Voyager Bulletin

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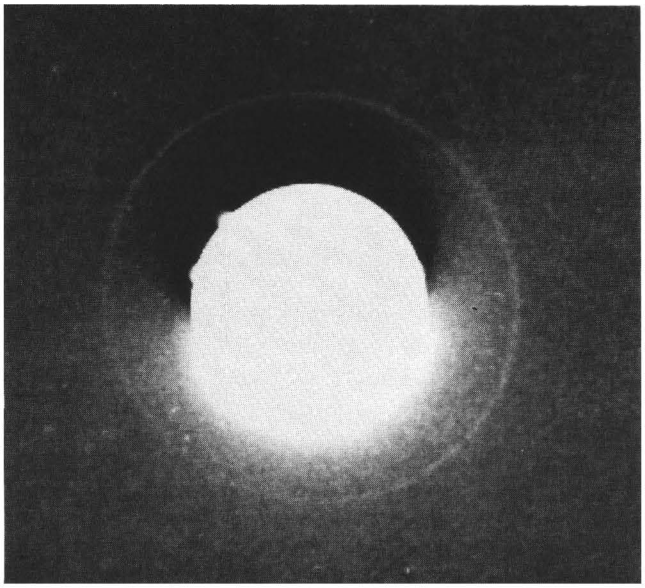


Uranus' epsilon ring is seen in this computer summation of six images returned on November 28, 1985 by Voyager 2's narrow-angle camera while still 72.3 million kilometers from the planet. The epsilon ring, some 51,200 kilometers from the planet's center, is the outer and most prominent of the planet's known nine rings. Because the ring is so narrow and dark, long exposure times were required to obtain a good image. Six images were added together by computer to produce this picture, which has an equivalent exposure time of 84.5 seconds. The central image of the planet is greatly overexposed. Artifacts due to electronic effects and image processing include the dark region just above the planet image, the diffuse brightening below it, and the small, bright projections from the edge of the planet in the upper right. The ring is distinctly less prominent in the lower left portion and more prominent in the upper right. This is in agreement with the predicted locations of the narrow and wide portions of this eccentric ring, respectively.

Early Results

Fifty-two days from its meeting with Voyager 2, a pipsqueak upstart of a robot from a distant planet called Earth, Uranus continues to swathe itself in secrecy. No cloud features are yet visible in images taken in late November. No radio emissions from the planet have been detected. The known satellites — Miranda, Ariel, Umbriel, Titania, and Oberon — obey the Keplerian laws of motion by faithfully circling the planet with monotonous regularity.

"Actually, it's an interesting evolving story," Voyager Project Manager Dick Laeser said of the planet's noncooperation. Uranus may be vastly different from the other gas giants (Jupiter, Saturn, and Neptune).

The only inroad has been successful imaging of the epsilon ring, the outer and most prominent of the planet's nine known rings. The epsilon ring is elliptical (eccentric), ranging from 20 to 100 km wide. The ring is also very dark, with a reflectance of only about 1 to 2 percent. Scientists speculate that its composition may be carbonaceous material similar to that of dark asteroids, or it may be radiation-darkened methane ice, perhaps like the dark side of Saturn's satellite Iapetus.

Color images from Voyager 2 show the planet itself to be aqua blue, but at the present resolution limit of about 1400 km per line pair the atmosphere remains featureless. At Jupiter and Saturn, scientists tracked the motions of atmospheric cloud features to determine atmospheric dynamics, wind speeds, and planetary rotation rates. Such studies at Uranus are thus far impossible.

