Pulsar astronomy

Spin-up more apparent than real

Andrew Lyne

GLOBULAR clusters of stars have recently been found to be a rich source of millisecond pulsars¹⁻³. In a search for such objects, Wolszczan *et al.*, who report on page 531 of this issue⁴, have discovered a pulsar, PSR2127+11, near the centre of the globular cluster M15, one of the most dense clusters in the northern skies. What makes this pulsar interesting is that, not only does it have a relatively long spin period, but it is solitary and, unlike any other known radio pulsar, its rotation rate seems to be increasing. The authors conjecture that this apparent spin-up may be an illusion due to the acceleration towards us of the object in the gravitational field of the collapsed core of the cluster. There seem to be two mysteries which need to be explained: why is the acceleration so large and why is the pulsar solitary?

Globular clusters are gravitationally bound swarms of 10^5 – 10^6 old stars found in our Galaxy. The central stellar density is often as high as 10^4 – 10^5 stars per cubic parsec compared with less than 1 pc^{-3} in the solar neighbourhood. This relatively large density probably causes many stellar interactions, resulting in a high incidence of low-mass X-ray binary systems in which we see compact objects, probably neutron stars, being spun up by accretion of material from less evolved companions. We detect many of these systems by the copious X-rays emitted by the hot accreting gas. This is the process by which it is believed old long-period radio pulsars are given the rapid rotation rates which we subsequently see in millisecond pulsars after the accretion has ceased (see ref. 5). Hence the success of the searches for such pulsars in globular clusters carried out recently.

The new pulsar has a period P of 110 ms so that it is not a true millisecond pulsar and the absence of varying Doppler effects indicates that it is not in a short-period binary system. But although all other known pulsars spin down as they lose rotational kinetic energy through their radiation, PSR2127+11 is observed to be spinning up slightly. This cannot be due to any accretion process as it has no companion and so it seems probable that the observed spin-up ($\dot{P} = -2 \times 10^{-17} \text{ s s}^{-1}$) is only apparent. It is likely to be the result of the acceleration of the pulsar towards the Earth in a gravitational field, either that of its nearest neighbour or that of the collapsed core of the cluster: the chain of regular pulses from the object becomes increasingly compressed from our point of view. The implied acceleration of about

$5 \times 10^{-8} \text{ m s}^{-2}$ is, on the other hand, rather large for either of these explanations; the pulsar needs to be improbably close to its nearest neighbour or the core must be substantially more massive than we believe. Precise timing measurements over the next few years and the determination of the second period derivative could allow the distinction to be made between these two rather uncomfortable possibilities.

Although not a millisecond pulsar, PSR2127+11, with a period of 110 ms, is spinning rapidly compared with normal old pulsars. Together with the seemingly small value of intrinsic spin down rate, this suggests that the pulsar is an old one which was rejuvenated somewhat by accretion in a binary system. This leaves the question as to what has happened to the donor companion star. Wolszczan *et al.*⁴ suggest two possible explanations. First, the companion star has been ablated by radiation from the pulsar, a mechanism proposed⁶ to explain the recently discovered eclipsing binary pulsar PSR1957+20. However, they argue that it is unlikely that this pulsar was ever spinning rapidly enough to have the required energy output to achieve this. Second, perhaps the binary system was disrupted by an encounter with a third star⁷.

There is a third possibility that should be considered: the disruption of the binary system by the supernova explosion of the companion. The circumstances of the

explosion would be similar to those involved in the formation of the celebrated Hulse–Taylor system containing the binary pulsar PSR1913+16 and another neutron star⁸. In this case, the binary system survived the supernova explosion in which the first neutron star was formed. The companion subsequently evolved, and overflowed its Roche lobe (beyond which its gravity fails to hold back material), so spinning up the neutron star, before it underwent a supernova explosion itself. In the case of PSR1913+16, the binary system was not quite disrupted and the old pulsar with a period of 59 ms was left in a very eccentric orbit around the new neutron star formed by the exploded companion.

The solitary pulsar PSR2127+11 could have been formed in circumstances only slightly different: the second supernova could have disrupted the binary system and, provided it was not ejected from the cluster, PSR2127+11 would have been left in its intermediate-period spin state. If this was the case, it must have happened a long time ago when the cluster was young and there were still young, massive stars which could suffer supernova collapse. □

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Photosynthesis

Giant revelations to come

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CONSIDER a huge, membrane-located protein complex that is so complex that about a quarter of its mass consists of tightly bound pigment molecules. Imagine this protein assembly also contains an intricate electron pathway which, using light energy, produces stable reduced components at redox potentials around minus 500 mV. This is no fictitious giant, but one of the two light-energy-utilizing systems of plant photosynthesis, the photosystem I reaction centre. Ingrid Witt and her collaborators have now succeeded¹ in showing that crystals of this reaction centre can diffract X-rays to 4 Å. Moreover, the hexagonal crystals are relatively stable in the X-ray beam, which will reduce the problems for data collection. It seems likely that the atomic structure of this big but beautiful protein will soon be obtained.

As a source for their reaction centre, Witt *et al.* use one of the most thermophilic photosynthetic organisms known, the vivid blue cyanobacterium *Synechococcus*, found in a Japanese hot spring at temperatures of around 70 °C. The reaction centre crystallizes as a trimeric complex which has a total relative molecular mass of about 800,000. Each of the three reaction centres contains about 60 chlorophyll *a* and 10 carotenoid molecules, giving the crystals an intense green colour. The overall form of the cyanobacterial complex is known from electron microscopy (see figure). Witt *et al.* present a model for the organization of the complexes within the crystals in which the repeating unit of dimensions 285 × 285 × 167 Å is composed of two pairs of trimeric complexes.