Voyager 2's Uranus: 'Totally different'

"Data compression" is a technical term, referring to a computer technique that would increase the amount of information the Voyager 2 spacecraft could transmit to earth from its distant encounter with the planet Uranus. But the phrase turned out to be a more than adequate description of the entire event—an intense few days that had scientists reeling under startling findings and that at least tripled the planet's already considerable medley of known moons.

Discovered more than two centuries ago, yet invisible to the naked eye (it is four times as far away as Jupiter), Uranus seemed determined to keep its secrets until the last moment. For decades astronomers had sought to pick out visible features in the atmosphere, in the hope that the rotation of such features could be timed to reveal the length of a Uranian day. Yet it was not until Jan. 22, just two days before the craft's closest approach to the planet, that imaging-team leader Bradford Smith of the University of Arizona in Tucson was able to announce "the first time that any discrete clouds, much less their motion, have been measured in the atmosphere of Uranus."

As expected, the rotation periods (between 16.2 and 16.9 hours) varied with the clouds' latitudes. The real answer would come from detection of the planet's radio emissions, if it had any. For months researchers had hoped to detect such signals as Voyager 2 crossed the millions of miles in silence, until, on Jan. 23, project scientist Edward Stone of Caltech in Pasadena began the daily press briefing with: "Good morning. And yes, there is radio emission from Uranus."

The signals had actually been first detected four days earlier by the craft's plasma-wave instrument, but similar detections by its radioastronomy instrument were initially ambiguous enough that the announcement was delayed. Even after a few more days, in fact, the rotation period implied by the radio waves remained difficult to pin down. James Warwick of the University of Colorado in Boulder could only say that it was 16.8 hours — plus or minus 18 minutes. However, longer-term measurements, he added, should reduce the uncertainty by about 90 percent.

But why should such a usually reliable measurement be uncertain at all from such a short distance? The answer was perhaps one of the flyby's most unexpected findings: The mere existence of radio emissions virtually confirmed that Uranus has a magnetic field. But Voyager's magnetometer soon added the unexpected fact that the axis of the field was tilted some 55° away from the planet's own rotation axis, compared with less than 20° for the fields of other worlds known to have them. The result is that the turning of the planet sweeps its magnetic axis through a wide cone, making it difficult to determine the length of a day from modulations in the radio emissions. In addition, the "tail" of the field is twisted by the motion of its axis into what Warwick calls a "double helix," rather than simply trailing out behind, as in the case of earth, Jupiter or Saturn.

Voyager 2 also added a new dimension to the strange matter of whether the planet has an aurora—a notion prompted by 1982 observations from an earth-orbiting satellite of a brilliant ultraviolet (UV) glow at Uranus. An aurora implies a magnetic field, but the lack of detectable radio emissions had left the conclusion in doubt. It had been suggested that the glow might be "airglow" stimulated by solar ultraviolet light rather than by excited electrons. Instead, Voyager 2 found that the glow was of yet another variety, which requires both UV sunlight *and* electrons, and Voyager scientists dubbed it "electroglow." The same phenomenon exists at Jupiter and Saturn, says Lyle Broadfoot of the University of Arizona, but there it is dominated by other processes. At Uranus, he says, the UV glow detected from earth was about 70 percent due to electroglow and only 30 percent to airglow — although the complex planet has auroras as well.

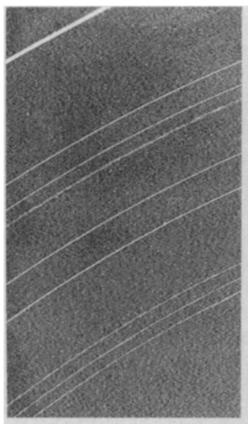
Perhaps the most eagerly awaited result was a better look at the Uranian rings, discovered nine years ago when they blocked the light of a star but were never clearly seen. Nine rings had been identified, so skinny and dark that they were completely invisible to Voyager 2's cameras until late last year (SN: 12/14/85, p. 373), when one of the nine was imaged by dint of heavy computer processing. Closer and closer the spacecraft came, and with about two days to go, an even fainter tenth ring was identified.

Hopes were high that the rings would show up far better when the spacecraft looked back "over its shoulder" to view them by "forward-scattered sunlight," a technique that had previously yielded a brilliant image of the otherwise faint ring system of Jupiter. But it is only the tiniest dust grains, no bigger than particles of smoke, that make such forward-scattering possible, and in the Uranian rings, such particles seem to be in short supply. Measurements made by aiming Voyager's earthward radio beam *through* the rings indicated that most of the particles were more like boulders a meter or more in size, according to G. Len Tyler of Stanford University, and the first few forward-scattering images showed little obvious improvement.