"It's possible we can't look deep enough into the atmosphere to see ammonia cloud features," suggested Brad Smith, leader of Voyager's imaging team. Clouds visible in the atmospheres of the giant planets Jupiter and Saturn are composed of ammonia ice and usually form at about the same temperature on all planets. Since Uranus is so much colder than either Jupiter or Saturn, the ammonia clouds form deeper in the atmosphere and the imaging cameras may not penetrate the thick atmosphere above them. Water-ice clouds undoubtedly also exist at deeper levels in the atmospheres of the giant planets, completely hidden by the overlying ammonia-ice clouds. Atmospheric scientists are not totally disheartened, however, as Voyager 2's "eyes" may yet see atmospheric features. Voyager's cameras may discern thin methane clouds that form at levels higher than any ammonia clouds. In addition, vertical convective motion may carry some ammonia clouds upwards to where Voyager 2 might yet detect them.

Recent studies indicate that the helium abundance on Uranus may be as much as 40 percent that of hydrogen — nearly four times the hydrogen-to-helium ratios on Jupiter and Saturn. All planets supposedly started out with the same hydrogen-to-helium ratios at the formation of the solar system. Voyager Project Scientist Ed Stone suggests that at Uranus, much of the hydrogen may be combined with carbon and oxygen to form methane and water in the atmosphere and in a deep ocean layer beneath the atmosphere.

"Uranus is distant, almost invisible, and virtually unknown... In seven weeks we will see Uranus' unknown face, its rings, and its moons... The Voyager Project and Program teams deserve a lot of credit..."

Burton I. Edelson, NASA Associate Administrator for the Office of Space Science and Applications.

Magnetosphere Puzzle

Planetary scientists have come to expect that any planet possessing a magnetic field will be a radio source. Charged particles trapped within the planet's magnetic field (the magnetosphere) are swept around in space with the planet's rotation, producing radio emissions.

Jupiter is the strongest planetary radio source in the sky. In fact, Voyager's planetary radio astronomy experiment, which uses a pair of 10-meter-long "rabbit ears" to listen for radio emissions in space, detected Jupiter's radio signature the day the spacecraft was launched, while still 600 million kilometers away. Saturn's radio emissions were detected shortly after the spacecraft rounded Jupiter. Earth's natural radio emissions were detectable on the spacecraft until the spacecraft was beyond the orbit of Mars. Yet, no radio emissions have been detected from Uranus, generally thought to be similar in many respects to the gas giants Jupiter and Saturn.

"This suggests three possibilities," said Mike Kaiser, a member of Voyager's planetary radio astronomy team from Goddard Space Flight Center, Greenbelt, Maryland. "Uranus may have no magnetic field — or one so tiny that it doesn't form a magnetosphere. It may have a weak magnetic field with low frequency emissions or emissions only on the dark side of the planet. Or, it may be a totally bizarre planet."

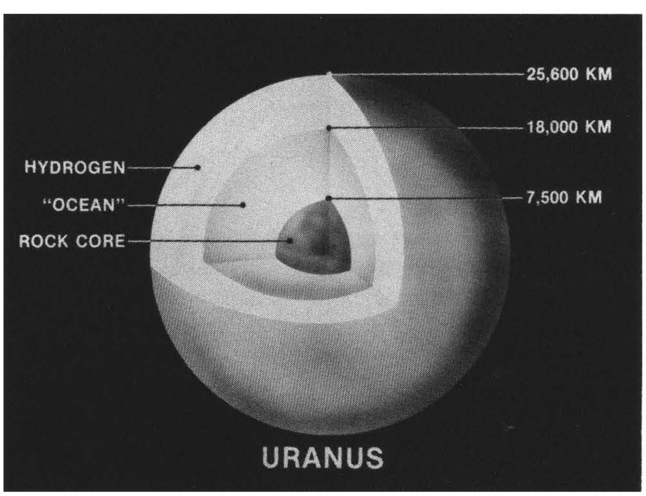
Dr. Stone carried the speculation further, suggesting that the magnetosphere may be similar to what was observed at the comet Giacobini-Zinner: there may be no bowshock (where the fast-traveling solar wind particles bump into slower particles captured in the planetary magnetosphere), but neutral hydrogen "boiling" off the planet may slow the supersonic solar wind and drag it past the planet.

