Millisecond pulsars

Shock wave reveals pulsar wind

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OLD pulsars with millisecond periods are remarkable end-products of binary-star evolution: neutron stars which have been spun up by accretion. The initial rotational energy of a millisecond pulsar is as great as the kinetic energy of the supernova which originally created the neutron star, and the observed rates of period increase imply that this rotational energy is lost at a rate greater then 10^{35} erg s^{-1}, probably as a wind of relativistic particles. These winds are surprisingly difficult to detect. Soft X-ray nebulae have been found around a few pulsars[1], but most could not be seen. Kulkarni and Hester report on page 801 of this issue[2] the detection of another manifestation of a pulsar wind, a faint nebula of pure hydrogen Balmer-line (Hα) emission, marking a shock wave that the wind drives into cold interstellar gas.

Hester and Kulkarni have previously studied[3] the emission nebula created when a rapidly moving pulsar strikes the dense shell of its own supernova remnant, CTB 80. The new nebula encloses the recently discovered eclipsing binary pulsar PSR1957+20. The orbital period and velocity amplitude of this object imply that the binary partner has an extremely low mass (about 0.022 solar masses), yet the eclipse duration requires it to be larger than the Sun and opaque to radio waves. This can be understood if the opaque object is actually a wind evaporating from the low-mass companion[4].

Energetic electrons and positrons in the pulsar wind can produce enough γ-ray emission in a shock around the secondary to heat its surface and drive the wind. The evaporation may be rapid enough to destroy the secondary entirely, explaining the existence of solitary millisecond pulsars[5,6] and the dearth of short-period low-mass X-ray binaries[7].

The Hα nebula around PSR1957+20 reported in this issue[2] is another consequence of the pulsar wind. It is very faint and the quality of the image (see page 802) demonstrates the sensitivity of the current generation of instruments. Its bow-shock shape results from the motion of the pulsar, at a velocity v of about 100 km s^{-1}, through the ambient gas. The distance between the pulsar and the bow shock is given by the balance of the ram pressure, ϱv^2, of the bow shock (ϱ is the density of the interstellar gas) and the pressure of the pulsar wind. The pure Hα emission spectrum is interpreted as a non-radiative shock (a shock for which radiative cooling is not dynamically important), similar to those observed in a few young supernova remnants. The Balmer-line emission is produced by collisional excitation of neutral hydrogen swept up by the shock, and if the line profile can be measured, its width determines the shock velocity[8].

This interpretation imposes very strict limits on the pulsar-wind emission and on the nature of the ambient interstellar gas. The presence of neutral hydrogen so close to the pulsar strongly suggests there is a low-energy cutoff to the power-law emission of the wind. Some difficulties may arise in applying the existing models of non-radiative shocks. The intensity ratio of the two Balmer lines Hα/Hβ is much higher than in model predictions, and even the non-radiative nature of the shock is barely consistent with the size and density of the nebula.

Although these difficulties could indicate an interaction between the pulsar-wind particles and the interstellar gas more direct than a pressure-driven shock wave, the most exciting aspect of this discovery is the opportunity to measure the impact of a pulsar wind on the interstellar medium. □

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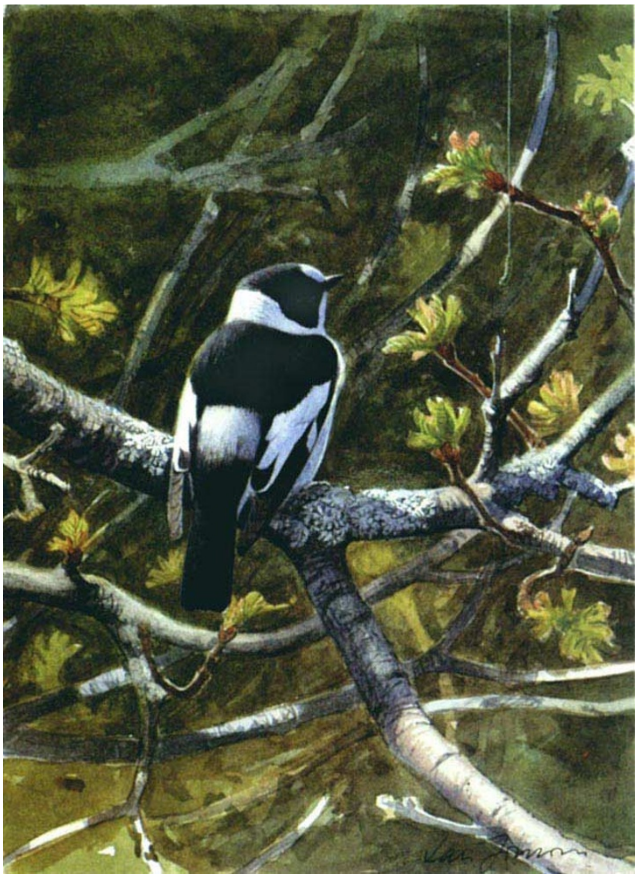

IN BIRDS, the most common clutch size varies from one species to the next; gannets, for instance, tend to incubate eggs singly, whereas great tits typically incubate half a dozen or more eggs. Moreover, there is considerable variation in clutch size even within some species. In Wytham Wood near Oxford, for example, the actual number of eggs laid by great tits varies from five to a dozen. How is this inter- and intra-specific variation to be explained? Group selectionists such as V.C. Wynne Edwards have argued that clutch size is regulated so as 'altruistically' to avoid population over-crowding. Followers of David Lack, however, argue that clutch size is adjusted by natural selection so as to maximize the number of surviving offspring. The picture shows a male collared flycatcher (*Ficedula albicollis*): on page 813 of this issue, Lars Gustafsson and William Sutherland report the results of experimental manipulations of actual clutch size in this species, and conclude that large clutches have considerable concomitant costs. In a separate study soon to be published in *Nature*, R.A. Pettifor, C.M. Perrins and R.H. McCleery report that individual female great tits (*Parus major*) lay that size of clutch from which they can maximize the number of recruits (young which survive to enter the subsequent breeding population). Despite the differences evident in these two studies, together they suggest that clutch size has evolved by individual rather than by group selection. (Painting by Lars Jonsson.)

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