High-Energy Summer for Astrophysics

With the well-known gamma-ray source at the center of our Milky Way galaxy suddenly flickering out, and with an otherwise obscure star in the constellation Cygnus suddenly producing an explosion of x-rays—both events coincidentally discovered on 22 May—the summer of 1989 has so far been a lively one for high-energy astrophysicists.

The discovery of the disappearing gamma rays came as something of a disappointment to University of California, San Diego, physicist James Matteson and his co-workers. On a 22 May balloon flight launched from Alice Springs, Australia, they flew a new gamma-ray spectrometer designed to pinpoint the galactic center emissions with unprecedented resolution. They found nothing above background.

On the other hand, even negative results can have their compensations. "This is a very exciting finding," declares Matteson. It provides yet another piece of evidence that stars and gas in the galactic center are being gobbled up by a huge black hole.

When the source is on, explains Matteson, it emits gamma rays at the 511-thousand-electron-volt (keV) energy of electron-positron annihilation. The positrons are presumably generated when a wandering star or clump of interstellar gas falls into the hole and says good-bye to the universe with a flash of thermonuclear radiation. Furthermore, the fact that the source has now flickered out—it flared in 1977 when it was first discovered, it vanished in 1980, and then flared again in 1988—is exactly what you would expect: if the gas supply is erratic, then the positrons will be erratic.

So, if the past is any guide, another clump of matter will eventually die and the 511-keV radiation will flare again. Until then, however, San Diego theorist Richard Lingenfelter is just as excited about the group's separate observation of gamma rays above the annihilation energy. "These hotter emissions come from the source that actually produced the positrons," he says. So a careful analysis could allow the researchers to look right at the monster in the middle, and perhaps come closer to answering a fundamental question: is it a galaxy-sized behemoth as big as a million times the mass of the sun, as some researchers have suggested? Or is it, as Lingenfelter suspects, just a baby of less than a thousand solar masses?

Meanwhile, even as the gamma-ray spectrometer was drifting over Australia, the Japanese Ginga x-ray satellite was detecting a flux of x-rays coming out of Cygnus. Ginga's angular resolution was not good enough to pinpoint the source. But on 26 May, astronomers Sumner G. Starrfield of Arizona State University and R. Mark Wagner of Ohio State University decided to take a quick look at the area during the last minutes of their observing run at the Lowell Observatory near Flagstaff, Arizona.

"I just saw it visually on the TV screen," says Wagner: fading rapidly into the dawn was a blip of light far brighter than anything recorded on the standard star charts in that position. The next night it was picked up again by the International Ultraviolet Explorer satellite, which made the identification certain. An obscure star known as V404 Cygni, located some 3000 to 4500 light-years from Earth, had suddenly brightened by a factor of about 2000.

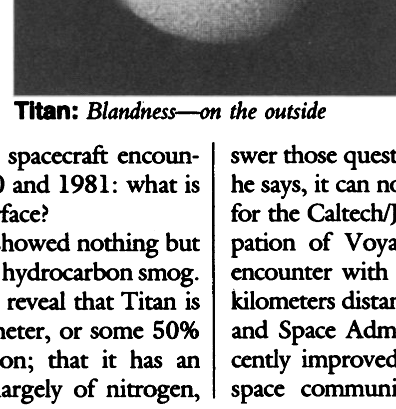
As it happens, says Wagner, this was not the first time for V404. Astronomers had noticed it going through a similar flare back in 1938. But that was before radio telescopes, x-ray satellites, and the like. This time around V404's outburst has triggered a fairly large campaign, he says. In addition to Ginga and the International Ultraviolet Explorer, it has been observed by optical telescopes, by the Very Large Array of radio telescopes, and most recently, by the gamma-ray detector aboard the Soviet Union's Mir space station.

"Flares like this are certainly not common," says Wagner. The last such "x-ray transient" was in 1975. The general idea is that V404 is a binary system in which a compact object—a neutron star, or perhaps even a black hole—is orbiting around a more or less normal star and occasionally pulling off globs of matter. The matter then plunges across the gap to strike the compact object with an explosive burst of radiation. But understanding the details will not be easy, says Wagner, not with the fast-fading x-ray signal jumping up and down by a factor of 10 or so on a time scale of seconds.

