Puzzling Particle Showers Point to Pulsars

Bursts of mysterious, high-energy particles beamed from a distant star sound more like something Buck Rogers would encounter than the stuff of physics. Nevertheless, data from two sets of detectors at the Los Alamos (N.M.) National Laboratory show that the neutron star Hercules X-1, about 15,000 light-years away, is the source of surprisingly powerful pulses of what appear to be neutral particles. The discovery has led some physicists to speculate that the particles are of a previously unknown type or that gamma rays behave in unexpected ways at extremely high energies.

Hercules X-1, composed mainly of neutrons, is one member of a double-star, or binary, system. The dense remnant of a collapsed star, it packs the equivalent of the sun's mass into a sphere about 30 kilometers across. Such a system emits copious quantities of X-rays generated when matter spirals into the neutron star. As the star rotates, its X-ray beam sweeps the sky like a lighthouse beacon to produce the characteristic pulsed signal seen by Earth-based observers. In other physical processes, a neutron star may also produce beams of charged particles, especially protons, and electromagnetic radiation in the form of gamma rays.

As reported in the Oct. 24 PHYSICAL REVIEW LETTERS, the Los Alamos detectors record particle showers initiated in the upper atmosphere when particles or gamma rays from Hercules X-1 strike atoms in the air. Successive collisions create a cascade of subatomic particles — electrons, positrons, pions and muons — all the way to the ground.

The investigators, including Darragh E. Nagle of Los Alamos, Jordan A. Goodman of the University of Maryland in College Park and Guarang B. Yodh of the University of California, Irvine, focus on the number of muons created in the particle shower. The results show more muons produced than expected for incoming gamma rays. The signal is also too well-defined to be caused by protons, which would suffer the scrambling effects of the Earth's magnetic field. Other measurements indicate the incoming particles have an average energy of 200 quadrillion electron-volts, 1,000 times more than any accelerator on Earth can produce.

"If the beam is made up of particles, to come this far, the particles must be neutral, very stable and very light," says Nagle. "In addition, they must interact strongly with atmospheric particles." Neither gamma rays, as presently understood, nor protons fill the bill.

One possibility is that gamma rays, at sufficiently high energy, behave much more like particles than like waves, interacting significantly more strongly with atomic nuclei. The mystery particles may also be beams of unusual, massive neutrinos. Normally, neutrinos are thought to have little or no mass and readily pass through matter without any interactions. Alternatively, the particles may be new to physics.

"None of those alternatives are attractive to particle physicists," Nagle says. "They don't fit naturally into our present knowledge. It's a real puzzle."

The Los Alamos group delayed publishing its results until the measurements and calculations could be carefully checked. "We wanted to make the best possible assessment of the work's significance," Nagle says. The published results reflect data collected in 1986 — in particular, two 30-minute bursts recorded on July 24 that year.

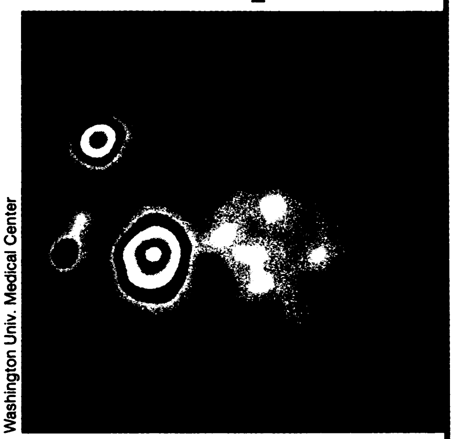
The Los Alamos results lend credence to other observations of anomalous bursts from pulsars. In 1983, Manfred Samorski and Wilhelm Stamm of West Germany's University of Kiel reported similar signals coming from the pulsar Cygnus X-3. Now, researchers are taking a closer look at a number of star systems known to be sources of peculiar emissions. "For Hercules X-1 and Cygnus X-3, we see only occasional emission episodes," Nagle says. "But there are other sources in the sky that may be completely steady."

At Los Alamos, the detectors are still busy, gathering data from Hercules X-1. Meanwhile, the research team is preparing to analyze data collected in 1987 — to see if any more light can be shed on the mysterious pulsar emissions.

— I. Peterson

PET scan spots breast-cancer receptors

Medical researchers see no shortage of applications for positron emission tomography (PET), the imaging technique that pinpoints with near-psychedelic artistry tiny biochemical targets in living patients. The procedure, mostly applied in the brain so far, can map the location of specific chemical receptors by illuminating — within one to two hours — the "parking places" of injected, radioactively labeled compounds.



Washington Univ. Medical Center

PET scan image of a horizontal "slice" through a breast cancer patient. Red-centered pattern (top) is the primary cancer. White-centered pattern is the liver, where the fluorine-18 estrogen analogue collects before being cleared from the body. The small green spot is a metastatic tumor in a lymph node.

Now scientists have designed a traceable, "hot" analogue of the female hormone estrogen that allows them to distinguish between the two major types of breast tumors — those with estrogen receptors and those without. The former are often responsive to relatively innocuous drugs that block the tumor-enhancing effects of estrogen. The latter require more aggressive treatment as soon as possible.

Until now, cancer specialists had no way of differentiating between the two tumor types *in vivo*. Researchers can measure estrogen-receptor densities on biopsied specimens. But with secondary, or metastatic, tumors often difficult to find or biopsy — and with many metastases lacking estrogen receptors even when the primary tumor may have many — months could pass before a physician finds that anti-estrogen therapy is not working.

Michael J. Welch and his colleagues at the Washington University School of Medicine in St. Louis and John A. Katzenellenbogen of the University of Illinois in Urbana-Champaign injected into 10 women diagnosed with breast cancer an estrogen analogue containing positron-emitting fluorine-18. As confirmed by laboratory tests on biopsied specimens, they correctly identified breast tumors with estrogen receptors as well as estrogen-receptor-rich metastatic tumors in the lymph nodes and the chest wall. Ongoing tests will tell whether PET data can predict the success of estrogen-blocking therapies, the researchers report in the October RADIOLOGY. *— R. Weiss*