

**Figure 2 Fishing out life histories.** a, As Olsen *et al.*<sup>7</sup> describe, the probability of an individual maturing at a specific age or size can be determined from where the negatively sloped probabilistic reaction norms (solid lines), which represent the age and size at which 50% of a population reaches maturity, intersect the positively sloped growth function (dashed line), which relates length to age. In this hypothetical example, an individual growing at the average rate in 1960 would intercept the 50% maturation probability contour — the reaction-norm midpoint — at about 3.6 years and 38 cm. Following intensive fishing, an individual growing at the same rate in 1990 matures at 2.3 years and 22 cm. b, How traditional reaction norms might look in an unfished population (solid line), and as fishing increases to low (dotted line) and high (dashed line) levels. (Growth rate is often used as a proxy for environmental change in the study of reaction norms for organisms that continue to grow after maturity.)

as possible, and expend higher reproductive effort at that age<sup>14</sup>, irrespective of growth rate (Fig. 2b). With sufficiently high mortality, the potential for phenotypes to change might decrease, leading to relatively invariant phenotypic life-history responses to environmental variability — a prediction borne out recently by work on European grayling fish<sup>15</sup>.

In any case, the potential for fishing to generate evolutionary change within harvested populations can no longer be seriously discounted. This may well be the most enduring contribution of Olsen and colleagues' research<sup>7</sup>. If evolutionary change in response to harvesting proves to be the rule rather than the exception for exploited species, we must begin to address questions concerning the magnitude of evolutionary change, the reversibility of such change, and its consequences for sustainable harvesting, population recovery and species persistence. As with

unintentional selection by humans against, for instance, large animals and antibiotic-susceptible pathogens, the long-term repercussions of fishing are almost certainly more complicated than previously believed. ■

Jeffrey A. Hutchings is in the Department of Biology, Dalhousie University, Halifax, Nova Scotia B3H 4J1, Canada.  
e-mail: jeff.hutchings@dal.ca

1. Coltman, D. W. *et al.* *Nature* **426**, 655–658 (2003).
2. Stockwell, C. A., Hendry, A. P. & Kinnison, M. T. *Trends Ecol. Evol.* **18**, 94–101 (2003).
3. Stokes, K. & Law, R. *Mar. Ecol. Prog. Ser.* **208**, 307–309 (2000).
4. Conover, D. O. & Munch, S. B. *Science* **297**, 94–96 (2002).
5. Handford, P., Bell, G. & Reimchen, T. *J. Fish. Res. Bd Can.* **34**, 954–961 (1977).

6. Sinclair, A. F., Swain, D. P. & Hanson, J. M. *Can. J. Fish. Aquat. Sci.* **59**, 361–371 (2002).
7. Olsen, E. M. *et al.* *Nature* **428**, 932–935 (2004).
8. COSEWIC (Committee on the Status of Endangered Wildlife in Canada). *COSEWIC Assessment and Update Status Report on the Atlantic Cod, Gadus morhua* (COSEWIC, Ottawa, 2003). Available at [www.sararegistry.gc.ca](http://www.sararegistry.gc.ca)
9. Heino, M., Dieckmann, U. & Godø, O. R. *Evolution* **56**, 669–678 (2002).
10. Schlichting, C. D. & Pigliucci, M. *Phenotypic Evolution: A Reaction Norm Perspective* (Sinauer, Sunderland, 1998).
11. Stearns, S. C. & Koella, J. C. *Evolution* **40**, 893–913 (1986).
12. Hutchings, J. A. *Can. J. Fish. Aquat. Sci.* **56**, 1612–1623 (1999).
13. Stokes, T. K., McGlade, J. M. & Law, R. (eds) *The Exploitation of Evolving Resources* (Springer, Berlin, 1993).
14. Hutchings, J. A. in *Handbook of Fish Biology and Fisheries* Vol. 1. *Fish Biology* (eds Hart, P. J. B. & Reynolds, J. D.) 149–174 (Blackwell, Oxford, 2002).
15. Haugen, T. O. & Vollestad, L. A. *J. Evol. Biol.* **13**, 897–905 (2000).

Astrophysics

# Jump-start for a neutron star

Duncan Lorimer

Radio emission from one of the neutron stars in the 'double-pulsar' system is strangely enhanced in two sections of its orbit — stimulated, perhaps, by radiation from its companion.

One of the most exciting discoveries in astronomy in recent times was that of the binary system<sup>1</sup> J0737–3039, and its confirmation as a 'double-pulsar' system earlier this year<sup>2</sup>. Pulsars are rapidly spinning neutron stars that form during the supernova explosions of massive stars; although their masses tend to be slightly larger than that of our Sun, their radii are only about 15 km. For the first time, both neutron stars in this binary have been identified as radio pulsars — one that spins about its rotation axis every 22.7 milliseconds (which I shall refer to as 'A') and another ('B') that spins with a period of 2.77 seconds.

