(Berkeley) and Michael Davis (Arecibo) were granted seven nights of recording time at Arecibo. They quickly reconfirmed the 642-Hz pulsation with more sophisticated equipment, and they found that the pulse shape was quite stable. At a spin rate so close to the centrifugal breakup limit, Backer explained, one might have expected to see considerable rotational instability.

They also observed interstellar (as distinguished from interplanetary) twinkling, a clear indication that the pulsating source was smaller than one *micro*arcsecond. This interstellar scintillation, caused by minute-to-minute fluctuations in the interstellar medium, explained the erratic signal seen two months earlier.

From the small apparent difference between the September and early November data, the group deduced and reported a spindown rate of about 10^{-14} sec/sec. "This report of dP/dt in the first telegram, which I now regret, was premature," Backer concedes. As the group continued to record the signal from the object newly christened as PSR 1937 + 214, it became clear that the period was stable to at least one part in 10^{-6}, indicating[4] a much slower dP/dt.

In late November, Joseph Taylor (Princeton) joined the group at Arecibo with specialized equipment he had developed to measure the orbit decay of a binary star system by gravitational radiation (see PHYSICS TODAY, May 1979, page 19). With this equipment the group measured the period derivative of 1.26×10^{-19} sec/sec reported in December at Texas. The primary source of the considerable uncertainty remaining in this determination is the uncertainty in the position of the pulsar, which one needs in order to correct for the motion of the Earth.

In the usual scenario, a radio pulsar is born when a supernova explosion leaves behind a neutron star with sufficiently strong magnetic field and rapid spin. If the spin and magnetic axes are not aligned, one gets a "lighthouse effect." The collimated radiation from the acceleration of highly relativistic electrons emerging at the magnetic poles will appear as a pulsed radio signal to an observer in the cone swept out by the radio beam as it precesses about the spin axis. As it ages, the neutron star slows and its magnetic field decays. Eventually, after 10^7 or 10^8 years, it ceases to be a pulsar.

How then do we come to find a pulsar with an apparent age (determined by its slowing rate) of half a billion years spinning much faster than its juniors? Shaham and his colleagues Ali Alpar, Malvin Ruderman (both at Columbia) and Andrew Cheng (Rutgers) suggest that 1937 + 214 was once a slowly spinning, old neutron star with a relatively weak field of a few times 10^8 gauss and a low-mass, close binary partner. The transfer of material from the now departed, low-mass companion star, they argue, is responsible for spinning the neutron star up to pulsar speed. The accreting material forms a spinning disk around the neutron star, coupling to its corotating, plasma-filled magnetosphere. The weaker the magnetic field of the neutron star, they calculate, the smaller will be the inner radius of the accretion disk. The rotation speed of the disk material is simply given by Kepler's laws; the smaller the radius, the faster it rotates. If the inner edge of the accretion disk is spinning faster (slower) than the magnetosphere, it tends to spin the neutron star up (down). The weaker the field, therefore, the more the accretion of material from the binary partner will spin the neutron star up.

We are likely to see such accretion-generated ultrafast pulsars even if the phenomenon is quite rare, Ruderman told us, because they live so long; their anomalously weak magnetic fields dictate a very slow rate of energy loss. He points out that the few known examples of pulsars with living binary partners are among those with the weakest apparent magnetic fields. A plausible class of ancestors for the accretion-generated ultrafast pulsars, the Columbia group suggests, are the binary x-ray sources that one finds predominantly in the central bulge of our Galaxy. These are thought to be long-lived neutron stars generating continuous (non-pulsing) x-ray emission as they accrete matter from a lighter companion star with an orbital period of a few hours or days. Although these "bulge x-ray sources" can be seen from everywhere in the galaxy, the eventual pulsars would be visible only at distances up to a few kiloparsecs.

This scenario, in its broad outlines, is gaining acceptance among adherents of the "standard model" of pulsar behavior. Arons suggested a similar scheme, as do Andrew Fabian and his coworkers[5] at Cambridge and V. Radhakrishnan and G. Srinivasan[6] at the Raman Institute (Bangalore).

Curt Michel and Alex Dessler at Rice, however, have for several years dissented from the standard model, arguing that it does not deal adequately with the balance of positive and negative charge expelled by the corotating magnetosphere. To solve this "charge closure problem," they contend, one needs to invoke a fossil disk of material left over from the supernova explosion or the accretion from a binary partner. All radio and x-ray pulsars must have such Saturn-like disks, they contend.

The electromagnetic coupling of this fossil disk with the magnetosphere, they argue, is an essential ingredient of the mechanism by which the pulsar slows down. After the discovery of 1937 + 214, Michel and Dessler (now at the Marshall Space Flight Center) were quick to point out that the rate of energy loss in their model varies as P^{-3} in contrast to the P^{-4} dependence of the standard models, which do not assume the existence of fossil disks. Thus they claim to have a natural explanation for the "unexpectedly" slow rate of energy loss by ultrafast pulsars. The millisecond pulsar "is nothing special," Dessler told us. It's simply an ordinary pulsar with a magnetic field about a hundred times weaker than most, he contends.

In a very recent conversation, Arons told us that he is having second thoughts. Spinning an old neutron star up to a millisecond period by accretion from a binary partner, he now believes, would involve an implausibly large mass transfer—at least a tenth of a solar mass. He now proposes that the millisecond pulsar was born in isolation, between 10^5 and 10^6 years ago, with a field of less than 10^9 gauss. New surveys sensitive to periods of less than 0.1 seconds should find more such objects, he expects.

Whatever the ultimate explanation for the slow deceleration of the newly discovered millisecond pulsar, Backer told us, it provides us with our best clock in the sky. It could prove useful, he suggests, in improving our determination of the masses of the outer planets. —BMS

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in brief

The Model A stellarator, the very first experimental device built for magnetic-confinement fusion studies at the Princeton Plasma Physics Laboratory, has been given to the Smithsonian Institution. The figure-eight shaped device was designed by Lyman Spitzer. He and astronomer Martin Schwarzschild wound the instrument's copper coils themselves in 1952. □