Voyager Bulletin

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Uranus Encounter Begins: Observatory Phase

On November 4, eighty-one days before Voyager 2 flashes past the seventh planet, Uranus, the Voyager flight team began continuous, extended observations of the Uranian system at better resolution than possible from Earth.

The one-ton spacecraft is now travelling at nearly 15 kilometers per second (relative to Uranus), and radio signals travelling at the speed of light take 2 hours 25 minutes to reach Earth, 2.88 billion kilometers away. Uranus lies 103 million kilometers ahead.

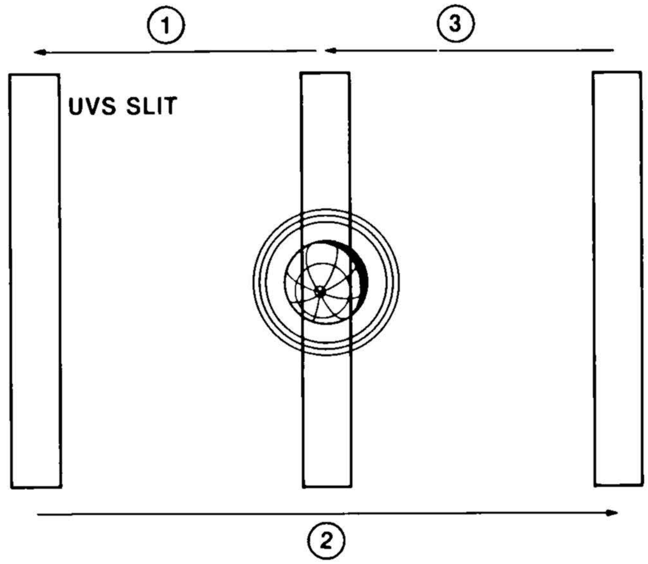
The first 67 days of the Uranus encounter period have been labeled the "observatory" phase. Some of what is learned during this time will be used to fine-tune the close-in observations. This phase will last until January 10.

Three computer loads have been designed to operate the spacecraft during the observatory phase. The first two will operate the spacecraft for almost one month each, the last for a week and a half.

During the observatory phase, the spacecraft's reference star will be Alkaid rather than Canopus, the usual reference.* The orientation of the spacecraft's roll axis determines what stars are seen in the background data of the ultraviolet spectrometer. If the spacecraft were using Canopus as a reference during this time, the spectrometer would see too much of the Milky Way. The use of Alkaid provides a less "busy" background.

The ultraviolet spectrometer will conduct daily searches for auroral emissions at the Uranian south pole, similar to the auroras (northern or southern lights) at Earth's poles. (Earth's auroras are caused by energetic particles spiralling into the atmosphere along magnetic field lines.) The UV spectrometer will also step across the Uranian system from one side to the other, looking for neutral hydrogen or other gases near the planet and its satellites. These system scans will occur twice daily, sweeping across a distance that will gradually shrink from 5 million kilometers to 260,000 kilometers by the end of the observatory phase.

In interplanetary cruise, the spacecraft maintains its orientation by using electro-optical devices that detect light from the Sun and a star, usually Canopus. This prevents the spacecraft from tumbling out of control. The sun sensor affects the spacecraft's pitch and yaw axes, while the star tracker affects the roll axis.



During the observatory phase, the ultraviolet spectrometer is scanning the Uranian system edge to edge, searching for clouds of neutral hydrogen or other gases.