■ M. Mitchell Waldrop

Titan: Continents in a Hydrocarbon Sea

Breaking all distance records for interplanetary radio astronomy, researchers from the California Institute of Technology and Caltech's Jet Propulsion Laboratory have bounced radar signals off the cloud-wrapped surface of Saturn's giant moon Titan, 1.25 billion kilometers from Earth. Encoded in the echo, moreover, are hints of a surprisingly rich, if frigid, geography: at least one Titanian "continent" of ice, rock, and solid carbon dioxide seems to be rising out of a satellite-wide ocean of liquid hydrocarbons.


Jet Propulsion Laboratory

Titan: *Blandness—on the outside*

"The radar echo from Titan is the weakest such echo that has ever been measured," says Caltech planetary scientist Duane O. Muhleman, leader of the group. Nonetheless, it has yielded the first direct information on a mystery that survived even the Voyager spacecraft encounters with Saturn in 1980 and 1981: what is the nature of Titan's surface?

The Voyager images showed nothing but a smooth orange haze of hydrocarbon smog. Other Voyager data did reveal that Titan is 5150 kilometers in diameter, or some 50% larger than Earth's moon; that it has an atmosphere composed largely of nitrogen, with an admixture of hydrocarbons such as methane and ethane (the action of sunlight on these compounds is presumably what produces the smog); and that its surface conditions—a pressure 1.3 times that of Earth and a temperature of 94 K—are sufficient to trigger showers of ethane and methane rain.

From these findings it was only a short step to hypothesize a satellite-wide ocean of methane and ethane. Indeed, many scientists began to think of Titan as a remarkably Earth-like body, despite the chill. On the other hand, says Muhleman, no one could say how deep the Titanian ocean might be—a kilometer, perhaps?—or whether any dry land might rise above its surface.

But if the Voyager program failed to answer those questions on the first go-around, he says, it can now take some indirect credit for the Caltech/JPL radar success. In anticipation of Voyager 2's upcoming August encounter with Neptune, some 4.5 billion kilometers distant, the National Aeronautics and Space Administration (NASA) has recently improved the sensitivity of its deep space communications antenna in Goldstone, California, by expanding it from 64 meters in diameter to 70 meters in diameter. However, the same expansion that will help the antenna hear that distant whisper from Neptune also makes it into a more efficient transmitter. And with time to spare before Voyager 2's arrival, Muhleman and his co-workers took the opportunity to send 360 kilowatts of radio energy blasting toward Titan on three successive days: 3, 4, and 5 June 1989. That is a little more than seven times the power allowed to commercial radio stations. The researchers used the same 3.5-centimeter wavelength that Voyager does, and they transmitted continuously for 5.5 hours each day.

Meanwhile, NASA has also recently equipped the 27 antennas of the National Science Foundation's Very Large Array (VLA) near Socorro, New Mexico, to function as another giant receiver for Voyager 2 at Neptune. It was here, some 2.5 hours after each transmission began, that the team detected the infinitesimally faint radar echoes from Titan returning to Earth.

The result: in the first and last sessions Titan produced a very weak echo, consistent with reflection from a smooth, deep ocean. But in the 4 June session Titan returned a much stronger echo, reminiscent of radar reflections from the rocky surface of Venus. Since Titan rotates about 23 degrees each day, says Muhleman, each day's data sampled a different face of the satellite. "We concluded that these differences in reflectivity are real, and that we were seeing evidence for surface variability," he says.

The Caltech/JPL team is already planning a fresh round of observations for next summer, when Saturn will again be closest to Earth. By then NASA plans to have boosted the Goldstone antenna's power to 500 kilowatts. Moreover, the agency is considering boosting the power again to a full megawatt sometime in the early 1990s. And that means, in turn, that the researchers could begin to produce crude maps of Titan. The VLA's resolution at that distance is about one-fourth Titan's diameter. "With more signal to noise, we'll be better able to define where the continents and oceans are," says team member Martin Slade of JPL. "We can even be more definitive as to whether the surface is water ice, methane ice, solid carbon dioxide, or silicate rock."

Meanwhile, he says, these results strengthen the case for putting an imaging radar aboard JPL's proposed Cassini mission, which would orbit Saturn in the late 1990s and which could study Titan's surface in detail. "Would there be any point if it were just a global ocean?" he asks. "No." But now there appears to be something to see. ■ M. MITCHELL WALDROP

Sun-Powered Pollution Clean Up

Sunlight may not yet have lived up to its promise in generating cheap electricity, but scientists at Sandia National Laboratories have demonstrated a second potentially valuable use for it. A team headed by Craig Tyner has cleaned up polluted water with a sun-powered detoxification system.

