[to be published in Mercury Magazine, May/June 2000 issue]

Invasion of the Giant X-ray Bubbles

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More bizarre news from the bizarre world of neutron stars: They got dozens of giant X-ray bubbles taller than the Empire State Building forming and popping every second.

Yet finding evidence of this bubble blowing was no childish endeavor. It took a team of Berkeley scientists just about all they could muster: three days' worth of observational data and 1,200 hours of number-crunching on the slickest of supercomputers at the Lawrence Livermore National Laboratory (LLNL).

Mind you, these are the same powerful computers used to model nuclear reactions and calculate Bill Gates' salary.

Neutron stars are already known as the bad boys of the cosmic neighborhood. They are the core remains of exploded stars, with a mass greater than our sun condensed into a sphere no bigger than Manhattan. A teaspoon of its densely-packed surface matter, the analogy goes, would weigh three billion tons back on earth. Its 10 trillion gauss magnetic field could wipe your credit card clean at a distance half-way to the moon. Its intense gravity lures gas from nearby stars, spinning the neutron star to speeds of up to a thousand times a second.

But giant X-ray bubbles dancing on the surface? That even freaked out the discoverers.

"Early on, I tended to disbelieve what the calculations were telling me," said Richard Klein, who splits his time between Berkeley and LLNL. "The bubbles 'appeared' and I wasn't convinced they were real."

What Klein and one of his Berkeley partners, Jonathan Arons, were trying to visualize was the effect of streams of gas striking the neutron star with the force of a billion hydrogen bombs exploding every second every square yard in a region only a few miles wide. That had to be making some kind of dent, they thought. Arons tinkered with calculations on paper and pencil as early as 20 years ago; Klein began plugging equations into a supercomputer 10 years ago. Slowly, a concept called "photon bubble oscillations" emerged from the numbers. These would be caused by X-ray photons so intense that they push matter away to form a cavity before bursting in less than a millisecond. The problem was finding an instrument capable of observing such rapid flashes of high-energy action so deep in space.

Enter J. Garrett Jernigan, an observational astronomer familiar with NASA's Rossi X-ray Timing Explorer (RXTE). Jernigan told his Berkeley colleagues that RXTE specialized in capturing X-ray flashes. He then recommended that a good place to start the X-ray bubble hunt was a neutron star called Centaurus X-3, a tiny thing only 13 miles in diameter and nearly 30,000 light-years away.

Centaurus X-3 is part of a binary star system, and it bullies its companion star by stealing blobs of its gas. This gas, captured by Centaurus X-3's extreme gravity and channeled by intense magnetic fields onto its polar caps, moves at one-third the speed of light and glows in X rays. We, on earth, see what seem to be pulses of X rays from the polar regions as the neutron star spins -- every 4.8 seconds in the case of Centaurus X-3, making this neutron star an X-ray pulsar as well.

RXTE saw bubbles popping on Centaurus X-3. Strong surface pressure from X-ray radiation was pushing infalling matter aside, poking holes in the matter and creating empty bubbles that fill with 100 million degree X-rays. These cavities appear only on the poles, a region about the size of midtown Manhattan. The sausage-shaped bubbles themselves rise up higher than the tallest of skyscrapers and wiggle, bob and burst in less than a New York minute -- about 2000th of a second. The scene is like an ever-changing skyline of mile-high buildings.

Klein said that X-ray bubbles form on the majority of neutron stars that are X-ray pulsars, of which there are scores in our galaxy alone. If the bubble theory holds up, the Centaurus X-3 finding would mark the first time scientists have "seen" the surface of a neutron star -- and not the stream of matter falling onto it from way above, stretching all the way back to the companion star.

Of course, no one has really seen the dancing bubbles nor the neutron star surface. RXTE data take the form of cycles of X-ray intensity. The X-ray bubble hunters simply concluded that variations in X-ray signals that they observed from the polar regions (which are actually a blending of the two indecipherable poles) are caused by surface physics and not by the physics of the flow of infalling matter. The team spent a year refining the math on the Centaurus X-3 observation and published its second bubble paper this March in Astrophysical Journal.

Klein is now shopping around for other neutron star bubble candidates, ones in which RXTE can get a long, continuous look of particularly bright X rays. To date, there has been no published scientific refutation or confirmation of the team's observations or theoretical calculations. So for now, it seems, the only absolute confirmation of high-speed bubble action will be from a well-shaken can of soda pop.

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