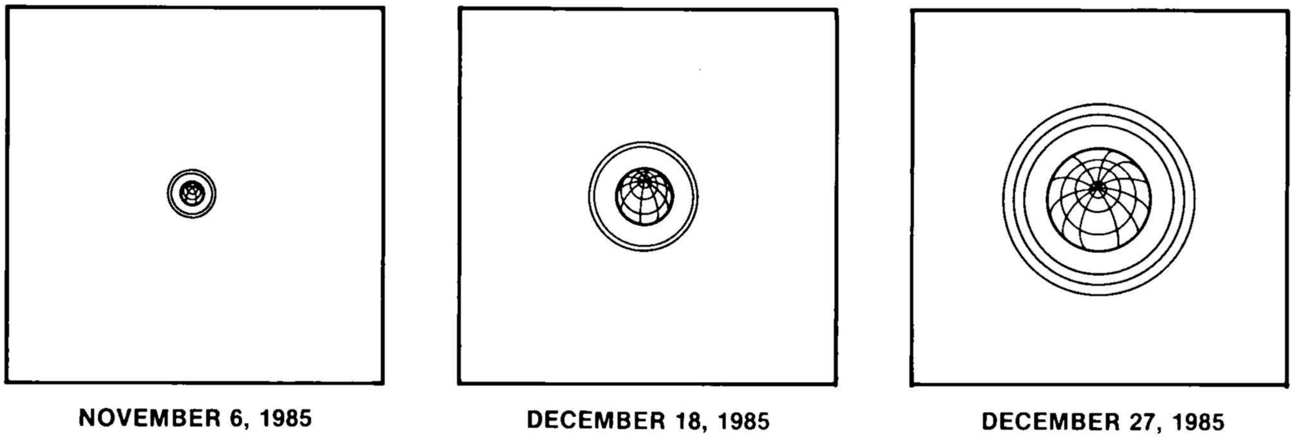
The photopolarimeter will observe changes in the light reflected from the clouds as the planet rotates. These observations will lead to later high-resolution photometry of the planet.

Five times during the observatory phase, the imaging cameras will image the system for about 36 hours, or about two complete rotations of the planet (the rotation period has not yet been determined definitively). At a rate of 12 frames per hour, each of these imaging periods will yield about 400 frames, 80 percent of which will be taken by the narrow-angle camera.

"If we see features in the Uranian atmosphere that we can track, we may splice these frames together to create a short movie sequence such as the rotation movies obtained at Jupiter and Saturn," said Ellis Miner, Assistant Project Scientist. "We only plan to do this if there is scientific value in such a movie."

(For a rotation movie, the imaging is more or less continuous as the planet rotates. This differs from a "zoom" movie in which only a specific area is imaged as the spacecraft closes in.)

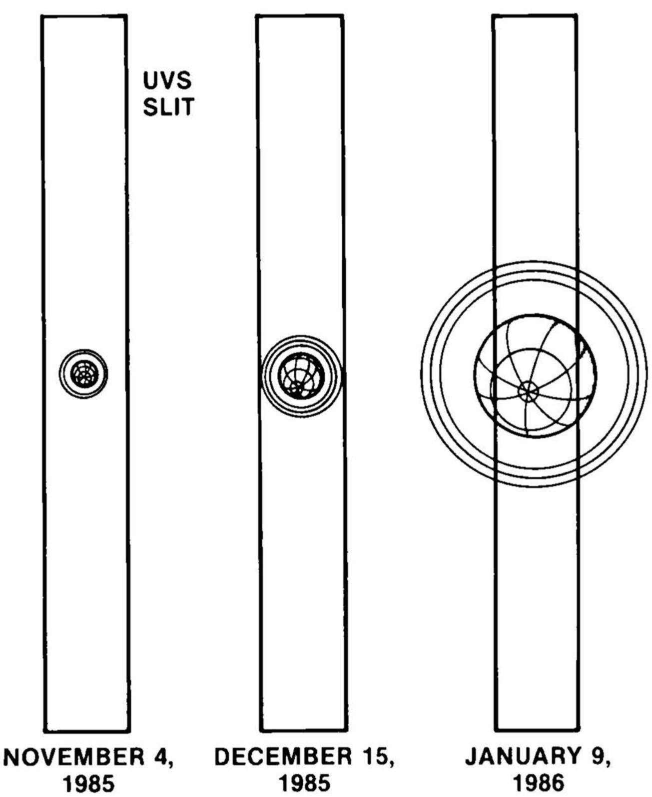
Most of the imaging sequences in the observatory phase will be relayed to Earth in real time rather than recorded for later playback.



The planet and its rings will loom larger in the narrow-angle camera field-of-view as the spacecraft closes in.

During the first month of the observatory phase, several calibrations will occur, including calibrations of the fields and particles instruments, the radio frequency system's automatic gain control, and the antenna and sun sensor.

Torque margin tests will monitor the health of the spacecraft's scan platform, on which are mounted the four optical instruments.



The ultraviolet spectrometer is searching for auroral emissions at the planet's sunlit pole.