Fortunately, the craft's computer carried instructions to take a single time exposure lasting 96 seconds. And the result—in that single frame—was a transformation. "This is the one we've been waiting for!" exulted Richard J. Terrile of Jet Propulsion Laboratory in Pasadena, from which the mission is controlled. "This is the fingerprint — the key to the structure of the whole ring system."

A glowing, disklike form with multiple thin "ringlets" prompted ready comparison with similar-looking Voyager images of the much more substantial rings of Saturn. All of the nine previously known rings are there (though difficult to identify), and some of the brightest features are ones that had not been known at all from the "front side."

In addition, analysis of another frame,



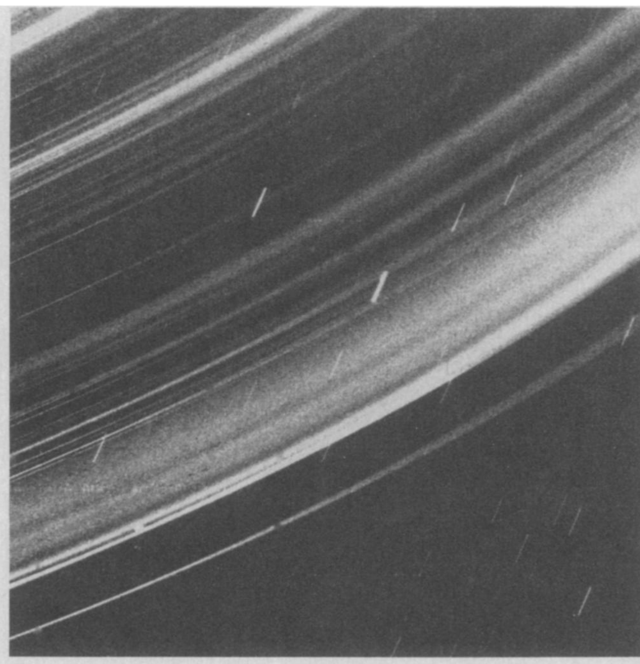


Photo: JPL

The nine main rings of Uranus, repeatedly photographed (above) by Voyager 2, revealed a much more complex structure only when a single 96-second exposure (right) was taken by forward-scattered sunlight while looking back at the planet.

URANIAN SATELLITES DISCOVERED BY VOYAGER 2

Name	Diameter* (km)	Orbit Radius (km)	Period (hr:min)	Discovery Date
1985U1	130	85,892	18:17	Dec. 30
1986U1	90	66,090	12:19	Jan. 3
1986U2	70	64,350	11:50	Jan. 3
1986U3	70	61,750	11:06	Jan. 9
1986U4	50	69,920	13:24	Jan. 13
1986U5	50	75,100	14:56	Jan. 13
1986U6	50	62,700	11:24	Jan. 13
1986U7	15	49,300	7:55	Jan. 20
1986U8	20	53,300	8:55	Jan. 20
1986U9	50	59,100	10:23	Jan. 24

*Figures are estimated by assuming reflectances similar to the approximately 0.05 albedo of 1985U1.

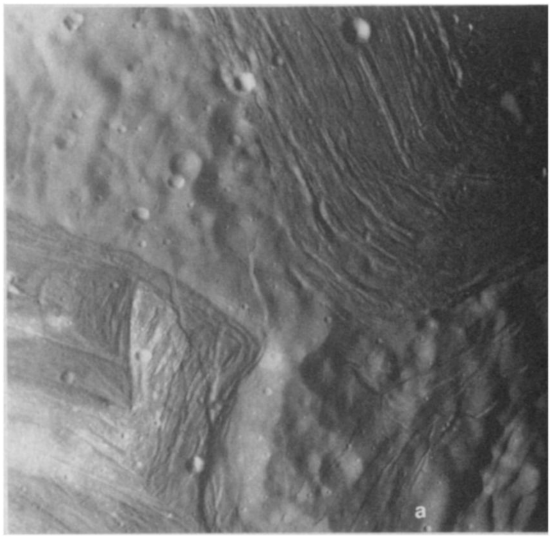
taken while Voyager was only a few degrees out of the plane of the rings — looking, in other words, almost across the rings — was said to be showing a broad, diffuse sheet of particles *inside* the previously known rings. Separated by about 1,500 kilometers from the innermost known ring (designated the 6 ring), it was believed to continue inward for another 3,000 kilometers.

