Physics

Ivars Peterson reports from Baltimore at a meeting of the American Physical Society

A surfeit of millisecond pulsars

Finding a millisecond pulsar — a rapidly spinning neutron star — is about as difficult as locating the proverbial needle in a celestial haystack. Nevertheless, recent systematic searches have uncovered nearly a dozen of these faint objects within the Milky Way galaxy and in associated concentrations of stars known as globular clusters. These few, fast-spinning pulsars represent only a tiny fraction of the thousands likely to be found in globular clusters, says astronomer Ramesh Narayan of the University of Arizona in Tucson. Narayan and his collaborators base their estimate on a statistical study of which pulsars are likely to be discovered first.

Of the nearly 500 pulsars now known, millisecond pulsars represent a special class. These stars spin so rapidly — with periods ranging from 1.6 milliseconds to tens of milliseconds — that astronomers suspect they achieved their high spin rates by gravitationally stealing matter from nearby companion stars. Such a transfer of matter typically would be marked by the emission of X-rays. When the X-ray emissions eventually cease, the neutron star, now spinning much faster than at earlier stages of its life, would presumably begin sending out radio waves again. Astronomers have identified nearly 100 bright X-ray sources that may end up as "recycled" pulsars.

However, whereas conventional theory suggests that the number of millisecond pulsars and X-ray sources should be approximately equal, Narayan's population estimates indicate 100 times more pulsars than X-ray sources. "There are too many pulsars and not enough X-ray sources," he says.

One way out of the discrepancy is to say that only a small fraction of the recycled pulsars come from bright X-ray sources. For example, the collapse of a star in a supernova may itself produce a millisecond pulsar. A not-yet-confirmed observation that supernova 1987A produced a pulsar with a period of only 0.5 millisecond supports this scenario (SN: 2/18/89, p.100). However, astronomers at Columbia University in New York City contend the observed flashes from 1987A may actually represent rapid vibrations of a slowly spinning neutron star.

Another possibility is that X-ray sources that become pulsars last only 10 million years, rather than 1 billion years as astronomers have assumed. Such a short life is possible if radiation from the vicinity of a neutron star heats the surface of its stellar companion, generating a "wind" that accelerates the companion's evaporation, says Columbia's Jacob Shaham (SN: 12/10/88, p.374). Previous theoretical models of binary X-ray systems assumed the stars interacted only gravitationally.

Out of the center: Gamma-ray redux

The center of the Milky Way galaxy, 25,000 light-years from Earth, is again producing large quantities of radiation in the form of gamma-rays of a specific energy, 511 kilo-electron volts. These emissions, detected by a sophisticated, balloon-borne gamma-ray telescope, result from collisions between electrons and positrons (the antimatter equivalent of electrons), which destroy the particles and generate gamma-rays. Scientists first detected positron annihilation from the galactic center in the 1970s, but the signals abruptly dimmed, then disappeared in the early 1980s (SN: 1/21/89, p.44). Such a sharp change indicates the radiation source must be compact.

Now, Marvin Leventhal of AT&T Bell Laboratories in Murray Hill, N.J., and Jeffrey E. McClintock of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., suggest the gamma-ray signals may be coming not from the galactic center but from an unusual X-ray source known as GX1 + 4, in the same region of the sky. The source appears to be a binary system consisting of a neutron star and a nearby red giant (SN: 7/2/88, p.6). Leventhal and McClintock note that changes in the intensity of X-ray emissions from GX1 + 4 appear to mimic the positron source's fluctuating behavior. Such a correlation suggests that GX1 + 4 itself may be the positron source.

New gamma-ray instruments that provide a narrower field of view would settle the question by pinpointing the source's true location, Leventhal says. Until that measurement is done, most astronomers still favor the presence of a black hole at the galactic center as the explanation for the gamma-rays.

SSC gets off to a magnetic start

Although Congress has yet to appropriate funds for starting construction of the Superconducting Super Collider (SSC), researchers have completed the first phase in the magnet development program. Last month, they demonstrated a full-scale magnet that meets the principal requirements for bending the paths of protons to follow the collider's ring geometry. The effort to develop a prototype took about four years.

In the collider, two beams of protons speed through pipes slightly more than an inch in diameter. Each pipe is surrounded by magnet coils made out of cables containing tens of thousands of superconducting niobium-titanium filaments, each filament about one-sixth the diameter of a human hair. The coils are chilled with liquid helium so that they can carry currents as large as 6,500 amperes without any energy loss.

In tests at Fermilab in Batavia, Ill., the prototype magnet operated successfully at 7,500 amperes, demonstrating that it could hold together even at magnetic forces greater than those needed to run the collider. "We have achieved the desired performance in one demonstration magnet," says Thomas B.W. Kirk of the SSC Central Design Group, based in Berkeley, Calif.

The next step involves working with industry to develop methods for manufacturing such magnets. About 8,000 magnets, each 55 feet long, will be needed for the main collider ring, which has a circumference of 53 miles.

Splotchy supernova shakes assumptions

The expanding shell of gas surrounding supernova 1987A is more likely to be lumpy or disk-like than a uniform sphere, says Scott Barthelmy of the NASA Goddard Space Flight Center in Greenbelt, Md. Until now, astronomers have always assumed in their theoretical models that the gas cloud from a supernova explosion has a spherical symmetry as it expands.

Barthelmy and his collaborators measured the gamma-rays given off by the radioactive decay of cobalt-56, which was synthesized in the supernova explosion. The standard model of a supernova explosion predicts that Earth-based observers should see only the gamma-rays coming from the Earth-facing side of the explosion. This forward motion would shift the emitted gamma-rays to a slightly shorter wavelength. Furthermore, because the gamma-rays should be coming from a narrow shell of gas, the range of wavelengths would be small, producing a sharp line in the gamma-ray spectrum. However, the researchers saw a wide spectral line and detected no shift to a shorter wavelength.

Two possible scenarios explain these results. In one, the expanding envelope of gas has broken up into fragments, allowing observers to detect gamma-ray emissions from both the front and the back of the gas cloud. "There may be tunnels and holes so that we can see all the way to the back side," Barthelmy says. Alternatively, the gaseous material may be flattened into a disk that's tilted with respect to the line of sight to the Earth. This would allow observers to detect gamma-rays emitted from material traveling toward or away from the Earth.

"By studying the shape of gamma-ray lines, we're learning a lot about the explosion itself," Barthelmy says. "Until these results, nobody had ever speculated that asymmetries [in the expanding gases] could show up at such an early age."