Uranus Science Experiments

Brief summaries of the Voyager's eleven scientific experiments will appear in the *Bulletin.*

Imaging

Each Voyager spacecraft carries a narrow-angle, 1500-mm reflector telescope (with an aperture of f/8.5) and a wide-angle, 200-mm refractor telescope (f/3) as part of their imaging subsystems, mounted on the spacecraft's steerable scan platform. Each camera has a vidicon (TV camera tube), shutter and filter assemblies, power supply, and support electronics.

Each image frame is an 800-line by 800-column array of picture elements (pixels) captured on a vidicon. Eight bits are used to describe each pixel's gray level, which can range from 0 (black) to 255 (white). The filters include ultraviolet, violet, blue, green, methane, orange, sodium, and clear. Color images are made by combining two or more images exposed through different filters. This is done on the ground in JPL's Multi-Mission Image Processing Laboratory (MIPL).

Due to Voyager 2's increased distance from Earth, the telecommunications capability at Uranus will be considerably reduced from what it was at Jupiter and Saturn. This poses problems for returning imaging data. Two techniques have been devised for coping with this imaging problem: data editing and data compression.

There are two options for data editing. When telemetry performance is down, full format frames will be returned, but some pixels will be systematically deleted, resulting in reduced resolution. The preferred option will be to return only part of the frame, but at full resolution.

In data compression, the brightness of each succeeding pixel is expressed as its difference from the preceding pixel. This technique reduces the total number of bits needed to transmit an image. Full resolution will be obtained, although the edges of a frame may be jagged if the imaged scene is "busy." It is also possible to use only 7-bit encoding, reducing the gray-level resolution by a factor of two (0 to 127).

At Jupiter and Saturn, time-lapse movies of the systems were used to study the meteorology of the planets' atmospheres as well as properties of the satellites and rings. Seven 36-hour movie sequences are planned for Uranus as Voyager 2 approaches the planet. Each will show about two rotations of the planet so that scientists can observe changes in the atmosphere. By identifying specific features in the clouds and tracking them, wind speeds can be estimated. For example, at Saturn, equatorial wind speeds were found to be over 400 meters per second. In contrast, Earth's stratospheric jet streams blow at only 50 meters per second.

Complementary data among the infrared radiometer, the photopolarimeter, and the cameras will aid in determining the planet's heat balance by measuring the differences in brightness at different phase angles.

An "anti-smear" campaign has been implemented to reduce image blurring caused by long exposures (due to the low light levels at this distance from the Sun), combined with high relative velocities between the spacecraft and its targets, and the normal gentle swaying of the spacecraft. The spacecraft team has made changes in the spacecraft's attitude control system to reduce the natural spacecraft rates of rotational motion and, furthermore, to turn the spacecraft to match the speed of its target during selected imaging sequences targeted for the five known satellites. This latter technique, known as image motion compensation, is so effective that the resolution of the best satellite images will be increased by factors from 4 to 50 over what would be obtainable without image motion compensation.

The narrow Uranian rings will be imaged best by Voyager as the spacecraft crosses the ring plane and in occultation with high forward-scattering angles (i.e., when the rings are between the Sun and the spacecraft and appear backlit). The cameras will also be used to search for small satellites in and near the rings.

