observed for rotating neutron stars — also known as pulsars — and indicates that angular momentum must have been removed somewhere along the way. But when, how and by how much? In two papers appearing in *Physical Review Letters*, Stergioulas and Font[2] and Lindblom *et al.*[3] provide support for the idea that neutron stars are slowed, at least in part, by the emission of gravity waves.

Single pulsars, typically observed 1,000 years or more after their birth, rotate relatively slowly, just 30 times per second for the pulsar in the Crab Nebula. Although faster, literally, than the blink of an eye, this is a snail's pace compared with the maximum value. So why do pulsars rotate at this slower, seemingly arbitrary value? Two possibilities emerge. Either they were born rotating slowly, or they were born rotating much faster but radiated away their excess rotational energy shortly after birth. The key issues here are the spin frequency of a neutron star when it is first born, and whether that neutron star will emit copious gravitational radiation.

Theory is, at the moment, unable to discriminate between these two possibilities. For a neutron star to be born rotating slowly, angular momentum must be removed from the spinning iron core before it collapses. Calculations[4] of the effects that might transport angular momentum in massive stars — friction, convection, circulation and the like, but ignoring magnetic fields — still allow a neutron star to be born spinning at nearly 1,000 times per second. Other calculations that crudely attempt to include the effects of magnetic forces[5] predict, with great uncertainty, a larger effect and a very slowly rotating neutron star.

Given this uncertainty, astronomers have assumed values of the spin frequency appropriate to their tastes. Those needing enough rotation to explain gamma-ray bursts by the creation of disks around collapsed stellar cores[6] or very luminous pulsars[7] assume high spin frequencies of around 1,000 times per second. So do those who want rotation to be important in supernova models, especially those desirous of the large gravitational radiation signature that comes from a highly deformed, rapidly rotating neutron star. On the other hand, those seeking a simpler life and not wanting to include rotation in their supernova models adopt the slow value.

The alternative explanation for slow spin frequencies is that the neutron star is in fact born rotating with a spin frequency near 1,000 times per second, but radiates away the excess rotational energy as light or gravity waves. If this energy were emitted through a pulsar mechanism, it would drastically affect the explosion energy and emission from the supernova remnant. Observations of supernovae and young supernova remnants seem to rule this option out. Although not all astronomers agree[7], it seems that, if neutron stars born rotating rapidly are to be slowed, gravitational radiation must do the job. Gravitational waves are ripples in the fabric of space–time that were predicted by Einstein's theory of general relativity but that are normally too weak to be detected directly. Could young neutron stars be spinning fast enough to produce detectable gravity waves? And will such radiation significantly slow the rotation of the star?

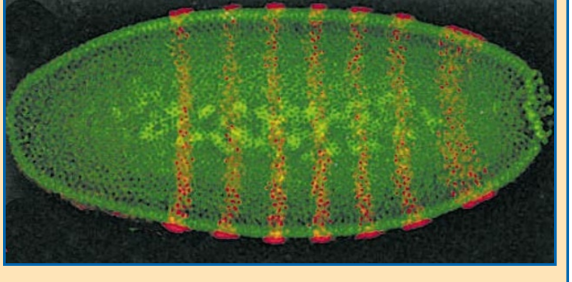
This is where the latest results[2,3] come in. They provide the first three-dimensional simulations of a process responsible for generating gravity waves in neutron stars, and show that it can become strong enough to slow the rotation. A rapidly rotating neutron star produces fluid motions or currents, called r-modes, which are similar to hurricanes or ocean currents on the Earth. These currents produce gravitational waves. The strength of the gravitational radiation depends on the maximum amplitude of the r-mode, which in turn depends on the competition between viscous effects that damp the flow, and driving forces that strive to increase it. The r-modes in neutron stars are driven to larger amplitudes by the same gravitational waves that they produce.

How does this positive feedback work? One way to view it is to consider an r-mode propagating on the surface of the neutron star in a direction opposite to the neutron star's spin (Fig. 1). If the r-mode is moving more slowly than this spin, it will appear to an astronomer observing from a safe distance above the star surface to move in the same direction as the neutron star (albeit slower). The gravitational waves produced by the velocity perturbations of the r-mode carry angular momentum away from the r-modes and, to the stationary astronomer, the emission of these gravitational waves appears to make the r-mode move slower. But on the rotating neutron star the already negative velocity of the r-mode becomes more negative and its magnitude (that is, its velocity amplitude) grows.

As the amplitude of the r-mode grows, its gravitational radiation increases, causing a runaway instability. Andersson[8] and Friedman and Morsink[9] first showed by calculation that this instability does indeed occur in neutron stars. How much it actually grows depends on the angular momentum lost through gravitational radiation, which increases rapidly with neutron star spin, and the strength of the opposing viscous forces. The viscosity is highly dependent on the temperature of the neutron star, reaching

Cell biology

Asymmetry in action



G. S. WILKIE & I. DAVIS

The tops and bottoms of cells generally differ in shape and structure, as well as in their protein components. In embryos, such asymmetry is crucial in establishing the pattern of cells and tissues that will make up the adult organism. One way in which the asymmetric distribution of proteins is achieved is through their encoding messenger RNAs. Take, for example, the early fruitfly embryo, pictured here. Some mRNAs (red) form stripes along the top (apical part) of the monolayer of cells that constitutes this stage of development. Others are found at the bottom. Two groups, writing in *Cell*, now delve deeper into the asymmetric distribution of RNA in fruitflies.

Andrew J. Simmonds and colleagues (*Cell* **105**, 197–207; 2001) show that the mRNA encoding a signalling protein, Wingless, is concentrated at the apical side of certain cells. Wingless is involved in many embryonic patterning processes, and, as Simmonds *et al.* show, if its mRNA is not distributed correctly the protein does not function properly. The authors also identify the 'address labels' in the mRNA that are crucial for its distribution.

Meanwhile, Gavin S. Wilkie and Ilan Davis (**105,** 209–219; 2001) have traced the journey of some apical mRNAs from where they are produced to their final destination. They find, first, that all mRNAs diffuse at random from their source in the nucleus. In other words, apical mRNAs do not necessarily leave the nucleus on the apical side.

Instead, once outside the nucleus, particles containing the apical mRNAs make their way rapidly towards the apical part of the cell. These particles are now transported specifically in the right direction — rather than, for example, diffusing randomly throughout the cell and becoming anchored only in the apical part. They are probably transported along microtubule-based tracks, with a motor protein known as dynein acting as the transport vehicle. It remains to be seen, however, how the address labels in the mRNAs connect with this transport machinery. **Amanda Tromans**