SCIENCE NEWS of the week

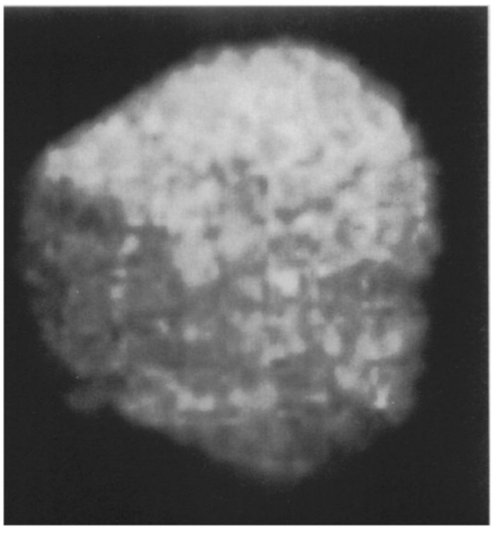
'What a Way to Leave the Solar System'

Voyager 2's journey past distant Neptune and its moons yielded a host of new discoveries and raised just as many new questions. Neptune, long known for its moons Triton and Nereid, now has eight known satellites, and scientists in the Voyager control center at NASA's Jet Propulsion Laboratory in Pasadena, Calif., continued poring over data this week in search of more. In addition, the craft finally detected radio emissions from the planet (evidence that it has a magnetic field), photographed its strange family of rings, and delighted scientists and public alike with its spectacular pictures of Triton.

Voyager scientists, engineers and managers repeatedly described the encounter as "the end of an era," climaxing a 4.36-billion-mile odyssey that began with the craft's launching on Aug. 20, 1977, and continued with visits to Jupiter, Saturn and Uranus. Neptune was the last official objective on the list, though Voyager 2 could add another feat if it can still report back to Earth when it crosses the heliopause, the boundary where the sun's magnetic domain, or magnetosphere, runs into charged particles coming this way from distant stars. No one knows just how far away the heliopause lies, but officials estimate that Voyager's radio messages may remain detectable from Earth until about the year 2020.

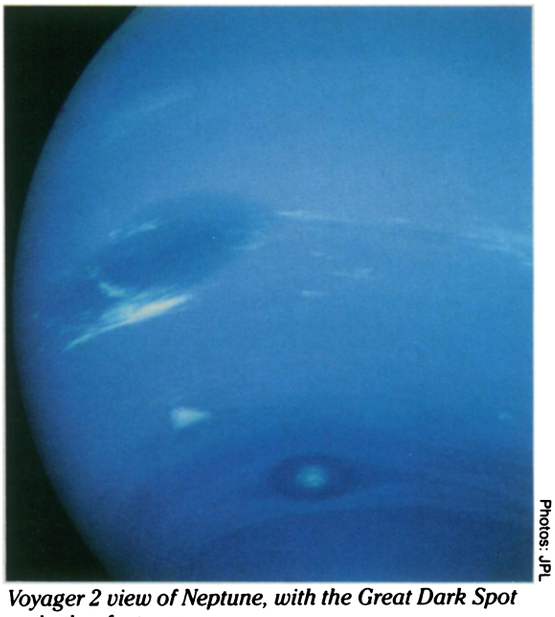
Beyond the heliopause, the craft will enter what officials call its "interstellar mission," although its nearest encounter with another star may not occur for about 40,000 years, when it comes within 1.7 light-years (about 10 trillion miles) of the star Ross 248. The sun, in comparison, is only about 8 light-*minutes* away from Earth.

If Neptune's newly found moon 1989 N1 were any larger than its average radius of 120 miles, its own gravity might have pulled its odd shape into a sphere.



The mission's featured attraction in recent weeks, however, has been Neptune, glowing with an elegant blue due to the absorption of the red in sunlight by the methane in the planet's atmosphere. Neptune did not reveal the numerous complex swirls that bedeck Jupiter and to a lesser extent Saturn, but high above the atmosphere's visible cloud deck are bright streaks of frozen methane resembling Earth's cirrus clouds.

The most striking feature visible in the clouds is a huge oval that scientists on the Voyager imaging team dubbed the Great Dark Spot, about 20° of latitude below Neptune's equator. At about 33°S lies a smaller, brighter feature known simply as the "bright companion." Another 9° to the south, a much smaller, even brighter blob labeled the "Scooter" whips around the planet at about 175 meters per second. At about 55°S sits a second dark spot, called "D2," and over the whole atmosphere lies a high, thin haze, reports Heidi Hammel of Jet Propulsion Laboratory.



