ment, including a seismometer and a telemetered Global Positioning System (GPS) receiver, into the sparsely instrumented region as the winter's snow recedes. GPS should tell them within a few months whether a rapid uplift is continuing. If it is, they'll want to be ready should any of the Three Sisters or their relations awaken.

–RICHARD A. KERR

ASTROPHYSICS

Star-Cluster Census Shows Surprises

The ancient balls of stars known as globular clusters are a favorite place for astronomers to test ideas of stellar evolution. Born in the dark ages before our own sun, globular clusters contain many old, heavy stars concentrated at their cores. Those central regions are so star-rich that near-collisions abound, and heavy stars frequently grab companions to form binary star systems that can reveal crucial information about the history and destiny of the cluster.

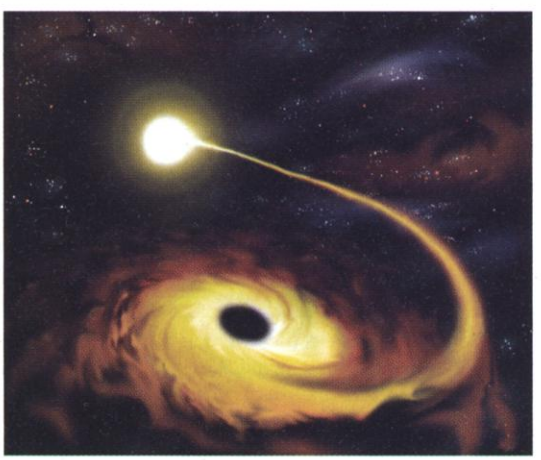
Astrophysicists trying to understand the intricacies of the globular heart have a new weapon: the Chandra X-ray Observatory, uniquely equipped to spot the x-rays emitted by many of the core's inhabitants. Past x-ray studies revealed little more than a flecked smudge compared with new results reported online by *Science* this week (www.sciencexpress.org) from a team at the Harvard-Smithsonian Center for Astrophysics (CfA), which has used Chandra to produce a sharp, color-coded x-ray map of a core.

"It is a big step in x-ray astronomy to have actually resolved what is happening in the middle of a globular cluster," says Andrew Fabian of the Institute of Astronomy in Cambridge, United Kingdom. Although radio astronomers and the Hubble Space Telescope have uncovered many secrets of cluster cores, resolving individual x-ray sources and their energies is something new, Fabian says.

The cluster, known as 47 Tucanae, is one of about 150 globular clusters sprinkled through our galaxy. The million or so stars in each are made of the material from which our galaxy grew. Because stars in a cluster all formed at about the same time and are all at about the same distance from Earth, globular clusters are a perfect space lab for astrophysicists to study how stars mature as they age. Heavier stars, more than eight times the mass of our own sun, have collapsed via a cosmic firework display—a supernova—into neutron stars. Many lighter cluster residents, their fuel likewise exhausted, have crumpled under their own weight to form white dwarfs.

But stars in clusters don't merely grow old; they also learn to tango. "Clusters are so incredibly dense in their cores that stars are, in the everyday vernacular, nearly smacking into each other," says Jonathan Grindlay of CfA, who led the new study. As a result, he says, "globular clusters are binary factories," creating new double stars or swapping partners in existing binaries even today.

In a typical binary pair, a small, dense partner—a neutron star or white dwarf—sucks material from its larger but less massive companion. As this accreted material crashes into the smaller star, it heats up, emitting x-rays. Different types of x-ray emitters have distinct x-ray signatures, but only Chandra has both the crisp vision and energy discrimination to pick out and label individual sources. As a result, it can provide information about neutron stars and accreting white dwarfs that has been "sorely lacking," says astrophysicist Sterl Phinney of the California Institute of Technology in Pasadena.



Round numbers. An inventory of x-ray sources in globular cluster 47 Tucanae (*top*) casts doubt on a suspected link between x-ray binaries (*bottom*) and millisecond pulsars.

Grindlay and his collaborators, Craig Heinke, Peter Edmonds, and Stephen Murray, set out to use Chandra to survey the relative numbers of x-ray sources in the well-studied globular cluster 47 Tucanae—"everyone's favorite globular cluster," according to Phinney. In the central core of the cluster alone, they picked out 108 distinct x-ray sources. By setting out the whole sample on an intensity-color diagram—an x-ray analog of the brightness-color diagram that optical-light astronomers use to classify stars—they claim to be able to estimate the relative numbers of four different types of x-ray sources in the cluster's core. About half are millisecond pulsars (MSPs), in which the x-ray pulse, with a period of just a few milliseconds, comes from a neutron star that spins madly after gobbling mass from its ordinary-star companion. About 30% are accreting white dwarfs, also dubbed cataclysmic variables, which are binaries comprising a white dwarf and an ordinary star. Some 15% are pairs of ordinary stars, while just two or three are what's termed quiescent low-mass x-ray binary (LMXB) stars, neutron star–ordinary star combos that accrete slowly and brighten up at intervals.

The sheer number of neutron stars "is really a bit of a surprise," Grindlay says. Those plentiful neutron stars derive from heavy stars, but astrophysicists expect that clusters should contain many more lightweight stars than heavy ones. Not only that, but neutron stars, freshly forged in a supernova inferno, travel at speeds of several hundred kilometers per second—so fast that they should just "zip out" of a cluster, Grindlay says. But Fabian thinks the problem may be an illusion. Relatively lightweight white dwarfs may well outnumber neutron stars in the cluster, he says. But because they emit few x-rays and don't form pulsars, the x-ray census may simply have undercounted them.

Another mystery is why MSPs so vastly outnumber the handful of LMXBs. Independent evidence suggests that MSPs are the children of quiescent LMXBs, and many astrophysicists believe such transformations can run backward as well. If so, the population of MSPs and LMXBs should show a delicate balance, Grindlay explains—a balance that Chandra does not see. The new results instead support alternative routes for the creation of MSPs, Grindlay says. Perhaps the pulsars result from the direct collapse of accreting white dwarfs. Or perhaps—as Fred Rasio and Saul Rappaport of the Massachusetts Institute of Technology have suggested—LMXBs made a one-way transformation into MSPs long, long ago. In any case, astrophysicists agree that puzzles, at least, are one thing 47 Tucanae is likely to keep producing in abundance.

–ANDREW WATSON

Andrew Watson writes from Norwich, U.K.

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