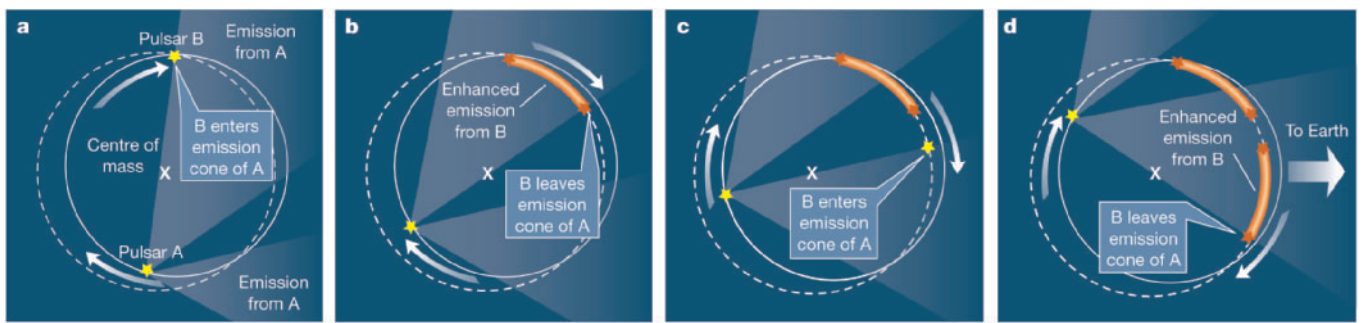
This duo promise to surpass even the original Nobel-prizewinning pulsar in a binary system<sup>3</sup> as a testing ground for relativity, but they are also a fantastic laboratory for studying pulsar emission. The intense magnetic fields of pulsars accelerate charged particles around them, causing the emission of beams of radiation that sweep the sky like the rotating beams of a lighthouse. Already there are intriguing observations<sup>2</sup> of the emission from the double-pulsar system — in particular that pulsar B seems to emit most strongly in two separate parts of its orbit. On page 919 of this issue, Jenet and Ransom<sup>4</sup> offer an explanation for this strange effect, in a model that will have important implications for our understanding of this binary system.

The rotation periods of pulsars increase over time, reflecting the loss of rotational kinetic energy of the spinning neutron star as it emits a 'wind' of electromagnetic radiation along its emission beams. The difference in spin properties of the neutron stars in the double-pulsar binary means that their winds carry away energy at significantly different

rates: the rate of loss of energy from A is some 3,000 times greater than that from B. This, and the compactness of the pulsars' orbit, implies that the energy carried in the respective winds from A and B is actually balanced inside the emission region of B (ref. 2). As a result, the energetics of A can be expected to dominate the system.

The panels of Fig. 1 show the geometry of the double-pulsar system, as seen from above the orbital plane. The two stars hurtle around their common centre of mass every 2.4 hours, at 0.1% of the speed of light. The two regions of strongest radio emission from pulsar B are indicated in orange in Fig. 1d. Because observers on the Earth are looking at the system nearly edge on, essentially in the same plane as the orbit, it is not surprising that the emission from B is strongest when it is closest to the Earth and A is furthest away. But it is not immediately obvious why there is a clear break in the emission between the two parts of the orbit.

Jenet and Ransom<sup>4</sup> postulate that the emission from B is somehow stimulated — jump-started into action — when the lighthouse beam of A sweeps through B's emission region. The authors make the reasonable assumption that A's beam is a wide, hollow cone<sup>1</sup> whose size and opening angle can be determined directly. It is then a relatively straightforward geometrical exercise to show that pulsar B intercepts A's beam at precisely the points of the orbit where increased emission is observed<sup>2</sup>. From current observations, the various angles in the system are constrained such that they fit two slightly different solutions of Jenet and Ransom's model, both of which produce the effect shown in Fig. 1.



**Figure 1** The double-pulsar system J0737–3039. The orbit of the pulsars, seen here from above the orbital plane, is so compact that it would fit inside the diameter of our own Sun (1.4 million kilometres). The radio emission from one of the pulsars, B, is known to be strongest in two particular regions of the orbit, and now Jenet and Ransom<sup>4</sup> propose an explanation for why this is so. They assume that the other pulsar, A, emits radiation in a wide, hollow-cone beam. Panels a–d are snapshots of the pulsars' motion, showing the area swept out by A's beam. a, B intercepts A's

beam and is stimulated to emit. b, This emission continues (orange band) until it enters the hollow midsection of A's beam and its emission is reduced. c, B is stimulated again as it enters the active part of A's beam for a second time. d, Once more, the emission is reduced when B moves out of A's beam. The orange bands representing stimulated emission from B match the regions of heightened emission seen in observations of the system. (Graphic derived from an animation at [www.physics.mcgill.ca/~ransom/0737\\_Bflux\\_model.mpg](http://www.physics.mcgill.ca/~ransom/0737_Bflux_model.mpg))

