SCIENCE NEWS of the week

Pulsar Encounters of a Third Kind

There used to be two classes of pulsars, astronomical objects from which we receive sharply pulsed signals, the radio and X-ray varieties. Different theories explained the origin and behavior of each. Now there is a third class, a variety of radio pulsar with a theory that has some elements of both of the other two. The theory of the third kind has crystallized around and about the recent discovery of an ultrafast pulsar, the "millisecond" pulsar. (SN: 12/4/82, p. 357).

The millisecond pulsar gets its name from its radio pulse period, which is about 1.5 milliseconds, 20 times as fast as any other known radio pulsar. Cataloged as 1937+215, it was discovered through a sequence of observations led by Donald C. Backer of the University of California at Berkeley that culminated in early November 1982.

According to the standard theory of radio pulsars up to then, a radio pulsar is a rotating neutron star that emits radio waves from a spot on its surface. We receive a pulse every time the emitting spot comes across our line of sight. The neutron star is supposed to be the collapsed core of an ordinary star that has undergone a supernova explosion. In the collapse the rotation of the star is speeded up. (Decreasing the extent of a rotating body makes the rotation go faster, an effect that figure skaters like to use.) The neutron star is thus born with a rotation rate many times that of an ordinary star. As the neutron star emits energy from then on, however, its rotation rate (and so the signal pulse rate) slows down in proportion to the energy loss.

At first the discoverers of 1937+215 believed they had an extremely fast pulsar that was losing energy very fast. Their first measurement of the rate of increase of the pulse period (rate of slowing of the rotation) was 10^{-14} seconds per second, a large number in the context. A good deal of excitement was generated because it seemed that this energy must be going into gravitational waves. Observations of this pulsar might provide a direct confirmation of the existence of those waves, one of the last major predictions of Einstein's general relativity theory not yet adequately confirmed.

On Dec. 15, about a month after the discovery of 1937+215 was reported, the Texas Symposium on Relativistic Astrophysics meeting in Austin, Tex., devoted a session to what the session chairman, Peter Sutherland of McMaster University in Hamilton, Ontario, called "the fastest little pulsar in a Texas symposium." By then things had changed. Continuing observations had revised the figure for the slowing of the pulse rate downwards, drastically downwards. At the Texas Symposium, Backer reported that as of that date the rate was 1.26 x 10^{-19} seconds per second, about a hundred-thousandth of the first estimate. The problem now becomes how to explain a pulsar that spins so fast and hardly loses energy at all.

Andrew Chang of Rutgers University in New Brunswick, N.J., Jonathan Aarons of the University of California at Berkeley and Kenneth Brecher of Boston University provided contributions to a theory that would fit. Chang made the most basic point explicit: 1937+215 and the three radio pulsars already known to be in binary star systems form a separate class of pulsars. They are radio pulsars born in binary systems without a supernova explosion. The three other binary radio pulsars had been something of an embarrassment to the theory. A supernova explosion should blow a binary system apart, so it was hard to see how a pulsar could be made in a supernova and remain in a binary system.

In this new case, however, the pulsar is a compact object, still presumably a neutron star, formed by the nonexplosive collapse of a star, so the binary system can remain intact. It need not, however. Aarons points out a region of ionized hydrogen located in the sky about 100 seconds of arc north of 1937+215 that is a planetary nebula. A planetary nebula is another kind of object into which a superannuated star may develop, and Aarons suggests that this one and the millisecond pulsar are former binary companions that have just come apart.

While the binary system lasts, the increasingly strong gravity of the gestating pulsar draws matter from the companion star. This matter forms a disk, called an accretion disk, around the incipient pulsar. (X-ray pulsars are supposed to be made in binaries and have accretion disks, too.) Torque from the accretion disk tends to increase the radio pulsar's rotation rate even beyond what collapse alone will do, and that torque also tends to maintain the pulsar's rotation rate. Thus a high rotation rate can be achieved without the high magnetic field that comes with it in the supernova type collapse. It is the high magnetic field that produces a high rate of energy loss and thus in this scenario the pulsar's rate of energy loss comes out small. The millisecond pulsar is therefore not a very young pulsar, as the swift rotation and fast rate of energy loss would have suggested, but possibly quite an old pulsar that loses energy slowly.

This low rate of energy loss for 1937+215 has proved a disappointment to the physicists who search for gravitational waves. Robert Wagoner of Stanford University in Palo Alto, Calif., calculates that this pulsar would yield 1.6 x 10^{-27} signal amplitude units, far too small to detect. He hopes for the discovery of other, faster pulsars of this type, which might produce a higher rate.

While the excitement was on, however, one search for gravitational waves was actually made. Gravitational waves are gravity's analog to light and radio. They carry energy and they involve gravitational forces in ways analogous to the ways radio and light involve electric and magnetic forces. One plausible way to detect gravitational waves is by the minute vibrations they would excite in large, heavy metal bars.

There are several such gravitational-wave antenna bars in the world. The length of each such bar tunes it to a particular frequency of radiation, and the bandwidth on either side of the resonant frequency that a given bar will respond to is quite narrow. Nevertheless one bar, at the University of Glasgow in Scotland, happens to have the frequency of expected gravitational radiation from 1937+215, 1,283.8 hertz, within its range. Ronald Drever of the University of Glasgow and California Institute of Technology reported that he turned this antenna on for an eight-hour period from 8:00 p.m. Dec. 6 to 4:00 a.m. Dec. 7 to search for a possible signal from the pulsar. Nothing was found, and he concludes that any signal from the pulsar must be less than 8 x 10^{-20} units.

There is still hope for detection of gravitational waves from pulsars of this class. Drever points out that by using mirrors attached to heavy weights and monitoring their motion through the interference of laser beams reflected off them, "a particular trick on searching for periodic sources" can be played that could greatly increase sensitivity and put pulsars of this class in range after a few years' development of the detectors.

Very fast radio pulsars are also suspected of emitting pulses of visible light as well as radio pulses. The two next fastest, the Crab nebula pulsar and the Vela pulsar, do. The millisecond pulsar has been identified with a 22nd-magnitude visible star, and groups of astronomers at Kitt Peak National Observatory and the Mt. Wilson Observatory in Pasadena, Calif., have been looking for signs of pulsations in the visible output. So far, reports Carlton E. Pennypacker of the Lawrence Berkeley Laboratory in Berkeley, Calif., neither group has found any.

Observations of 1937+215 are now at a temporary halt. The pulsar is behind the sun and will not emerge to a favorable viewing position for about two months.

—D.E. Thomsen