their demise within a few decades. Birds are the best documented; some 11% are "threatened" and 2% "critically endangered", usually meaning that there is considerable uncertainty about whether the species is still alive. The cover of a catalogue of threatened birds[3] depicts two more species from Hawaii — the nukupu`u, seen only sporadically over the past few decades, and the akialoa, not seen in 50 years. The catalogue's title, *Birds to Watch,* implies that there is some hope for these species. Indeed, species sometimes reappear after long absences; the Cebu flowerpecker is one[4].

There is a problem with retaining hope for species missing in action, however. If we chose the date of extinction to be, say, 50 years after the last record, then we record no extinctions for the past 50 years. Naive interpretations of counts of the number of extinctions per decade might conclude that extinction rates have declined in the past 50 years. Roberts and Solow's result provides a way of converting records of critically endangered species into predictions of what species might still be found and those for which the expiry date has passed. Other methods, using different statistical approaches individually or in combination, might be applied to the same end.

And what about the dodo — a universal symbol of stupidity and its fatal consequences? The familiar portrait is particularly unflattering, but we forget that so, too, were other bird drawings of that vintage. According to *The New Shorter Oxford English Dictionary,* the dodo "became extinct", perhaps implying that it deserved its fate. Put more accurately, however, the entry would read "humans wrecked its habitat, introduced species that ate it and perhaps directly bludgeoned the flightless birds into oblivion" (Fig. 1) — oblivion most likely coming, at least in the statistical terms of Roberts and Solow's analysis, in 1690, 28 years after the dodo's last confirmed sighting.

A more important question is on what date did we seal its fate? Or that of the Laysan `apapane? Or that of the Cebu flowerpecker — for its re-discoverers found only three individuals? Exactly when did human actions put these and other species into irrevocable decline? Roberts and Solow do not tackle this much more difficult matter. We must do so, of course, if we are to prevent the extinctions of the large fraction of species now threatened. ■

Stuart Pimm is at the Nicholas School of the Environment, Duke University, Durham, North Carolina 27708, USA.
e-mail: StuartPimm@aol.com

1. Roberts, D. L & Solow, A. R. *Nature* **426,** 245 (2003).
2. Lawton, J. H., May, R. M. & Stork, N. in *Extinction Rates* (eds Lawton, J. H. & May, R. M.) 1–24 (Oxford Univ. Press, 1995).
3. Collar, N. J., Crosby, M. J. & Stattersfield, A. J. *Birds to Watch 2: The World List of Threatened Birds.* BirdLife Conservation Ser. No. 4 (BirdLife International, Cambridge, UK, 1994).
4. Magsalay, P., Brooks, T., Dutson, G. & Timmins, R. *Nature* **373,** 294 (1995).

RON MURRAY & DEBRA BROWN/ADAM BLOCK/NOAO/AURA/NSF

Astronomy

The mystery companion

Noam Soker

A jet-like flow of material, detected in the vicinity of a dying star, supports a model in which such jets shape the gas cloud around the star into a bipolar nebula. The jet probably comes from an unseen companion star.

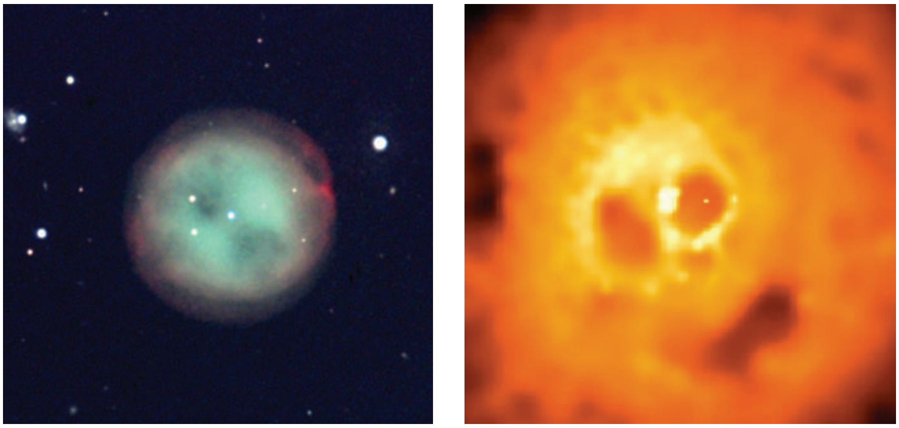
As Sun-like stars exhaust the nuclear fuel in their cores, they become 'red giants', swelling to a size several hundred times that of the Sun. The stars begin to lose mass, emitting a dense wind of gas that, in most red giants, would be expected to be spherically symmetric. Using the Hubble Space Telescope, Sahai *et al.*[1] have discovered a fast wind emanating from the vicinity of a red giant that is collimated, rather than spherical (page 261 of this issue). This, coupled with similar observations of another dying star[2], suggests why the gas clouds that form around many red giants — known as planetary nebulae — are elongated, or bipolar. But this latest detection[1], around the star V Hydrae as it begins its transition to a planetary nebula, also points more clearly to the origin of the cloud-shaping jets.

