Pulsars: a third class of star

Two years of observation yield some general agreement, but loose ends remain to be picked up

by Dietrick E. Thomsen

It is now almost two years since the discovery of the first pulsar was announced (SN: 3/16/68, p. 255). In that time a good deal of attention, both observational and theoretical, has been spent on pulsars.

Some thought pulsars—objects giving enormous, precisely spaced bursts of energy—would have to be neutron stars; some favored white dwarf stars. The pulses were variously attributed to pulsations of the neutron star or the white dwarf, rotation of a single body or rotation of two bodies with one periodically blocking the other.

At a recent meeting of the American Astronomical Society in New York the results of all the observations and theory were reviewed, and the review shows a consensus beginning to emerge, although there are still loose ends.

There now seems to be general agreement that in pulsars astronomers are dealing with what Dr. Martin Schwarzschild of Princeton University calls "a third fundamental class of stars: neutron stars," with a magnetic field exceeding that of any other known class of objects.

The other two fundamental classes are ordinary stars and white dwarfs. Ordinary stars are large, diffuse gaseous bodies that can be millions of kilometers in diameter—the sun is a small example of one. White dwarfs represent a contraction of such stars to a few thousand kilometers. Neutron stars, as predicted theoretically three decades ago, would be the most contracted of all: tens of kilometers across and with such high pressures in their interiors that almost nothing but closely packed neutrons exist there. No serious candidates for the title of neutron stars were found before pulsars.

The latest count shows 46 known pulsars, "all showing remarkably similar characteristics," says Dr. Frank Drake of Cornell University. "It is almost certain they are rotating," he says, "and there is a good case we are dealing with a neutron star with a magnetic field of a thousand billion gauss." (Earth's magnetic field, for comparison, is about half a gauss. Magnetic fields on the sun range from 1 to more than 50 gauss.)

The astronomers appear not only to have agreed on what a pulsar is, but to have established as well a bridge between two theories of how such a rotating magnetic neutron star could produce the observed radiation. The two have often been presented as rivals.

One comes from Prof. Thomas Gold of Cornell and is called the near-field theory because he believes that the pulsed radiation is generated near the surface of the neutron star. The source of the radiation, in this view, is the motion of electrically charged particles trapped by magnetic forces of the field surrounding the star.

The other theory, called the far-field theory, includes among its proponents Drs. Franco Pacini of the Laboratorio Astrofisica at Frascati, Italy, Jeremiah Ostriker and James E. Gunn of Princeton University and Peter Goldreich of California Institute of Technology. It sees the magnetic force lines surrounding the star skewed like the arms of a spiral galaxy. The skewing produces shock waves at some distance from the surface of the star, and the radiation comes from charged particles caught in these shock waves.

In both theories the signals are pulsed because emitting regions are carried across the line of sight by the star's rotation.

It is now becoming clear, says Dr. Drake, that the two theories are not really in conflict. "Both mechanisms could be operating and may be," he says. Prof. Gold's mechanism could operate in the skewed field, although it has often been presented wth the magnetic force lines running straight out from the star.

The "pulsed radiation is the frosting on the cake," Dr. Drake says; pulsars give off a great deal more energy by nonpulsed means than they do by the pulsed radiation. Dr. Drake suggests that the pulsed radiation may be produced by the mechanism of the near-field theory while the shock waves of the far-field theory account for some of the rest.

The heavy dissipation of energy is taken to be the reason that pulsar pulse rates are slowing down; energy loss slows the rotation and consequently the pulse rate, theorists assume. Most astronomers have thought that this slowing would go on until the pulsar stopped rotating, but Drs. Ostriker and Gunn propose that they shut off before they stop rotating.

Cornell

Drake: A good case for neutron stars.

"The average pulsar is about two million years old," says Dr. Ostriker. The rates at which their rotations are slowing down would give them much longer lifetimes than that, but very old ones are not seen among those currently known. Dr. Ostriker and Dr. Gunn suggest that something is turning them off.

They feel that a pulsar is a kind of electromagnet. Inside a neutron star there will be some charged particles, and these could form a current that generates the pulsar's magnetic field. Their conjecture is that if the interior of the neutron star is not a perfect conductor, at some time this current will run down. When it does, the magnetic field will go off and so will the pulsar's radiation.

Prof. Gold's theory connects the pulsar rotation rate to the kind of radiation that can be observed: radio only for the slower ones, light and X-ray possible for fast ones.

But in spite of concentrated searches, only one pulsar in light and X-ray is known, the one in the Crab nebula.

X-ray observations are still in a primitive state, says Dr. Herbert Friedman of the U.S. Naval Research Laboratory in Washington, D.C. There have only been about a half dozen X-ray observations of the Crab pulsar, he says, "and no observer has yet had a chance to do his thing a second time and do it better." There will thus be some further wait before detailed pulsar X-ray studies are available. □