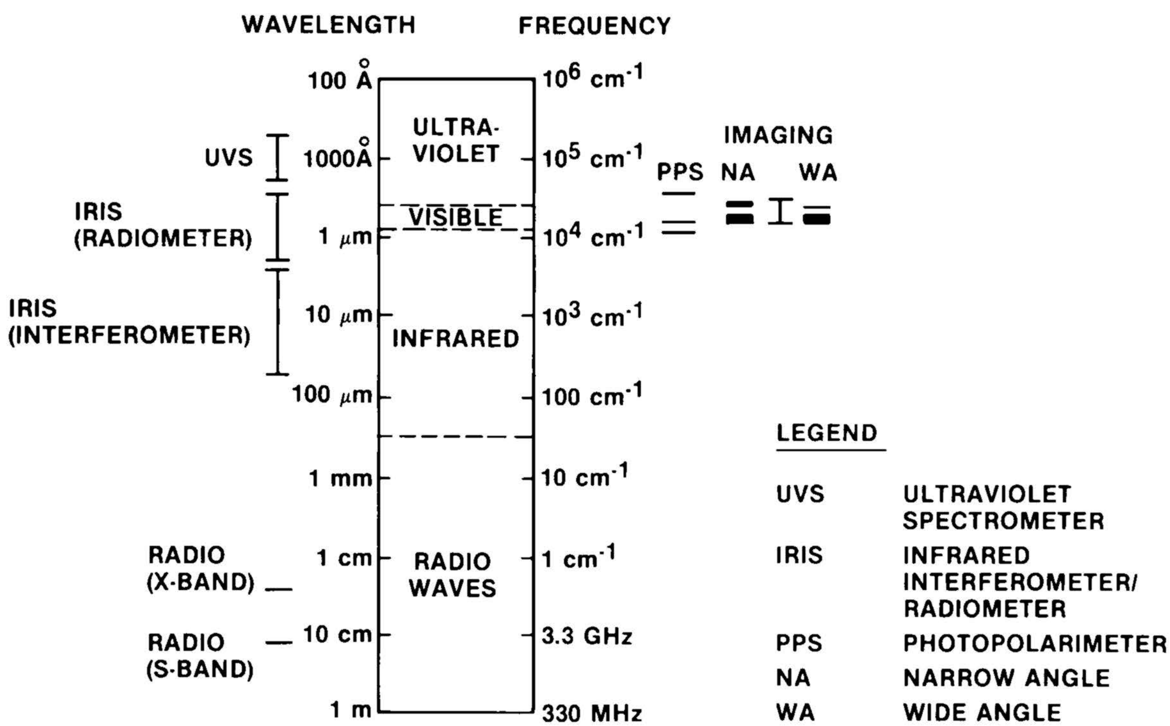
The team leader for imaging science is Brad Smith of the University of Arizona, Tucson. Twenty-two additional scientists make the imaging team Voyager's largest science team.

Photopolarimetry

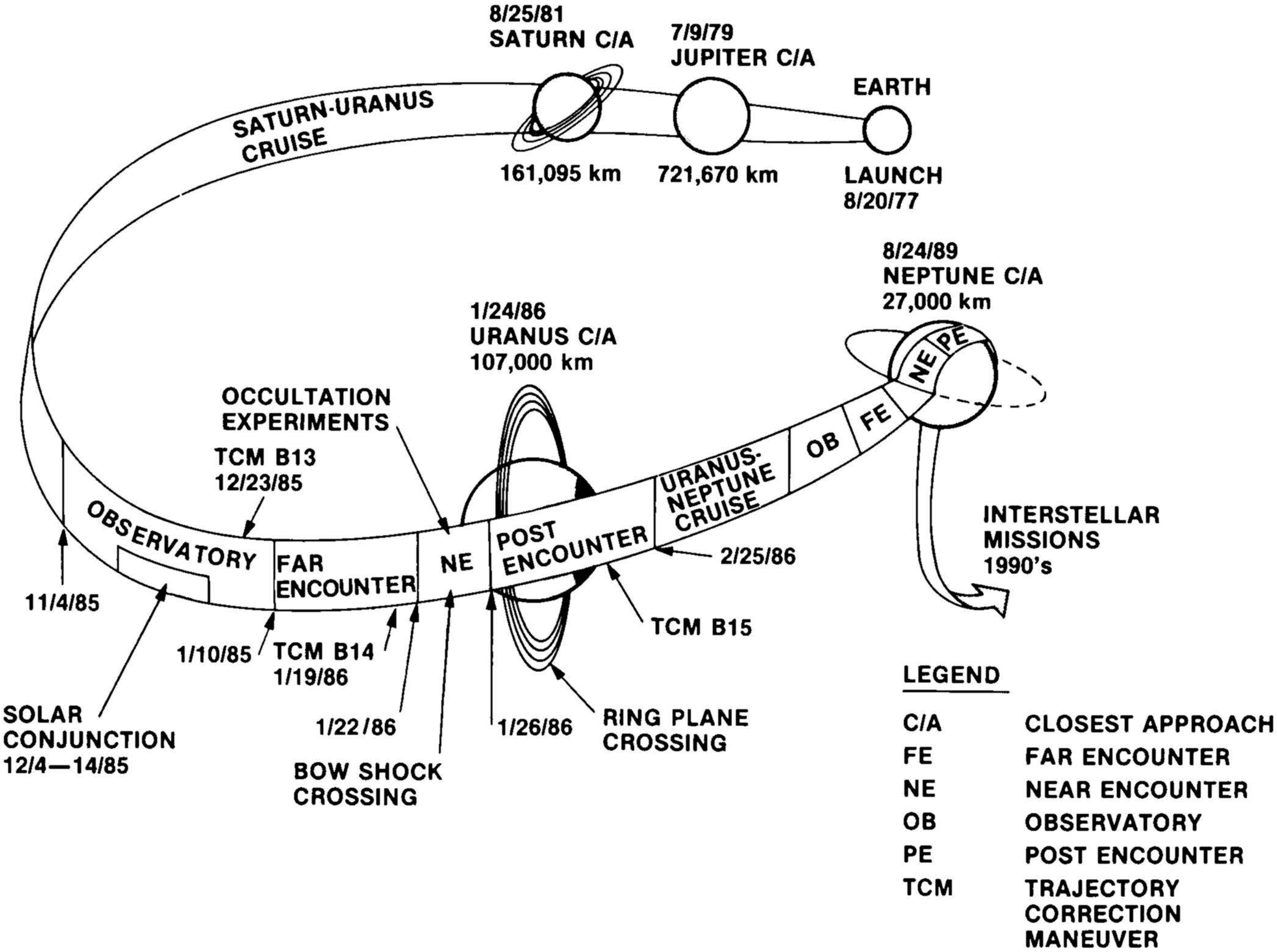
The photopolarimetry experiment addresses the basic problem of measuring the way in which light is scattered from particles which comprise the surface or atmosphere of a planet or satellite. The angles of sunlight illumination and reflection are measured (i.e., the incoming path and the emerging path). The intensity of the reflected light is measured as these angles change during the spacecraft flyby.

