Planetary Perks

Scientific fringe-benefits of Voyager 2's trip to Neptune

By JONATHAN EBERHART

Next August, the Voyager 2 spacecraft will fly past Neptune to provide the first closeup measurements of what is now the solar system's most distant known world, the apparently incomplete arcs of its rings and its big moon Triton. But even with the encounter still a year away, preparations for it are already enhancing research having nothing to do with Neptune – work ranging from other planets to the sun, quasars and galaxies.

NASA's principal means of communication with interplanetary spacecraft is its Deep Space Network (DSN) – three big dish-antennas located in California, Australia and Spain. From the vast distances of Uranus and Neptune, however, the spacecraft radio signals reaching Earth are so weak that more and bigger antennas must be included.

When Voyager 2 visited Uranus in 1986, the DSN station in Canberra, Australia, was electronically linked with Australia's Parkes Radio Telescope, producing in effect a single, much larger instrument. The Neptune encounter will take place about 50 percent farther from Earth – 2.75 billion miles compared with 1.84 billion – with the spacecraft's messages rendered less than half as strong by the time they get home. Therefore, the network is being augmented still further, with the coordination of Jet Propulsion Laboratory in Pasadena, Calif., into the most sensitive array of antennas ever combined for an interplanetary mission.

The main dish at each DSN station has been enlarged from 210 feet in diameter to 230, increasing its area by about one-fifth, and all three have been coupled at their sites with smaller dishes 113 feet across. The Parkes telescope again will be connected to the Australian station, and this time the Goldstone DSN facility in California will be hooked up with the National Radio Astronomy Observatory's Very Large Array (VLA), a spectacular expanse of 27 linked dish-antennas spread across the desert west of Socorro, N.M.

Together, the components of this hopped-up DSN will allow Voyager 2 to send back its data from Neptune as efficiently as it did from Uranus. According to VLA Project Engineer William D. Brundage, in charge of the facility's Voyager preparations, this will allow the spacecraft to send back the equivalent of about 220 "full-frame" photos per day (pictures occupy most of Voyager's "data stream"), instead of the roughly 100 NASA could receive without DSN enhancement.

Neptune is currently the solar system's most distant planet because Pluto's more elliptical orbit will keep it closer to the sun until 1999.

The VLA's astronomers are getting more out of the arrangement than just a role in the Neptune flyby, which would otherwise offer little more than the prospect of suspending a busy schedule of other observations for most of next August. Voyager 2 will make its closest approach to the planet on Aug. 25.

The spacecraft transmits over a range of radio frequencies called the X-band, whose 3.6-centimeter wavelengths the VLA was never before equipped to monitor. NASA, however, has provided $6.5 million to equip the VLA's dishes with specially designed X-band receivers. Two dozen have been installed; the other three (plus a spare) should be in place by the end of this year. And gearing up for Neptune is already paying off in totally unrelated research.

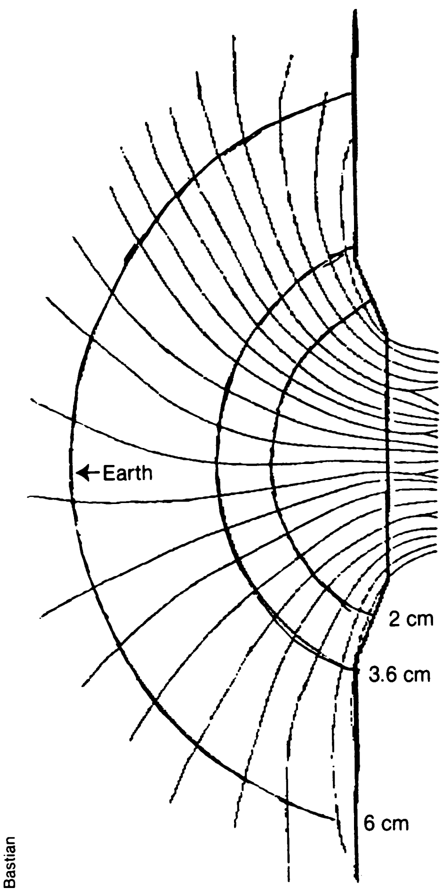
The big array is not at its best when studying the sun, for example, because the sun is so "radio bright" that it almost drowns out most of the electronic signal generators built into the VLA's receivers to calibrate their data. Before the facility agreed to join the Neptune network, only four of its receivers had strong enough "calibration sources" to do solar studies. But the new X-band receivers all have them.