Observatory Phase Continues

Voyager 2's ultraviolet spectrometer continues daily scans of the Uranian system to search for hydrogen or other gases near the planet, as well as daily searches of the south polar area for evidence of auroras caused by charged particles spiralling into the atmosphere along magnetic field lines.

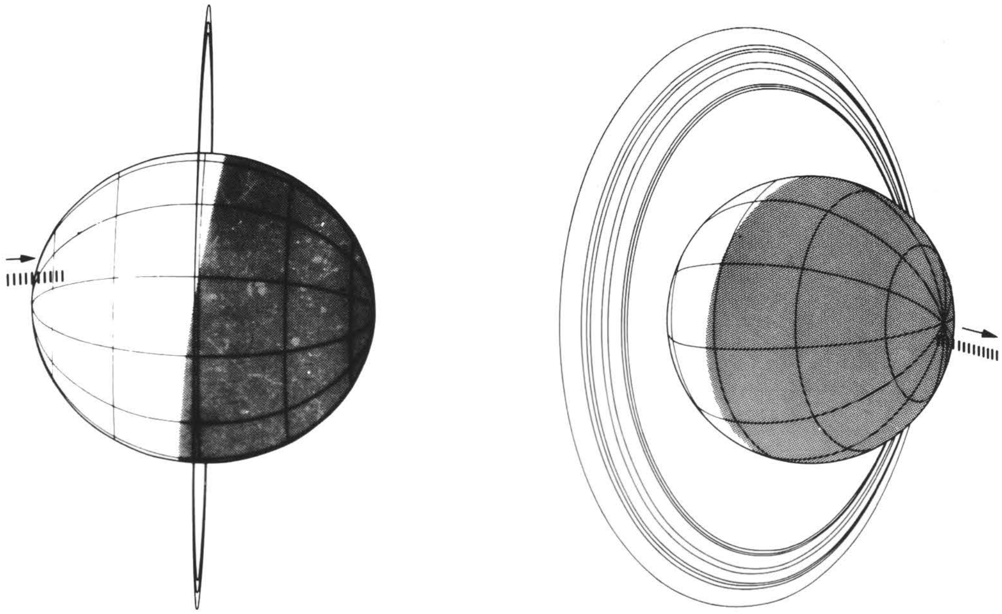
A "mini" cruise maneuver was performed on November 19 to allow the fields and particles instruments to scan the sky. The instruments that measure fields and particles are fixed in position on the spacecraft. A full-length cruise maneuver, in which the spacecraft maneuvers about its roll and yaw axes to allow the fields and particles instruments to view all of the sky, requires many hours and nearly fills the spacecraft's tape recorder. The "mini" cruise maneuver was designed many years ago to satisfy the needs of the fields and particles observers, yet to use only 40 percent as much time and tape recorder space as the full cruise maneuver.

The spacecraft has entered a ten-day period called "solar conjunction," when radio communications are hampered as the spacecraft and Earth are on directly opposite sides of the Sun. Solar radio emissions interfere with the radio signals from Voyager 2. As seen from the faster-moving Earth, the spacecraft appears to pass from left to right behind the Sun. Interference is greatest when the spacecraft is within 5° of the Sun. Spacecraft activities are designed to be at a minimum during such periods, which occur once a year. However, this geometrical alignment has been used for radio science studies of the Sun and of general relativity. Variations in the transmitted radio signal are studied as the signal passes close by the Sun. Solar conjunction also affords training opportunities for the operations people and equipment as preparations are made for the radio occultation experiments at Uranus, when radio communications with Earth will be severely reduced as the spacecraft passes behind the planet and its rings.



Uranus may have a rocky, Earth-sized core, overlain by an "ocean" of ice and a layer of molecular hydrogen. The temperature at the cloud tops is about 55 kelvins.

Uranus Science Experiments — Ultraviolet Spectrometry



To study the chemical composition of the atmosphere, the ultraviolet spectrometer will observe atmospheric effects on starlight from Gamma Pegasi as the star is occulted by the planet. The observation will be done at both the lit and dark poles during the near encounter in January.

