial width. Note, too, the faint additional structure revealed by the occultation in the eta and delta rings. The occultation was recorded by Keith Matthews of Caltech, using the 200" Hale telescope on Mt. Palomar at a wavelength of 2.2 microns. The image was generated by Philip Nicholson and Mark Showalter of Cornell University.



but a faint blue cast, believed due to atmospheric methane that absorbs the red portion of the sunlight falling there. Yet a host of baffling riddles have scientists eagerly awaiting Voyager 2's help.

For four years, a group of researchers has been monitoring data from the earth-orbiting International Ultraviolet Explorer satellite indicating Uranus to have a brilliant ultraviolet glow that the group interprets as evidence of an aurora and an active magnetic field. Yet other scientists have been expecting such a field to produce radio emissions like those from Jupiter and Saturn, but of which Voyager 2 has not yet heard a trace. On the other hand, Uranus produces less heat than Jupiter, Saturn or even Neptune (to which the spacecraft is headed for an encounter in 1989), which to still other researchers is a sign that the planet lacks the internal convection thought necessary to drive a magnetic field. But what about the aurora? Donald E. Shemansky and G.R. Smith of the University of Arizona in Tucson suggest that the glow may not be an aurora at all, with its presumed requirement of a magnetic field as an energy source. Instead, they say, it may be what is called "airglow," initiated by solar radiation but further energized by *electric* fields that derive their energy from the dynamics of the atmosphere. (A detailed description of the idea by Shemansky and Smith is to appear in the January GEOPHYSICAL RESEARCH LETTERS.) A similar situation, the researchers note, may account for low-latitude emissions observed at Jupiter and Saturn, although those cases, Shemansky acknowledges, have not yet been clearly explained either.

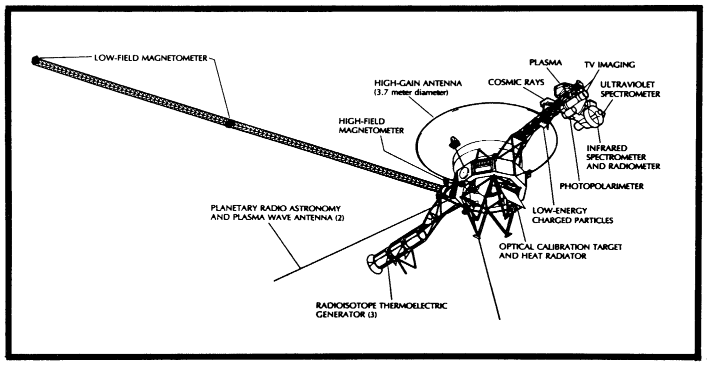


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Diagram shows Voyager 2's scientific instruments and radioisotope-driven power supply (used instead of solar panels because the craft is so far from the sun).

Then there is a puzzling infrared spectrum, reported by Glenn S. Orton of JPL, that seems to indicate the atmosphere of Uranus to have a far higher percentage of helium (as much as 40 percent) than either Jupiter or Saturn (SN: 11/9/85, p. 292). Besides raising potential questions about a variety of other Uranian measurements that have been built on the assumption of a much lower helium-hydrogen ratio, says Orton, "it's weird."

In addition to measuring the helium-hydrogen ratio with an infrared instrument, Voyager 2 will be using its earthward radio signals to profile the atmosphere, and will conduct a host of studies of charged particles, cosmic rays, plasma waves and other electromagnetic phenomena.

VOYAGER 2 KEY ENCOUNTER EVENTS AT URANUS

Date	Time at Voyager 2 (PST)	Received at Earth (PST)	Event
Jan. 23	8:25 p.m.	11:10 p.m.	Begin ring occultation of Sigma Sagittarii
Jan. 24	12:37 a.m.	3:22 a.m.	End ring occultation of Sigma Sagittarii
	7:11 a.m.	9:56 a.m.	Closest approach to Titania (365,200 km from ctr.). Diameter: 1,600 ± 120 km
	8:13 a.m.	10:58 a.m.	Closest approach to Oberon (470,600 km from ctr.). Diameter: 1,630 ± 140 km
	8:22 a.m.	11:07 a.m.	Closest approach to Ariel (127,000 km from ctr.) Diameter: 1,330 ± 130 km
	9:05 a.m.	11:50 a.m.	Closest approach to Miranda (29,000 km from ctr.). Diameter: 500 ± 220 km
	9:17 a.m.	12:02 p.m.	Ring-plane crossing, at 67° to plane
	10:00 a.m.	12:45 p.m.	Closest approach to Uranus (107,100 km from ctr.). Diameter: approx. 51,000 km
	10:28 a.m.	1:13 p.m.	Begin 1st ring occultation of Beta Persei
	11:07 a.m.	1:52 p.m.	End 1st ring occultation of Beta Persei
	11:20 a.m.	2:05 p.m.	Begin 2nd ring occultation of Beta Persei
	11:46 a.m.	2:31 p.m.	End 2nd ring occultation of Beta Persei
	12:53 p.m.	3:38 p.m.	Closest approach to Umbriel (325,000 km from ctr.). Diameter: 1,100 ± 100 km

Receiving Voyager 2's anticipated scientific treasure trove from Uranus has posed a particular problem, because of the weakness of the radio signal over such a vast distance, and the reduced amount of data that can therefore be sent. To improve reception on the ground, NASA has electronically linked multiple antennas at each of its Deep Space Network stations, including the incorporation, at its Australian station in Canberra, of the antenna of the Parkes Radio Astronomy Observatory. Such "arraying" will greatly increase the amount of data received from Uranus.

Another key technique is the use of "data compression," allowing the same amount of information to be conveyed in fewer "bits." In the case of sending back pictures, for example, each of the tiny "pixels" (picture elements) comprising each photo has heretofore been radioed back as an 8-bit binary number indicating the pixel's brightness on a "gray scale" of 256 levels. With data compression, instead of transmitting the full 8 bits necessary to represent numbers up to 256, only the brightness *difference* between successive pixels is sent. This required reprogramming one of the craft's computers to "preprocess" all the imaging data before they are relayed to earth, but the result is a saving of at least 60 percent in the number of bits needed for each image. "Voyager 2," says assistant project scientist Ellis Miner of JPL, "is now a smarter spacecraft than it was when it went by Saturn, and a *lot* smarter than when it was launched."

Uranus is waiting. □