Woodruff[12]. Applying modern analytical techniques and theoretical concepts to his hay infusions could provide an excellent, synthetically combined approach to many community problems that are intractable at other scales. I have tried unsuccessfully to interest graduate students in this approach, but Woodruff's 75-year-old work seems to hold little current charm. Nevertheless, his system seems to lend itself to the deconstruction and reconstruction necessary for an experimental attack on the functional consequences of community organization. Moore and Hunt, like all but a few ecologists[6], infer stability properties from community structure. The internal subdivision of food webs appears to be a critical property if more diverse webs are to be stable. Combining a tractable experimental system with modern technology and thought might allow a synthesis of correlative inference and experimental evidence. ☐

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Radioastronomy

An eclipsing binary pulsar

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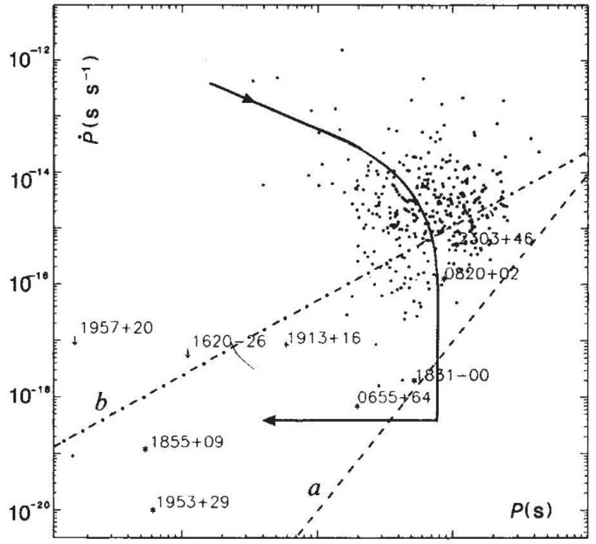
MOST of the 400 pulsars that have been discovered have rotational periods of 0.1–4 seconds. Unlike most stars, very few of these rapidly rotating neutron stars have been found in binary systems with an orbiting partner; it is generally supposed that the supernova explosion accompanying the collapse of a massive star to form a pulsar is large enough to disrupt most binary systems. But millisecond pulsars, whose periods are less than about 10 milliseconds, are typically in binary systems with other condensed stars, either white dwarfs or neutron stars, as partners. The discovery by A.S. Fruchter, D.R. Stinebring and J.H. Taylor, reported elsewhere in this issue (*Nature* **333**, 237–239; 1988), of a binary millisecond-pulsar system in which the partner is large enough to eclipse the pulsar, cutting off the characteristic radio pulses for a tenth of its orbit, is therefore a great surprise.

In a plot of pulsar period *P* against the slowdown rate $\dot{P}$, as shown in the figure, the youngest pulsars appear at the top left; typical young pulsars are the Crab and Vela pulsars whose respective ages are about 1,000 and 10,000 years. As they slow down, pulsars move downwards and to the right, as shown by the sloping track. During their lifetime of about 10^7 years, the slow-down process becomes less effective because the pulsar magnetic field decays, so that the track becomes more vertical. Eventually their radio emission stops or becomes too weak to detect; at this point they cross the 'death line' shown in the lower right.



Evolutionary track of pulsars (bold line). Period P and slow-down $\dot{P}$ for 361 pulsars. Catalogue numbers of millisecond and binary pulsars (*) are given. a, Death line; b, spin-up line.

Where then can the millisecond pulsars come from, located as they are in the lower left of the diagram? The clue to this lies in their binary partnerships. A binary pulsar which has crossed the death line can be resurrected; its partner can transfer angular momentum to it, spinning it faster than in its most youthful days. The process of mass transfer which can speed up the rotation to over 600 revolutions per second is already observed in the X-ray binaries, where material falling onto a neutron star is heated by gravitational energy to 10^7 K or more. The rejuvenated radio pulsar, however, conceals its true age, because its magnetic field has already decayed from about 10^{12} gauss (10^8 tesla) to about 10^9 gauss. The strength of the field, and hence the age of the pulsar, is revealed by the slow-down rate.

There now seem to be several ways in which a binary star system can evolve and produce an observable millisecond pulsar. The recent discovery by A.G. Lyne *et al.* (*Nature* **332**, 45–47; 1988) of a binary pulsar in the globular cluster M4 supports the proposal that the binary pair could be the result of a near collision of a neutron star and a red giant. Alternatively, the binary could date back before the neutron star was formed; this implies that a comparatively small amount of mass was expelled in the supernova explosion so that there was no disruption. Most current models lead us to expect that the binary partner should be a white dwarf. This is easily tested, because the orbital period and the changing Doppler shift of radio lines during the orbit can be combined to give information on the masses of the components. The partner of the M4 binary, for example, is clearly a white dwarf with a mass of about 0.3 solar masses.

The outstanding feature of the newly discovered binary system, reported in this issue, is the occultation (eclipsing) of the pulsar by its companion. This immediately shows that the binary orbit is seen approximately edge on, so that the mass calculations are reasonably certain. The companion turns out to have the unusually low mass of only 0.02 solar masses. The occultation, however, lasts for one-tenth of the orbit; it can easily be shown that the companion must be very large, with a diameter about three-quarters that of the Sun, instead of about 1 per cent as expected for a white dwarf.

This problem is solved by a further observation of this extraordinary object. Immediately before and after the occultation, the radio signals are delayed in a way which is characteristic of passage through ionized gas. Evidently the occultation is caused by an extended hot atmosphere surrounding the tiny white dwarf. There is even an observable difference between the beginning and end of the occultation, showing that the ionized atmosphere is not spherically symmetrical; the appearance is comet-like, with a more extended atmosphere on the trailing side.

Fruchter *et al.* speculate, very reasonably, that they are seeing the evaporation of the white dwarf by the pulsar. This would, incidentally, provide another model for the creation of solitary millisecond pulsars, but attention is naturally focused at this time on the mechanism by which the pulsar can heat the white dwarf. The total energy available from the pulsar rotation is probably about 100 solar luminosities, but it seems unlikely that it is the radiation from the rotating magnetic dipole that is directly responsible. The exciting proposal is that the companion is heated by a stream of high-energy particles, perhaps with the energy of cosmic rays, that are generated in the rapidly rotating pulsar. ☐

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