The ultraviolet spectrometer measures the intensity of light in the extreme ultraviolet to far ultraviolet region of the spectrum. The optics of this instrument include 13 identical aperture plates which form a mechanical collimator (lenses will not transmit in the far ultraviolet), a reflection grating which spreads the light into its spectral colors, and a series of 128 fixed detectors which cover an ultraviolet wavelength range from 500 to 1700 angstroms. Detectable within this range are helium, sulfur, neon, argon, nitrogen, atomic and molecular hydrogen, oxygen, carbon, methane, acetylene, and ethane.

Mounted on Voyager's steerable scan platform, the instrument operates in one of two modes: occultation or airglow. The occultation mode measures the absorption and scattering of sunlight or starlight in an atmosphere as the spacecraft motion causes the Sun or star to disappear behind a planet or satellite. The airglow mode senses weak emissions high in the atmosphere due to bombardment by energetic particles or by resonant scattering of sunlight.

Three types of ultraviolet observations are planned at Uranus: system scans, disk measurements, and limb observations. Every day during the observatory phase, the aperture of the ultraviolet spectrometer will be stepped from one side of the Uranian system to the other, looking for a possible donut-shaped cloud (torus) of neutral hydrogen enclosing the planet. During these 75 days, the extent of the system covered in this scan will decrease from 200 R_U to 10 R_U. At one point, two observations will be done to mosaic the entire system out to 40 R_U from the planet in all directions. (R_U indicates the Uranian radius, about 25,600 kilometers.)

The ultraviolet spectrometer will mosaic both the sunlit pole and the dark pole to search for auroras. On Earth, auroras such as the Aurora Borealis, or Northern Lights, are caused by energetic particles spiralling into the atmosphere along the Earth's magnetic field lines. Auroras were found on both Jupiter and Saturn.

To determine the composition of the upper atmosphere, the instrument's aperture will drift across the bright limb of the planet. Polar occultations on both the lighted and dark sides will use the star Gamma Pegasi, more popularly known as Algenib. The effect of the atmosphere on the starlight will tell much about the chemical composition of the atmosphere. The instrument will similarly track the Sun as it disappears behind the planet, observing the absorption of sunlight by the atmosphere to determine the constituents and composition of the lower atmosphere.

The ultraviolet instrument will also observe the rings and try to determine if there is any diffuse material between the rings. These observations will be analyzed in conjunction with observations by the imaging cameras and the photopolarimeter.

During the 4-1/2 years since the Saturn encounter, the instrument has been extensively used for ultraviolet stellar astronomy observations. It has detected two new white dwarf stars, monitored cataclysmic variables (binary stars that closely circle one another), monitored cepheid variables (pulsating stars whose diameters change by as much as 20 percent in hours), established a consistent stellar flux scale for wavelengths below 1200 angstroms, and helped in mapping the energy distribution of a number of stars for wavelengths from 912 angstroms into the visible range of the spectrum.

The principal investigator for the ultraviolet spectrometry investigation is Lyle Broadfoot of the University of Arizona, Tucson. Thirteen scientists form an international team of co-investigators.

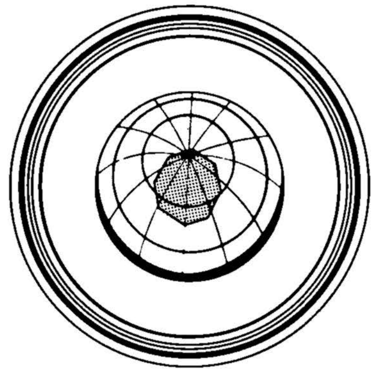
Infrared Interferometry and Radiometry

Every planet and satellite radiates infrared energy, determined by its temperature and atmospheric composition. Voyager's infrared interferometer and radiometer (IRIS) is designed to measure these temperatures, the molecular composition of an atmosphere (if present), and the reflectance of the body.