The evolution of a Sun-like star follows a particular cycle. For most of the nuclear-active life of such a star, hydrogen fuses to form helium in the star's core; later, helium fuses to form carbon and oxygen. Once the helium in the core is exhausted, nuclear burning continues in two thin shells surrounding the core: an inner shell of helium fusion to carbon and oxygen, and an outer shell of hydrogen fusion to helium. Many other elements are also formed during this last nuclear burning phase.

The size of the core with its two burning shells is typically only a few per cent of the size of the Sun today. But the star swells. As its production of energy reaches a rate 3,000 times higher than that of the Sun, its size might be up to three times the distance of the Earth from the Sun (hence the Earth may be swallowed by the Sun when our star reaches this final stage of its life, in around 7 billion years). To conserve angular momentum, the rotation of these stars must slow down substantially as their radius increases. So, as the red giants are at this stage losing mass at a very high rate, their slow rotation means that the winds they emit should be spherical. Later in the cycle of evolution, all that remains of the star is a hot bare core, which ionizes and heats its surrounding cloud of gas. This is a planetary nebula.

But most planetary nebulae have bipolar structures, rather than the spherical shape that would be the natural result of their formation from an even stream of gas emission by a red giant. They may be elliptical, or have two opposite narrow lobes or bubbles. This nonspherical structure is a puzzle that astronomers have been struggling to solve for more than 20 years. If the winds from most red giants are spherical, what then is the mechanism that shapes the nonspherical planetary nebulae[3]?

It has been suggested that jets of matter, thrown out in opposite directions by the dying star, are behind it. Not all astronomers agree — after all, many planetary nebulae are not shaped by jets, so these collimated flows cannot be a universal feature in planetary nebulae. There is also dispute over whether the jets, if they exist, are blown by the giant star



A. FABIAN *ET AL.*/NASA

Figure 1 **Blowing bubbles. At the centre of both the Owl nebula (left) and the Perseus cluster of galaxies (right) is a pair of bubbles, filled with high-temperature, low-density gas — although the bubbles in the galaxy cluster are 100,000 times larger than those in the planetary nebula. In clusters of galaxies, such bubble pairs are known to be formed by two jets. Data reported by Sahai *et al.*[1] suggest that they are also shaped by jets in planetary nebulae. The Owl nebula is shown in optical light; the Perseus image was taken by the Chandra X-ray Observatory.**

Plant development

Leaves by number

Fibonacci numbers are notorious for appearing in the most unlikely places, including the architecture of plants. Elsewhere in this issue, Didier Reinhardt and colleagues describe the role of the plant hormone auxin in phyllotaxis, the positioning of leaves around a stem (*Nature* **426,** 255–260; 2003). In so doing, they reveal a mechanism by which Fibonacci numbers can emerge.

Fibonacci was the nickname of the Italian mathematician Leonardo Pisano (1170–1250), who introduced the Arabic number system into Europe. In 1202, he also posed a seemingly inconsequential problem concerning the breeding of rabbits. Its solution required the use of a series of numbers whose members are the sum of the two preceding entries (1, 1, 2, 3, 5, 8, 13, 21, 34, 55,…). This series now bears his name.

The Fibonacci series occurs in the arrangement of many plant organs. The seeds of sunflowers, *Helianthus annuus*, and the leaves of cacti and succulents (such as *Mammillaria myrtax*, upper image here, and *Sempervivum hybrida*, lower image) are arranged in both left- and right-handed spirals. The numbers of leaves, or seeds, in these spirals are consecutive Fibonacci numbers.