In reality, the problem is formidably complex because the light beam undergoes many processes before it is reflected back into the photopolarimeter: it may be bounced off several surfaces, pass through a gas or liquid, or be diffracted by different sizes of particles. To make any sense at all out of the problem, scientists make several simplifying assumptions when formulating photometric theory: that the particles are uniform and spherical, that there is no multiple scattering, and that there are no diffraction effects. This allows them to look at the intensity of the scattered light and then to relate this to various parameters which in turn are related to the texture of a solid surface or the size of liquid droplets in an atmosphere.

Light scattered through two media — air and water, for example — usually gains some polarization: the light



Voyager's science instruments provide complementary coverage in selected ranges of the electromagnetic spectrum.



Voyager 2 will observe the Uranian system at better than Earth-based resolution for about four months.

waves vibrate in a definite pattern. By studying the polarization of the reflected light as the lighting geometry changes during the flyby, scientists can make inferences about the nature of a planetary surface or atmosphere. For example, dark surfaces tend to have higher polarization at certain viewing geometries.

Because the photopolarimeter is very sensitive to small changes in light, the instrument can also be used to gain a better understanding of the nature of planetary rings. This is done by measuring the intensity of a background star as the starlight passes behind the rings as viewed by the moving spacecraft.

Mounted on Voyager's steerable scan platform, the photopolarimeter is a Cassegrain telescope with filters, polarization analyzers, and a photomultiplier tube to record incoming light. It covers eight wavelengths in the region between 235 and 750 μm. The photosensitive material in Voyager 2's photomultiplier tube has degraded, perhaps due to chemical changes. Another problem sometimes results in occasional errors in positioning of the instrument's aperture wheel. The photopolarimeter team has devised methods to use the instrument effectively despite these problems.

At Saturn, the photopolarimeter returned spectacular data on the rings by measuring the starlight passing through the rings from a distant star. The radial ring structure was determined to a resolution of meters. The same technique will be used at Uranus, using the star Sigma Sagittarii (Nunki), as it passes obliquely behind the outer rings, and the star Beta Persei (Algol) to determine the fine structure of the entire ring system.

The photopolarimeter will also observe the Uranian atmosphere, studying how light reflected from the clouds changes as the planet rotates. Phase observations at the satellite Titania will study reflectance and polarization — observations that cannot be made from Earth or any other present spacecraft.

Principal investigator for the photopolarimeter is Lonne Lane of JPL. There are six co-investigators.

NASA

National Aeronautics and
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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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Status Bulletin Editor: Anita Sohus .... (818) 354-4438
Public Information Office .... (818) 354-5011
Recorded Mission Status .... (818) 354-3051