The ability to monitor the sun's X-band output provides a chance to study different levels in the chromosphere, the region just above the bright photosphere that radiates most of the sun's visible light. In studying the structure of sunspots, notes the VLA's Tim Bastian, the facility heretofore listened primarily to the 2-cm radio waves of what is called the U-band, originating near the bottom of the chromosphere, and to the 6-cm (C-band) emissions from the top. Together, they show differences in the structure of the sun's magnetic field lines, which sometimes spread outward and upward into huge loops, made spectacular in photographs by the hot, ionized plasma that follows along them.

However, the X-band receivers, first tried out with the sun in April, have now provided a chance to monitor emissions from the chromosphere's middle layer. Combined with the two other bands, the result has been what amounts to three-dimensional maps of a sunspot's structure, showing its depth, temperature and plasma density.

Furthermore, says Joan Schmelz of Applied Research Corp. in Landover, Md., the VLA will play a key role this month in the International Solar Month. This elaborate plan involves coordinated observations of the sun using the facilities – on the ground and in orbit – of at least 13 countries, including the United States and Soviet Union (SN: 8/27/88, p.134).

The VLA's new receivers, besides giving it a formerly unavailable wavelength, are also the most sensitive it has ever had



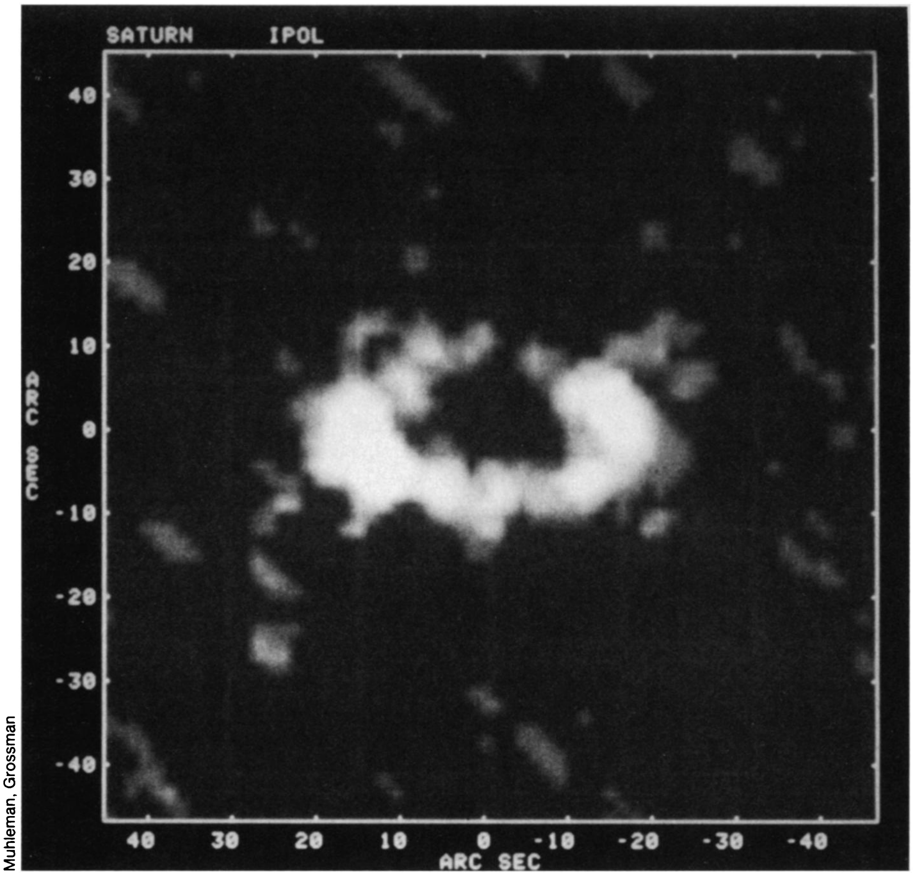
Bastian

Mapping the depths of a sunspot. Heavy line represents the sun's visible surface, or photosphere, with magnetic field lines fanning out from it. Semicircular contours are levels of different constant field strengths, producing radio emissions of different wavelengths: 2-cm waves from the inner chromosphere, 3.6-cm waves from the middle and 6-cm waves from the top.

in any part of the spectrum, with only a minimum of noise or static. This enables astronomers to observe fainter or more distant objects, and lets them record images more quickly – a significant improvement for an observatory whose observing time is at a premium.