Photos: JPL

Voyager 2 view of Neptune, with the Great Dark Spot and other features.

While Voyager 2 photographed the atmosphere through a filter tuned to the 6,190-angstrom wavelength of the light reflected by Neptune's methane, Hammel used a telescope on Mauna Kea, Hawaii, to take pictures at another methane wavelength, 8,900 angstroms. This indicated a methane layer much higher in the planet's atmosphere that the other filter could not see. The ground-based images also revealed an atmospheric "hood" over Neptune's south pole. Pinning down the hood's altitude will be part of the time-consuming task of unraveling the atmosphere's vertical structure.

The discovery of the magnetic field proved a more immediate addition to the understanding of Neptune. Voyager scientists had waited for months for the craft to detect the radio emissions such a field ought to produce, and those signals finally showed up on Aug. 18. Tracking the emissions as the planet turned held the key to determining a Neptunian day — which lasts 16 hours, 3 minutes, plus or minus 4 minutes, according to James W. Warwick of Radiophysics, Inc., in Boulder, Colo.

One surprise was Voyager's finding that the magnetic field's axis tilts about 50° away from Neptune's axis of rotation rather than being closely aligned with it. In 1985, Voyager 2 measurements revealed that Uranus' magnetic field tilts 58.6°, the largest magnetospheric tilt known. (Earth's field tilts 11.7°.) That prompted some scientists to suggest that perhaps another object had knocked Uranus onto its side. But two such events would defy extremely long odds.

Another explanation — though equally implausible, according to several scientists gathered at the Voyager control center — could be that the direction of the field at both planets is changing, an event that occurs periodically on Earth.

Both proposals, however, require a particular event sometime in Neptune's history — either an impact that tipped the planet over or the convenient timing of a reversal of the magnetic field's polarity. An easy answer appears unlikely, says Voyager magnetometer investigator Norman F. Ness of the University of Delaware's Bartol Research Institute in Newark.

If Neptune was the featured attraction of the encounter, its moon Triton stole the show. Triton's surface in certain places evokes numerous other objects in the solar system, including the fissures in Jupiter's big satellite Ganymede, vast expanses like the "seas" of Earth's moon, and terrain like diverse parts of Mars. Laurence A. Soderblom of the U.S. Geological Survey in Flagstaff, Ariz., describes part of the terrain along the edges of Triton's south polar region as resembling the skin of a cantaloupe.

Triton also has an atmosphere, primar-

Continued on p. 157

Continued from p. 148

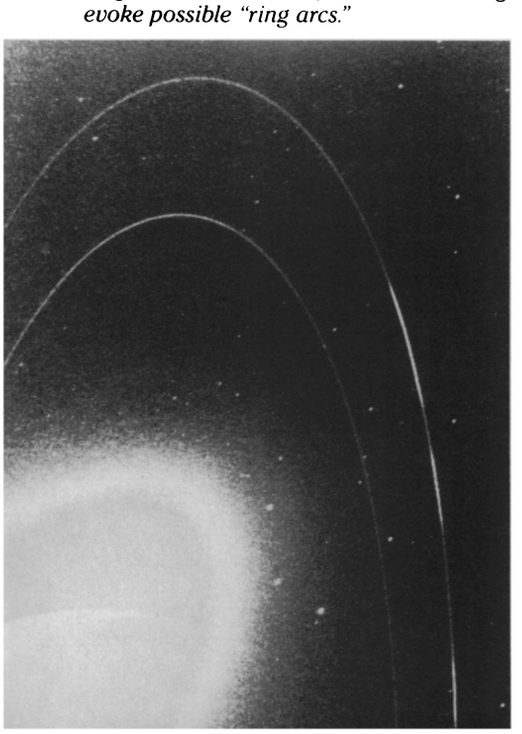
ily of nitrogen and methane and extremely thin. Its pressure at the surface is very low – only about one hundred-thousandth of that on Earth – but it may play a part in perhaps the most unusual phenomenon in the whole Neptunian system: volcanoes of ice. Near Triton's south polar cap, the Voyager photos reveal what some project scientists identify as streaks of dark material overlying the lighter surface, similar to streaks near the volcanic vents in the surface of Jupiter's surprising moon Io.

Scientists discovered Io's volcanoes in a Voyager photo of an eruption in progress, driven by the rapid expansion of sulfur dioxide gas. The photos of Triton reveal no such spectacle taking place, but Voyager scientists are at a loss to otherwise account for the streaks, which measure as much as 30 miles wide and 45 miles long.

