Saturn: Myriad moons and more

By the time Voyager 2 flew past Saturn last Aug. 25, photos and other data from the spacecraft, its Voyager 1 and Pioneer 11 predecessors and a number of earth-based telescopes had nearly doubled the number of moons known to be circling the planet. To the established nine had been added one tiny moonlet just outside Saturn's broad A-ring, two more bracketing the sometimes twisted strands of the F-ring, another pair periodically swapping leading and trailing roles in a mutual orbit, a satellite companion librating around one of the Lagrangian points in the orbit of Dione, and not one but two Lagrangian cohabitants in the path of Tethys. But not even 17 satellites are enough to tell the story of the complex family of Saturn.

This week, the preliminary report on the Voyager 2 encounter by the project's huge scientific team appeared in the Jan. 29 SCIENCE, suggesting the possibility of yet another addition to the list and raising the potential total to 18. And in the less than two months since the report went to press, additional analysis is now indicating that there could be as many as half a dozen more.

The possible 18th is inferred from measurements taken by Voyager 2's cosmic-ray detector, as the spacecraft crossed the orbit of Mimas. As Mimas moves along its orbit, it intercepts the omnipresent flow of passing electrons, leaving an electron-depleted wake that shows up as an "absorption feature" to counters in the detector. According to Caltech's R.E. Vogt and colleagues, Mimas's wake seems to show an additional "microabsorption feature," suggesting that "there is probably additional material, perhaps a small satellite, sharing the orbit of Mimas."

There is another sign in a single frame from one of the spacecraft's cameras, according to Stephen P. Synnott of Jet Propulsion Laboratory in Pasadena, site of the mission's control center. A single frame is not much to go on, he notes, adding that a precise orbit determination may require additional observations from earth. But there does appear to be an object in the vicinity of Mimas's orbit. Furthermore, a preliminary analysis suggests that it may not be in the same spot as the cause of the cosmic-ray detector's microabsorption feature. In other words, Mimas may have a pair of companions.

A photo each from Voyagers 1 and 2, Synnott says, appear also to indicate what may be a third companion in the orbit of Tethys. One conclusion from the limited data could be that the object is in a "horseshoe" orbit, changing in position relative to Tethys so that it is sometimes leading the larger satellite and sometimes trailing it. However, Synnott says, "I can't be sure both observations are of the same object," leaving the implication that Tethys may be sharing its orbit with as many as four other bodies.

Other photos from the spacecraft hold out additional tantalizing possibilities. One may be in the vicinity of Dione's Lagrangian companion, "Dione B." Another may be in an orbit between the paths of Tethys and Dione, and another between those of Dione and Rhea. The analyses are difficult with such limited data, and earth-based observations will clearly have a role to play, though that role may well turn out to include the addition of yet more moons to the burgeoning list.

The pinpoints and streaks of light in such photos, however, can reveal little about such moonlets beyond their sheer presence. The far greater number of scientists will be devoting their energies to studying Saturn's icy larger satellites, which have added an entire new category to the experience of planetologists. One of the most exotic is Enceladus, whose appearance is believed to have been significantly affected by the same sort of tidal heating that seems to drive the active volcanism of Jupiter's spectacular moon Io.

Voyager 1 only got close enough to Enceladus to indicate that it was unusually smooth. Voyager 2, however, revealed a wildly diverse terrain, ranging from heavily cratered areas to plains so smooth that some researchers believe that their resurfacing may still be going on. Now the Voyager images have been combined into a map (see p. 74) by the U.S. Geological Survey's Branch of Astrogeologic Studies in Flagstaff, Ariz., revealing a variegated appearance unmatched since the Voyagers' first close-ups of Jupiter's Ganymede.

At least five distinct terrain types can be identified on Enceladus, according to the Voyager imaging team. One shows craters, about 10 to 20 kilometers across, that seem "highly flattened" as though softened by internal heating. (The mere slumping of ice from its own weight, the researchers believe, would not affect features so small.) In another area, similarly sized craters do not seem flattened. A less-cratered region is inferred to represent a younger surface, while grooved regions and virtually crater-free plains add to the complexity. Such overt terrain variations could mean that Enceladus' tidal heating, far weaker than that of Io, has had greater or lesser consequences over different portions of the surface.

—J. Eberhart

Electron tunneling through a vacuum

Tunneling is one of the effects used by physicists to prove the principle of modern physics that a piece of matter is at the same time a packet of waves, the famous wave-particle duality. In the experiments, electrons—it's almost always electrons—approach a barrier, a very thin sliver of insulating material located between two electrodes. The electrons do not have the energy to surmount the barrier in the ordinary way, by burning out the insulator, yet some of them appear on the other side and the insulator remains intact.

This is tunneling, and it is explained by appealing to the properties of waves. If light, for instance, strikes an opaque surface, most of the wave will be reflected, but a small part will penetrate into the material. Generally the penetrating wave will be absorbed, but if the opaque substance is thin enough, some will get all the way through and there will be light on the other side of the barrier. In the wave mechanical analysis of quantum physics the wave equations that govern the behavior of electrons do the same thing. The presence of some of the electron wave on the far side of the barrier means that there is a finite probability that some electrons will appear there even though they don't have enough energy to burn their way through.

Tunneling may seem contrary to common sense, but it works. Tunneling junctions based on the principle are found in many practical devices. Tunneling through thin barriers of solid insulators was first demonstrated in 1957. Now, according to an announcement from IBM, tunneling has been demonstrated for the first time "unequivocably" with a vacuum rather than a solid insulator between the electrodes in the corporation's research laboratory in Zurich, Switzerland. The work is reported in the Jan. 15 APPLIED PHYSICS LETTERS by Gerd K. Binnig, Heinrich Rohrer, Christoph Gerber and Edmund Weibel of the Zurich Laboratory.

Tunneling with nothing for an insulator ought to be about the purest form from the point of view of the analysis — properties of the insulating substance don't have to be taken into account — but vacuum tunneling has been very difficult to demonstrate compared to that with solid insulators.

Precautions against vibration and other potential problems in the Zurich experiment started by placing the vacuum chamber that contains the experimental apparatus on a slab that is mounted on pneumatic buffers. Within the chamber the actual apparatus was levitated by magnetic forces so that it floated in the magnetic field without touching any solid object. Tunneling took place between a tungsten needle and a platinum plate.

In vacuum tunneling, the tunneling current is sensitive to minute changes in the surfaces of the electrodes. Since there is no solid insulator in the way, the effect can be used to study the physics and chemistry of such surfaces. The IBM announcement indicates that such determinations can be made to the fineness of a single layer of atoms adsorbed on the surface.

—D.E. Thomsen