ASTRONOMY

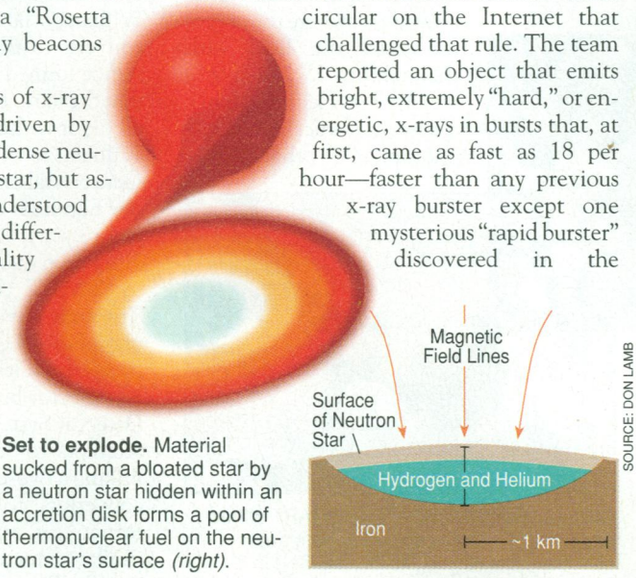
A Split-Personality X-ray Beacon Tantalizes Theorists

X-ray astronomers are burning the candle at both ends these days, thanks to the appearance of a bizarre and brilliant x-ray emitter that is doing its own kind of double duty. The object, thousands of light-years away from Earth in the direction of the galactic center, is an unprecedented hybrid: the only known x-ray source that combines regular, oscillating emissions like those recorded from some sources with the erratic flashes seen from others. Since the object was first reported on the World Wide Web last December, the puzzle has had theorists up nights, pondering what Paul C. Joss of the Massachusetts Institute of Technology calls a "Rosetta stone" of the powerful x-ray beacons that dot the galaxy.

Both of the known kinds of x-ray sources are thought to be driven by material falling onto a superdense neutron star from a companion star, but astrophysicists thought they understood why their characters are so different. The new split-personality object, first seen on 2 December by the Burst and Transient Source Experiment on the orbiting Compton Gamma Ray Observatory (GRO), is shaking up that understanding. It is triggering a flood of new theoretical models, among them an audacious early candidate from Don Lamb of the University of Chicago, who invokes a new kind of interplay between the infalling material and the neutron star's magnetic field. If it's right, the model could throw fresh light on how magnetic fields shape the personalities of dozens of other known x-ray sources.

According to current theory, what determines whether an x-ray source pulses or bursts is how the material makes its final plunge onto the neutron star. In x-ray pulsars, the neutron star has a powerful magnetic field that forces the material to trickle in through a funnel of field lines onto the neutron star's magnetic poles, where the release of gravitational energy heats the material enough to stoke steady thermonuclear burning. The x-rays emitted from the hot gas seem to pulsate because the neutron star rotates, periodically turning the hot spots toward Earth. In bursters, in contrast, the neutron star has a weaker field that allows cooler material to settle onto its entire surface until the accreted material becomes deep enough to set off a vast thermonuclear explosion.

In this picture, pulsing and bursting "could never happen together in the same source," says Lamb. Late last year, however, a team including Gerald Fishman and Chryssa Kouveliotou of the National Aeronautics and Space Administration's (NASA's) Marshall Space Flight Center, Jan van Paradijs of the University of Alabama, Huntsville, and the University of Amsterdam, and Walter Lewin of the Massachusetts Institute of Technology issued an International Astronomical Union circular on the Internet that challenged that rule. The team reported an object that emits bright, extremely "hard," or energetic, x-rays in bursts that, at first, came as fast as 18 per hour—faster than any previous x-ray burster except one mysterious "rapid burster" discovered in the 1970s. Underlying the bursts, Kouveliotou later showed, is a steady background signal that pulses twice a second. (A paper by Kouveliotou *et al.* announcing the discovery is in press at *Nature*.)



Set to explode. Material sucked from a bloated star by a neutron star hidden within an accretion disk forms a pool of thermonuclear fuel on the neutron star's surface *(right)*.

This combined behavior "is unlike that previously seen from any x-ray or gamma-ray transient source," Fishman and his colleagues reported in the circular. "We've seen some [x-ray] sources that play the trumpet, and some the drums, and a few the piano," says Fred Lamb, an astrophysicist at the University of Illinois, Urbana-Champaign, and Don Lamb's twin brother. "But this is a one-man band." Both GRO and the new X-ray Timing Explorer satellite (XTE), launched on 30 December, are keeping an eye on the object, which is now bursting about once an hour. "If we get some more details about it, we should be able to pin down [the theoretical] models," says XTE project scientist Jean Swank of NASA's Goddard Space Flight Center.

There will be plenty of models to pin down, starting with Don Lamb's, which he, Coleman Miller at Chicago, and Ron Taam at Northwestern University describe in a paper submitted to *Astrophysical Journal Letters*. Their starting point is the standard picture of an x-ray source, in which the neutron star strips away the outer layers of its bloated companion and draws them into an accretion disk around the neutron star. From there the material drops onto the neutron star itself. The group proposes that like an x-ray pulsar, this neutron star has a powerful magnetic field that funnels the material onto a small spot on the surface, which would explain the oscillating background signal.

To explain the other part of the object's split personality, its erratic outbursts, Lamb and his colleagues invoke a magnetic field several times stronger than that of a typical pulsar—a whopping 2×10^{13} times stronger than Earth's magnetic field. As Joss and his colleagues have noted for other neutron stars, such a field would force electrons in the infalling material to spiral around the field lines in orbits so tight that, like electrons in an atom, they can only take on certain discrete energies. The effect would limit the electrons' ability to intercept photons and other particles, allowing both photons and electrons to flee the hot spot and cool it. Providing the neutron star itself is old and cool, a deepening pool of unburned fusion fuel could build up.

Finally, says Don Lamb, the terrific pressure at the pool's bottom rises beyond some critical value, and "it will suddenly run away and you get a tremendous thermonuclear explosion." The model, he says, predicts both the hardness of the spectrum and the rapidity of the bursts. "It's a two-fer."

Other theorists trying to explain the object accept the general picture of a red giant being stripped bare by a neutron star. But that's where the agreement ends. "He's come up with a plausible argument," says Joss, but he points out that the rapid escape of heat could actually inhibit the outbursts, reducing them to fizzles. Joss's "gut feeling" leads him to an explanation based on more conventional physics. He speculates that something closer to an unsteady "drip" from the accretion disk—a model proposed for the rapid burster—might be at work. And Fred Lamb says, "I've put my money on another horse"—an explanation, in press in *Nature*, that he and his students plan to announce at a NASA press conference next week.

For now, says Joss, the only sure thing is that "it's a very mysterious object" and that explaining it could "tell us something important about what distinguishes these classes of sources." Doing so could also let theorists finally get a good night's rest.

–James Glanz