IRIS is an optical instrument mounted on Voyager's steerable scan platform. Light entering the instrument is split into two paths. One path leads to the radiometer, which measures light in the visible and near-infrared regions, while the other leads to the infrared (IR) interferometer. The radiometer measures the integrated reflected solar radiation and the interferometer measures radiation in the middle- and far-infrared portion of the spectrum. Inside the interferometer the light waves are divided and recombined after following slightly different paths. The interference pattern of the recombined light carries information about the temperature and molecular composition of the object viewed. A second interferometer, which uses a neon source within the instrument, is used as a reference to control the rate at which data are obtained by the main interferometer, and to provide a wavelength calibration.

On Voyager 2, the main infrared interferometer response slowly degrades while the instrument is at an operating temperature of 200 kelvins, apparently due to crystallization of elastic compounds in the instrument. A heater mounted on the primary mirror is used to warm the instrument and reverse the degradation. However, while this heater is on, the neon signal of the reference interferometer degrades. The neon signal gradually improves when the instrument is at its 200-kelvin operating temperature. Engineers must balance the conflicting temperature responses of these two parts of the instrument in order to use the instrument effectively.

The outer planets are a natural laboratory. Jupiter, with a 3° natural polar tilt, has little seasonal temperature differences between the northern and southern hemisphere. Saturn, tilted 27°, was 10° cooler at its north pole than at its south pole when the Voyagers flew by in November 1980 and August 1981. Scientists may see seasonal temperature differences between the northern and southern hemispheres of Uranus. The planet's polar tilt is a whopping 86°, and



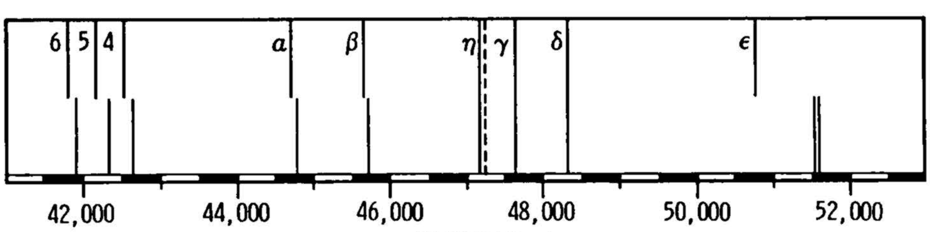
In this computer-generated drawing, the aperture of the IRIS instrument is overlaid on the planet's lit pole for composition studies of Uranus in the infrared.

its south pole will be pointing almost directly toward the Sun when Voyager 2 flies by, while the north pole will be totally shadowed.

The widths of the spectral lines of hydrogen are determined in part by the amount of helium in the atmosphere. These widths will be used to determine the ratio of hydrogen to helium. A high priority for IRIS will be to study the point in the atmosphere at which the radio signals to Earth will reappear as the spacecraft exits from behind the planet. This point will be studied nine hours before the occultation exit event. Combining the IRIS and radio science data sets will lead to a more precise determination of the hydrogen-to-helium ratio. This ratio will be compared to the ratios for Jupiter and Saturn and to abundances of these two elements predicted by theory for the primitive solar nebula.

Another prime objective of the IRIS experiment is to study the heat balance of Uranus. While the other giant planets, Jupiter, Saturn, and Neptune, all radiate more energy than they absorb from the Sun, ground-based measurements indicate that Uranus' radiation very nearly balances the solar input, making Uranus unique among the gas giants.

Principal investigator for IRIS is Rudy Hanel of NASA's Goddard Space Flight Center, Greenbelt, Maryland. There are ten co-investigators.



Three of Uranus' nine known rings — designated 6, 5, 4, alpha, beta, eta, gamma, delta, and epsilon — are very nearly circular, while the rest are somewhat eccentric. The epsilon ring also varies in width. Distances are given from the center of the planet.

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