Cygnus X-3: Missing link to binary pulsars?

Astronomers call Cygnus X-3 one of the most bizarre objects in the heavens. From this pair of stars come not only some of the most luminous X-rays in our galaxy, but also jets of radio waves and brilliant infrared light. These emissions led researchers years ago to identify one member of the duo as a burned-out, superdense star called a neutron star. That star uses gravity to steal mass from its partner, which lies hidden behind layers of dust. Though they had never seen the companion, scientists reasoned that it must have a low mass since it whips around the neutron star every 4.8 hours.

But new infrared observations have pierced the dusty shroud and suggest that the companion is actually a massive star orbiting close to the neutron star — two features that appear to make Cygnus X-3 the missing link to a type of stellar object whose origin has puzzled scientists since their discovery more than a decade ago.

These objects belong to a class of stars called binary pulsars. These rotating double stars beam radio waves — observed from Earth as flashes — tens of times a second. In common with Cygnus X-3 and other X-ray-emitting binary stars, binary pulsars contain a neutron star that pulls mass off an orbiting companion. But unlike X-ray binaries, the companion is another neutron star, orbiting close to its partner.

Scientists had speculated that some X-ray binaries could spawn binary pulsars — if they possessed a closely orbiting companion star at least eight times as massive as the sun. Such a star could eventually explode as a supernova, leaving behind a young neutron star that lies near its older neutron partner. But that scenario seemed to harbor a fatal flaw: None of the X-ray binaries observed for the past 20 years had a companion both massive enough and close enough to its partner.

Last June, Marten H. van Kerkwijk of the University of Amsterdam in the Netherlands decided it was time for a new set of observations. He asked Philip A. Charles and his colleagues at the Royal Greenwich Observatory in the Canary Islands, Spain, to study the infrared spectra of the X-ray binary. Using the 4.2-meter William Herschel Telescope and a new, large-format infrared detector, the researchers found that helium alone accounted for the surprisingly intense infrared emissions from Cygnus X-3.

Those spectra seemed odd, since most stars contain far more hydrogen than helium, Charles notes. But the patterns of light emission, which appear to have come from the vicinity of the companion, do match those of an unusual group of stars known as Wolf-Rayet stars, he says. Internal heat from these objects forms a huge surface wind that blows off their outer envelopes of hydrogen, leaving cores of pure helium.

Moreover, Wolf-Rayet stars are massive. On the basis of these observations, as well as studies with the U.K. Infrared Telescope atop Mauna Kea in Hawaii, Charles and his colleagues assert that the companion star in Cygnus X-3 has a mass about 10 times that of the sun. They report their work in the Feb. 20 NATURE.

Researchers already knew from its period that the companion star lies close to its neutron star partner. Combined with the new mass estimate, this suggests that Cygnus X-3 is the first known star system likely to form a binary pulsar, Charles says. Noting that Wolf-Rayet stars survive for an astronomically short 50,000 to 100,000 years, he speculates that "we're seeing a star [the companion] that is right in the middle of a fairly precarious piece of evolution."

In a commentary accompanying the NATURE article, Peter S. Conti of the Joint Institute for Laboratory Astrophysics in Boulder, Colo., says he believes the companion has a mass lower than that estimated by the researchers but within the range required for Cygnus to form a binary pulsar. The work may also shed new light on the violent nature of Wolf-Rayet stars, he adds.

A study conducted by Victoria M. Kaspi of Princeton University and her colleagues may provide an even earlier link to binary pulsars. She and her co-workers discovered a massive young star, called a Be star, orbiting a radio pulsar. Since Be stars can evolve into Wolf-Rayet stars, the finding suggests that the Be-pulsar system represents an even earlier precursor of binary pulsars than Cygnus X-3. Kaspi reported the work in January at a meeting of the American Astronomical Society in Atlanta.

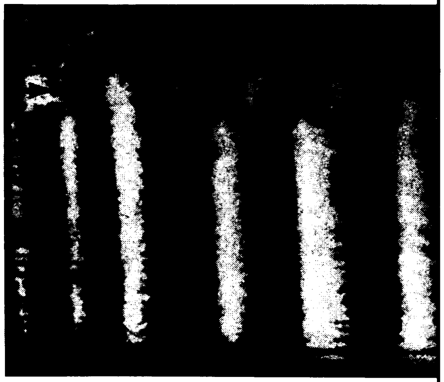
— R. Cowen

Magnetic tip sees fine detail, lost data

If you need more memory in your computer, or if you think computer programs that retrieve lost data files and "fix" bad disks work miracles, then you'll really like this new application of scanning tunneling microscopy (STM).

Scientists typically use STM to get atomic-scale images of the surfaces of materials. These researchers use a very fine metal tip to scan a surface. Variations in the current created as electrons hop the varying distances between the tip and the surface enable them to map the material's topography.

Two years ago, John Moreland and Paul Rice of the National Institute of Standards and Technology (NIST) in Boulder, Colo., reported that they could measure variations in magnetic force across a surface by replacing the standard metal STM tip with a flexible, magnetic one. The new tip allows scientists to see these variations more easily and in much finer detail than they would with other imaging techniques, says physicist Romel D. Gomez. In the Feb. 16 APPLIED PHYSICS LETTERS, Gomez and his colleagues at the University of Maryland in College Park detail the theoretical underpinnings of magnetic-force STM and say they have improved the resolution by tilting the tip as it scans.



Gomez/Univ. of Maryland

Created with magnetic-force STM, this image of a computer disk drive shows the magnetic pattern of "erased" data (arrow) as well as currently stored information.

"The theory tells you that the image you get is directly the field that you see on the surface," Gomez says. The tip moves closer to or farther from the surface depending on the strength and direction of the surface's magnetic field at any given point. That distance alters the current between the tip and the surface, so the hills and valleys in the resulting image show in submicron detail how the magnetic field changes.

"It's a much more sensitive way of reading magnetic domains, which will allow us to have very high-density computers," Gomez adds.

A computer stores information on hard disks by creating microscopic patterns of magnetization on the disk. When it erases or writes over data, the computer covers the old magnetization pattern with a new one. Under the magnetic STM tip, this pattern shows up with greater resolution than a computer can read, says Gomez. In addition, the magnetic tip can "read between the lines," detecting old patterns of magnetization — erased data — as well.

NIST has a patent pending for using this technique to image and alter magnetization patterns on surfaces.

— E. Pennisi