Leaves are also spirally distributed around the stems of less exotic plants. Here they tend to be separated by an angle of 137.5°. This is the radial equivalent of the golden ratio, ≈1.618, the ultimate proportional increase between successive Fibonacci numbers. Many hypotheses, ranging from the prosaic to the mystical, have been proposed to explain why leaves should stick out at this angle. Some invoke physical properties of the stem, whereas others propose that growing leaves emit an inhibitory field to prevent new leaves from arising in their vicinity, but none has had direct supporting evidence.

Leaves originate at the tips of growing shoots in a self-renewing region known as the shoot apical meristem. Using the thale cress, *Arabidopsis thaliana*, Reinhardt and colleagues saw that new leaves formed where the concentration of auxin was highest. Indeed, artificially adding auxin to specific points on the surface of the meristem caused leaves to be produced at those points.

Auxin is a growth stimulator that is propelled through plant tissues by specific influx and efflux transporters. Reinhardt *et al.* looked at the distribution of one of the most important of these, the efflux protein PIN1, as well as mutants in which it was missing, and deduced that auxin is moved towards the shoot tip through the outer layers of the shoot apical meristem. Existing leaf buds act as sinks, preventing auxin from continuing its progress directly above them. The maximum auxin concentration, and so the site of new leaf formation, is thus as far away as possible from already-formed leaves.

Reinhardt *et al.* have therefore uncovered a mechanism in which the position of leaves is determined neither by a physical property of the stem, nor by an inhibitory field produced by growing leaves. Instead, the gaps between leaves, by allowing the free flow of auxin, mark out the position of each new leaf.

Christopher Surridge

---

itself or by a stellar companion. Increasingly, observations and calculations are pointing to stellar companions as the source of such jets.

Many so-called symbiotic binary systems, which contain a red-giant star and a smaller stellar companion, have bipolar nebulae around them that are remarkably similar to some planetary nebulae. This suggests that binary companions could be at the root of the shaping process in both symbiotic nebulae and planetary nebulae[4]. Some symbiotic systems are known to have jets[5,6], and the newly found jets near red-giant stars[1,2] strongly support jet shaping of some planetary nebulae as well. Sahai and colleagues' discovery[1] is particularly suggestive on this point: the wind speed of the jet from around V Hydrae is much higher than the value expected for material ejected from giant stars; so it seems more likely that the jet is emanating from a much smaller stellar companion as it accretes matter from the dying star. Furthermore, V Hydrae is known to rotate more rapidly than expected, suggesting that its rate of spin is being affected by a companion star.

The existence of jets in planetary nebulae may also help to explain the similarity between bipolar structures in some planetary nebulae and those in some clusters of galaxies — even though the latter are a million times larger. Both can appear to have oppositely balanced pairs of bubbles in their structure (Fig. 1). In galaxy clusters, these are known to be formed by two oppositely ejected jets. The new finding[1], then, brings us closer to describing a unified formation mechanism for pairs of bubbles in astrophysical systems, over many orders of magnitude in system size.

Stimulating and significant as this jet discovery is, some links are still missing. The collimated flow detected by Sahai *et al.*[1] is less than three years old — is there also a long-lived jet in that direction, or does this indicate that mass loss is sporadic rather than continuous? A second jet to balance this one would also be expected. As Sahai *et al.* state, the counter-jet may be obscured by dense gas, but it or its signature should now be sought. And, of course, efforts must be made to find the stellar companion, the suspected source of the jets that will shape the planetary nebula of V Hydrae. ■

Noam Soker is in the Department of Physics,
Technion – Israel Institute of Technology,
Haifa 32000, Israel.
e-mail: soker@physics.technion.ac.il

1. Sahai, R., Morris, M., Knapp, G. R., Young, K. & Barnbaum, C. *Nature* **426,** 261–264 (2003).
2. Imai, H., Obara, K., Diamond, P. J., Omodaka, T. & Sasao, T. *Nature* **417,** 829–831 (2002).
3. Claussen, M. *Nature* **417,** 798–799 (2002).
4. Corradi, R. L. M. & Schwarz, H. E. *Astron. Astrophys.* **293,** 871–888 (1995).
5. Kellogg, E., Pedelty, J. A. & Lyon, R. G. *Astrophys. J.* **563,** L151–L155 (2001).
6. Brocksopp, C. *et al. Mon. Not. R. Astron. Soc.* (in the press).