The receivers' sensitivity also represents the equivalent of a faster shutter on a camera. While that usually means less-blurred pictures of moving objects to a photographer, for a radio astronomer it can mean the ability to study radio sources that vary rapidly in intensity or quickly change in shape – changes that might otherwise go undetected.

One advantage the VLA never had before its grooming for the "Neptune network" is the ability to take part in "radar astronomy" – picking up radar beams sent from Earth to bounce off the surfaces of other planets. Despite its sophisticated receivers, the array cannot transmit anything. So it cannot send out the radar signals for whose echoes it is such a good listener. Now the transmitting can be done for the VLA by the Goldstone dish in California, which for years has compiled planetary radar maps of its own.



Radar map of the rings of Saturn shows their tilt as seen from Earth. The radar beam was sent from Goldstone in California to bounce off the rings and back to the VLA in New Mexico, where the image was formed. Made in June using 23 of the VLA dishes, the image shows no return from Saturn itself.

Planning for the Neptune network began in 1984, and work at the VLA started the following year. Scientists conducted the VLA's first radar experiment in June 1987. The target was not Neptune but the rings of Saturn, says Duane Muhleman of the California Institute of Technology in Pasadena, who worked on the project with Caltech graduate student Arie Grossman.

The result is not a photo, or even the sort of radar image a single dish antenna would make. Instead, it is a "synthesized" image, a term that usually describes the result of picking up the radar echoes with a single antenna that is moving, such as aboard some aircraft or satellites. In the VLA's case, in fact, the image is called *super*synthesized, since it incorporates not only the motion of the rotating Earth but also "synthetic apertures" formed by the distances between pairs of antennas.

Only nine of the 27 dishes were wired for X-band at the time and the array, whose antennas can be moved about on a Y pattern of rails, was then in its smallest configuration. This means that the three lines of dishes would fit in a circle a "mere" three-quarters of a mile across. (The largest of the VLA's standard configurations spans 26 miles.) The image resembled two bright spots where the rings, as projected against the sky, extend farthest from the sides of the planet, and are where the concentration of ring particles reflecting the radar beam is greatest. None of the echo is due to Saturn itself.

When the observation can be repeated with all 27 dishes taking part, says Muhleman, "we hope to be able to see effects in the radar echo that are due to some sort of coherence among the ring particles." Thus, astronomers may get a clearer picture of how particles are distributed within the rings.

A second planetary subject, tentatively scheduled to get its radar picture taken by the VLA/Goldstone team on Sept. 12, is Mars. "We have really big hopes for Mars," Muhleman says, even though it has been radar-mapped from Earth before. The huge antenna array offers room for the VLA to add significantly to such studies as global measurements of the planet's surface roughness.

In 1976, scientists peering at photos taken by the orbiting Viking spacecraft had carefully selected a place for the Viking 1 lander to touch down on the Fourth of July. But the site was rejected with only days remaining when radar measurements from Earth indicated the terrain there might be so rough the lander would crash. However, the radar data could not give a certain answer – nor could even today's VLA on such a critical question – so it was for reasons of safety-first conservatism rather than knowledge of inevitable doom that the site-selection team abandoned the goal of celebrating the United States' 200th anniversary of its independence in the New World with a landing on a new world. Two months later, in fact, Lander 2 settled to the surface with one of its three footpads on top of a rock, invisible in advance to either Mars-orbiting camera or Earth-based radar beam.

Another possible candidate for the VLA's new ability is Saturn's big moon Titan. Some researchers have proposed that Titan may be covered with an ocean of ethane, which would not freeze at Titan's temperatures. "Getting a radar echo from Titan is probably one of the most important things that radar astronomy can do," Muhleman says.

Venus is the smoothest thing planetary radar has looked at yet. If Titan should show a sharp, spike-like radar echo similar to what one would get from a smooth ball, it could be evidence of a Venus-like surface, Muhleman says, but he adds that a far more likely interpretation would be that the surface is liquid. This would be the first strong evidence for a liquid surface on any body in the solar system other than Earth.

These diverse additions to the VLA's activities – the planetary radar, the three-layered mapping of the sun's chromosphere, and so forth – have been possible only because a little spacecraft named Voyager 2 has been purring along on its way toward an unprecedented close look at Neptune, its last scheduled encounter in what will have been a 12-year career. Not bad for fringe-benefits. □