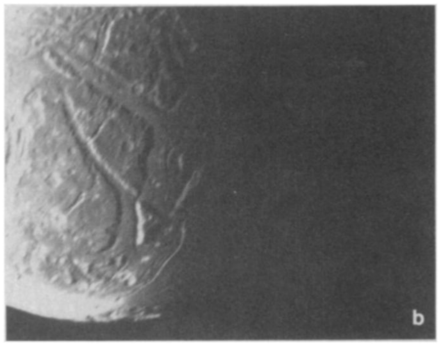
Still, the Uranian ring particles are extremely sparse. "There's more material in the Cassini division of Saturn's rings [which appears virtually empty to earth-based observations] than in the entire Uranian ring system," says Terrile. Also, measurements by the plasma-wave instrument indicated that only about 30 dust particles per second were vaporized against the device's antennas during the ring-plane crossing, compared with about 600 per second in the plane of the rings of Saturn, according to Frederick L. Scarf of TRW in Redondo Beach, Calif.

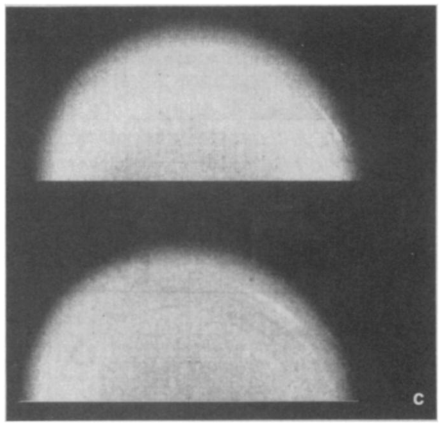
One question was whether Voyager 2 would identify any small satellites "shepherding" the rings, keeping them narrow and sharp-edged from gravitational effects along the outside and inside of each ring. By Jan. 28, only two such shepherds had been identified, though it was deemed possible that others might be present but too small for cameras to spot. "We are assuming [the existence of shepherds]," said Smith, "because we don't know any other way to do it."

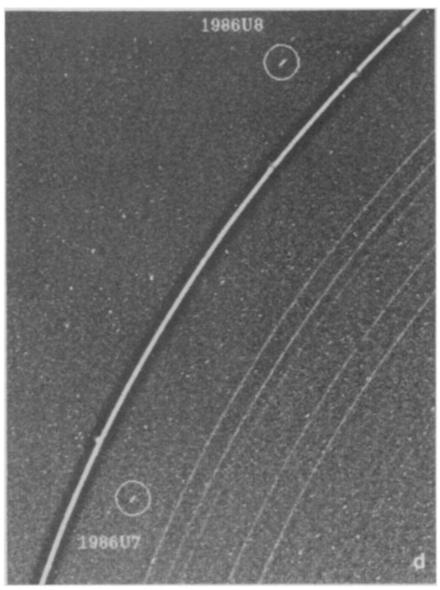
But even with all the ring details, little moons, radio emissions and other new features detected by Voyager, some of the most fascinating finds included never-before-seen details of the five major Uranian satellites.

Far and away the most spectacular is Miranda, innermost of the group, whose diverse surface ranges from regions of relatively old-looking, rounded terrain to striking patterns of parallel ridges or grooves, not dissimilar to those on Jupiter's biggest moon, Ganymede. In some places these fracture patterns form enclosed areas, looking as though some of the cracks have been widened, perhaps by liquid or plastic flows that rose up from beneath them.









Right, top to bottom: (a) Bizarre patterns of parallel grooves, including a light-colored V-shaped feature dubbed "the chevron," bedeck this 140-mile-wide swath of the satellite Miranda, evoking a complex and unusual geologic history; (b) faults edging linear valleys on the Uranian moon Ariel are not visible where the valleys intersect, suggesting that the valleys may have been filled in by tectonic processes some time after their formation. Sinuous rilles or trenches also show in the valley floors; (c) two streaky white clouds were among the few features visible in the Uranian cloud tops even with extreme computer-processing. Their changing relative positions in this two-picture sequence indicate bands of wind differing in speed (at latitudes 26° and 33°) by almost 220 miles per hour; (d) two Uranian satellites believed to be gravitationally confining the particles in the planet's epsilon ring were the only such "shepherds" among 10 moons discovered by Voyager 2.

The next moon out is Ariel, showing flat-floored, valleylike shapes formed where parts of formerly level terrain dropped away and left walls between which floods of debris created smooth channels. Next is Umbriel, far less dramatic, offering what Laurence Soderblom of the U.S. Geological Survey in Flagstaff, Ariz., thinks may be some of the oldest topography among the five moons. Titania, says Soderblom, is like "Ariel without the volcanism," heavily cratered and bearing a major fracture pattern but without the readily apparent flow features. And outermost Oberon is just craters, craters, craters, like a reminder of earth's moon.

There is much more to be learned — some of Voyager 2's data have barely been examined, and those that have are often baffling. "Each day it just gets better," said Edward Stone, "totally different from anything we've seen." — *J. Eberhart*