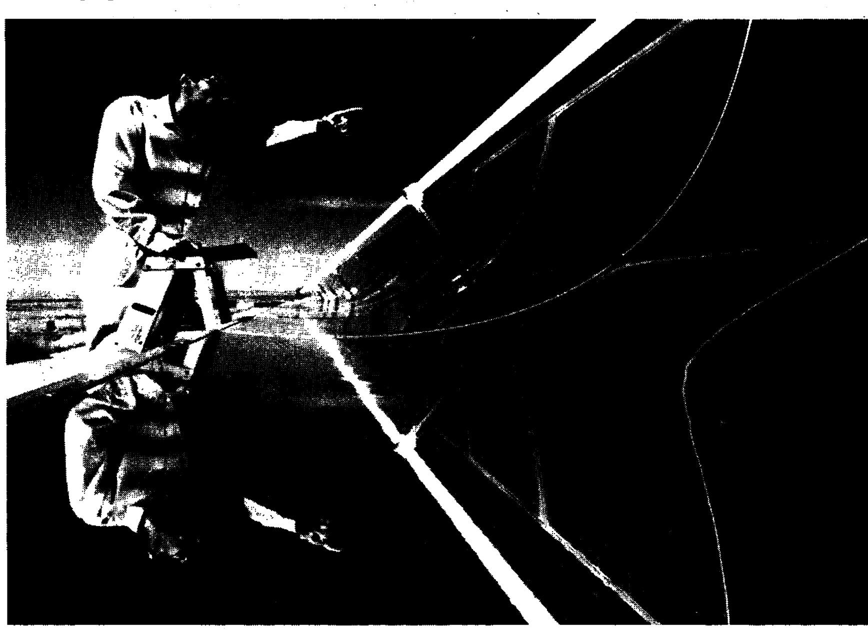
"We believe this process will destroy most organic materials," Tyner said; these include industrial solvents, pesticides, dioxins, PCBs, and munitions chemicals. He added that because the process breaks these toxic chemicals down into smaller, safer molecules, it offers an advantage over conventional waste disposal systems which do not destroy the waste products, but instead leave them still to be disposed of one way or another. (The two most common methods of removing organic wastes from water are bubbling air through the water in order to release the volatile chemicals into the air or running the water through carbon filters.)

In Sandia's solar-powered detoxification process, developed in cooperation with the Solar Energy Research Institute, grains of titanium dioxide are mixed into waste water and the mixture is run through a long glass tube, which sits at the focus of a 720-foot-long parabolic trough. When concentrated ultraviolet light from the sun hits the solution in the tube, it frees electrons from the titanium dioxide, creating electron "holes"—the absence of electrons. These holes combine with water, dissolved oxygen, and a small amount of hydrogen peroxide to create hydroxyl radicals and peroxide ions. These in turn attack the organic wastes, breaking them down into water, carbon dioxide, and some very dilute acids which can easily be neutralized.

The system cleans about 30 gallons of water a minute now, and Tyner said he expects to be able to increase that by a factor of 2 or 3. Initial tests were run on salicylic acid, a nonvolatile organic compound that is easy to work with and that has similar reaction rates to a number of the compounds the system is likely to be used on. The Sandia group has begun a second series of tests using trichloroethylene, a solvent used in electronics processing and one of the most common toxic organic pollutants.

Eventually, the system should be able to reduce the concentration of organic pollutants to a few parts in a billion, said Sandia engineer James Pacheco. At this level, the water would be suitable for drinking or discharging into lakes or rivers.

The successful detoxification signifies an engineering breakthrough rather than a scientific one, Tyner said, because the chemistry behind the reactions has been known for some time. "We have demonstrated that the process can work very well even on a large scale," he said. The ultimate commercial success of the process will depend on how economical the system is compared with other methods of removing organic pollutants from water, Tyner said, adding that so far cost analyses indicate it should stack up quite well. ■ ROBERT POOL



Sandia National Laboratories

Sandia scientist Jim Pacheco *in front of solar detoxification system.*