NEWS AND VIEWS

A superfast new pulsar

from David J. Helfand

FIFTEEN years ago last autumn, Morse-code-like signals pulsing with extreme regularity were received at a Cambridge radio telescope — pulsars had been discovered. Although the first such object was dubbed an LGM (for Little Green Man), a total of four such sources had been identified by the time the discovery was announced in February 1968 and the signals were soon explained, without recourse to the presence of extraterrestrial intelligence, as lighthouse-like flashes from highly magnetized rotating neutron stars. With nearly 350 objects now catalogued, it might seem surprising that the detection of a new pulsar would generate much excitement. But PSR1937+214, whose discovery is reported by D. Backer *et al.* on page 615 of this issue of *Nature*, is not typical; it is rotating at an astonishing 642 times a second and may well represent the first of a whole new class of objects.

The story of the discovery is one of perseverance combined with a dash of good luck. The source first appeared in the fourth Cambridge catalogue of radio emitters as 4C21.53. Its peculiarity was first noted in 1972. Using the Cambridge interplanetary scintillation telescope with which pulsars were discovered, A. Readhead and A. Hewish reported¹ that the source 'twinkled' in the interplanetary medium, unusual behaviour for an object lying in the plane of the Galaxy where interstellar material generally broadens the apparent angular diameter of compact sources and destroys the IPS modulation. Backer's attention was drawn to the source in 1979 following a report² that it had a steeply rising spectrum at low radio frequencies which, along with the very small diameter implied by the IPS measurement, is a characteristic of radio pulsars. In perusing the literature, he noticed that 4C21.53 was roughly coincident with a diffuse region of emission with a contrasting flat radio spectrum. This combination of a scintillating, steep-spectrum source and a diffuse flat-spectrum region was strikingly reminiscent of the Crab Nebula and its embedded 33 ms pulsar, the youngest and fastest pulsar then known.

This area of the sky had been searched for pulsars in 1973 by R. Hulse and J. Taylor, then of the University of Massachusetts, using an extremely sensitive system at the Arecibo Observatory 1,000-foot radio telescope. As in most of the large-scale pulsar searches conducted to date, the workers would have found it impossible to detect a new pulsar with a period significantly shorter than that of the Crab since the threshold period for the search was ~ 30 ms. This constraint is usually dictated by limitation on computer time, but this had not been deemed a serious problem: there are no other objects like the Crab Nebula within the search range ($\sim 10^4$ light yr), and it was thus assumed that there were no younger and faster pulsars to be found. The assumption, that all fast pulsars are young, may have been the critical flaw in the argument.

In 1979 Backer conducted a search for a shorter-period source in 4C21.53 at both the Owens Valley Radio Observatory and at Arecibo without success. His interest persisted, however, and, in November, some tantalizing earlier results from S. Kulkarni and C. Heiles were followed up with a search for interstellar scintillation which has, to date, only been observed for pulsars. Deep modulation was found and the following day, the periodicity of 1.5578 ms was confirmed.

The source is remarkable in many ways. The rotation rate is within a factor of about 3 of centrifugal break-up. The star's surface is moving at ~ 20 per cent of the speed of light and the rotational kinetic energy of the object is nearly 10^{52} ergs, comparable with the entire energy output of a supernova explosion. Furthermore, this superfast pulsar shows no evidence of the

encircling supernova remnant expected to accompany the creation of such an object.

A measurement of the pulsar's slowdown rate is critical in addressing several important questions including the object's age, origin and energy loss mechanism (for example, gravitational waves versus magnetic dipole radiation and energetic particles). The limit quoted by Backer *et al.* implies a period derivative $\dot{P} < 10^{-15}$ seconds per second ($s\ s^{-1}$), a factor of several hundred smaller than the Crab. J. Taylor of Princeton University has recently taken his equipment used in monitoring the binary pulsar to Arecibo and has already lowered this limit substantially in a week's observation. It thus appears that, despite its huge store of rotational kinetic energy, the pulsars energy output is quite small. Optical observations, also reported in this issue, and X-ray data taken with the Einstein Observatory by R. Becker suggest that the high-energy emission from this object both from within the magnetospheric (that is, pulsed) and from a pulsar-powered synchrotron nebula is several orders of magnitude less than that from the much slower Crab pulsar. These results will dampen the initial excitement caused by the discovery among the experimental general relativity community, where the early report³ of a high spindown rate led to quickly drawn plans for gravity wave detectors tuned to the pulsar frequency.

Backer *et al.* suggest that the pulsar and the nearby diffuse source (now known to be an HII region) may be associated, with the latter excited by an escaped binary companion of the fast pulsar. From the separation of the two sources and using a typical pulsar velocity, they infer an age for the pulsar of $\sim 10^4$ yr. The case is far from compelling, however. More recently, A. Alpar, M. Ruderman and J. Shaham of Columbia University, together with A. Cheng from Rutgers University, have proposed a scenario in which the neutron star is billions of years old and was reactivated as a pulsar after having been spun up by accretion from a companion. In a letter to appear in the next issue of *Nature* they suggest that the source is the remnant of a galactic bulge X-ray binary system. The standard scenario for bulge sources consists of an evolving low-mass star spilling matter onto a neutron star with a very low magnetic field. For such an object, the Alfvén radius at which the magnetic field dominates the inflowing matter is very close to the stellar surface, allowing for a large transfer of angular momentum to the star, spinning it up to millisecond periods. The ultimate spin rate is a function principally of the field strength and the mass transfer rate. Once the accretion stops as a result of the dissipation or ejection of the companion, the pulsar will begin to spin down again. But with its low field, the spindown time will be very long, preserving a population of old rapidly spinning pulsars.

The strength of this picture is that it offers a prediction of the current magnetic field strength and, thus, of the period derivative for such a source. The model gives the right answer for $\dot{P}$ for each of the three known binary pulsars, all of which have anomalously low spindown rates for their short periods. For 4C21.53, the prediction of $\dot{P} < 5 \times 10^{-20} s\ s^{-1}$ will be testable within a few months.

Many questions remain to be answered about this exciting new object and searches for other examples are already being planned. Future studies will focus on what such sources can tell us about the mechanism of pulse emission, neutron star interiors, and the origin and evolution of pulsars. At the moment, though, 4C21.53 serves as a reminder of the richness of the physical Universe in which each unexplored corner of parameter space holds a new mystery for the astrophysicist to ponder.

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1. Readhead, A.C.S.R. & Hewish, A. *Nature* **236**, 440 (1972).
2. Rickard, J.J. & Cronyn, W. *Astrophys. J.* **228**, 755 (1979).
3. Backer, D.C., Kulkarni, S.R., Heiles, C., Davis, M.M. & Goss, W.H. *IAU Telegram No. 3743*.