Soderblom and others suggest that even a slight rise in temperature beneath Triton's surface may be enough to change nitrogen from a frozen solid to an expanding gas, shooting up geyser-like vents and carrying with it extremely fine, dark particles that get strewn across the surface by the winds blowing in Triton's atmosphere. Some Voyager researchers calculate the wind speeds, and those of the material issuing from the vents, as high as 100 miles per hour.

Should scientists find volcanic activity as they examine the photos in greater detail, it would be only the third known example of active eruptions in the solar system. Imaging team leader Bradford A. Smith of the University of Arizona in Tucson likens such an eruption to an artesian system, in which a fluid is pressure-driven to the surface. Triton's nitrogen, he says, would fill "exactly the same role" as sulfur dioxide on Io.

Bright portions of Neptune's outer ring evoke possible "ring arcs."



Understanding the structure of Neptune's rings is more important than counting them.

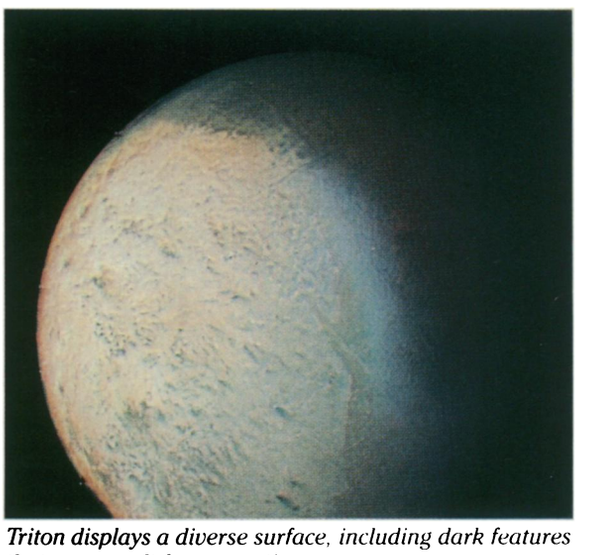
Unlike Neptune, Triton appears from Voyager's early data to lack a magnetic field of its own. But Neptune's field seems to play a role for its largest moon. The auroras of Earth and other planets such as Jupiter depend on the presence of a magnetic field, which traps charged particles and carries them down into the upper atmosphere, producing the familiar auroral glow. Though Triton apparently lacks its own field, its tilted orbit carries it in and out of Neptune's magnetosphere. The result may be a Tritonian aurora, energized courtesy of Neptune and glowing near Triton's equator rather than at its poles.

Trapped radiation, like Earth's Van Allen belts but considerably weaker, may surround Neptune itself. For every 100 ions in the Van Allen belts and every 1,000 in Jupiter's much more powerful radiation belts, Neptune's belts contain only 0.5 ions with energies of 50,000 electron-volts, says Stamatios Krimigis of the Johns Hopkins Applied Physics Laboratory in Laurel, Md. For electrons with the same energy, Neptune has 10 for every 100 orbiting Earth and 10,000 orbiting Jupiter.

The most discussed aspect of Neptune in the months – and even years – preceding Voyager 2's visit has been the possibly bizarre nature of the planet's rings. Based on the unusual way starlight blinked off and on as Neptune got in the way on several occasions a few years ago, some scientists had raised the possibility that Neptune might have not whole rings like those of Jupiter, Saturn and Uranus, but just short arcs.

As the craft neared the planet in recent weeks, astronomers eagerly waited to discover whether its photos would reveal the dim arcs, apparently too faint to see with Earth-based telescopes. Two faint arcs appeared a week before the encounter, but then, with barely three days to go, the cameras revealed a set of actual rings.

The images were so faint that Voyager scientists found it difficult to say how many rings they had detected. The narrow, outermost ring orbits about 39,000 miles from Neptune's center. Along the ring in one photo appear three prominent segments, as though the so-called "ring-arcs" are not isolated structures but part of the ring itself. (Some scientists have suggested that these segments may be "clumpy," like features in the F-ring around Saturn.)



Triton displays a diverse surface, including dark features that may result from eruptions.

Next in is a more subtle ring, about 33,000 miles from Neptune's center, which may be part of a wider and fainter ring informally dubbed the "plateau." Voyager scientists estimate that this structure ranges between about 33,500 and 36,400 miles from the planet's center. Still farther inward orbits a wide, even fainter ring that may extend all the way in to the cloud tops, though it is too faint for scientists to be sure.

Members of the Voyager scientific team are only beginning to work with their data, many of whose details remain baffling. Soderblom, summing up the mood at control center, exclaims: "All we can say now is, Wow! What a way to leave the solar system!" – *J. Eberhart*