As well as explaining observations, Jenet and Ransom's model makes testable predictions about the past and future visibility of the binary system. This is because the proposed geometry is strongly dependent on the relative orientation between A's emission beam and the line of sight from Earth. This angle varies with time through geodetic precession (a relativistic effect<sup>5</sup> that occurs when the spin axis of an orbiting body is misaligned with the angular momentum axis of the binary system). The perturbing effect of B on the space-time of A causes the spin axis of A to precess around the angular-momentum axis. The strong gravitational field produced in the double-pulsar system means that A's spin axis precesses through a full 360° in 75 years. Similarly, B precesses every 71 years. These are the shortest geodetic precession periods ever observed and as a result the emission beams of A and B also move in and out of our line of sight within these timescales. This effect probably explains why the system was not visible during a previous survey of the sky over a decade ago<sup>6</sup>.

Using this precession rate in their two best-fit solutions, Jenet and Ransom predict that the emission beam of A will precess out of our line of sight in either 4.5 or 14 years, depending on the solution considered. Within the next year, as changes in A's beam geometry begin to accumulate, significant variations in the shape of that pulsar's radio pulses are expected; they should be sufficient to enable observers to decide between the two model solutions. As Jenet and Ransom point out, it is not yet certain whether the same precession effect will be observed for B because the wind from A might have caused its spin axis to align with the orbit.

Nature has provided a magnificent spectacle. Time, however, is most definitely of the essence as these two neutron stars may not be visible for much longer. Observational astronomers are now working feverishly to characterize this system further, taking data

at many wavelengths across the electromagnetic spectrum. If we assume that the new model continues to describe the observations, the theoretical challenge is now to establish whether it is feasible to 'jump-start' a neutron star and what physical processes could cause this to occur.

Duncan Lorimer is at the Jodrell Bank Observatory, Department of Physics and Astronomy,

University of Manchester, Macclesfield, Cheshire SK11 9DL, UK.  
e-mail: [drl@jb.man.ac.uk](mailto:drl@jb.man.ac.uk)

1. Burgay, M. *et al.* *Nature* **426**, 531–533 (2003).
2. Lyne, A. G. *et al.* *Science* **303**, 1153–1157 (2004).
3. Taylor, J. H. *Rev. Mod. Phys.* **66**, 711–719 (1994).
4. Jenet, F. A. & Ransom, S. M. *Nature* **428**, 919–921 (2004).
5. Barker, B. M. & O'Connell, R. F. *Astrophys. J.* **199**, L25–L26 (1975).
6. Lyne, A. G. *et al.* *Mon. Not. R. Astron. Soc.* **295**, 743–755 (1998).

## Hearing

# Tightrope act

David P. Corey and Marcos Sotomayor

A component of the 'tip link' that conveys tension to mechanically sensitive ion channels in the inner ear has been identified. The finding raises new questions about elastic elements in our hearing apparatus.

A snatch of music from far away or a slight turn of the head to find its source generates mechanical stimuli that are detected by hair cells of the inner ear. A bundle of finger-like stereocilia rises from the upper surface of each hair cell; stimuli that deflect these stereocilia by just a few nanometres can be reliably perceived. Biologists have a detailed understanding of the morphology and biophysical properties of the mechanically sensitive apparatus at the tips of stereocilia, but not of the protein constituents of this apparatus. In this issue, however, Nicolson and colleagues<sup>1</sup> and Müller and co-workers<sup>2</sup> describe how they identified a major constituent of the tip link — an extracellular filament that is stretched like a tightrope between the tops of adjacent stereocilia.

Mechanical stimuli that deflect a hair bundle towards its tallest stereocilia cause the tip links to tighten (Fig. 1a, overleaf). This tension is conveyed to specialized 'transduction' channels at each end of the tip link, which open to allow ions into the cell

(Fig. 1b). This is the process of mechanotransduction, and is the first step in sending a signal to the brain. Within each stereocilium, several dozen myosin-1c molecules set a resting tension on a tip link and its channels, to bias the system to its most sensitive point.

Other than myosin-1c, the molecular contributors to mechanotransduction have not been positively identified. But some components of stereocilia have been identified from studies of genes that are defective in people or mice with inherited deafness. For instance, genes that are mutated in the human Usher's syndromes — which produce both deafness and blindness — have been found to encode the myosin-7a, harmonin, SANS, protocadherin 15 and cadherin 23 proteins<sup>3</sup>. Defects in any of these cause the stereocilia bundle to fall apart, suggesting that they participate in other, lateral links that connect adjacent cilia. In younger mice, cadherin 23 is most abundant near the transduction apparatus at the tips of stereocilia. But it was thought to disappear in adults, suggesting a role in development but not in mechanotransduction<sup>3</sup>.