PROFILE OF A MAGNETAR

Normally, the X-ray afterglow of a γ -ray burst fades rapidly, but the breakneck speed of a magnetar's spin flings out surface matter and delays the final collapse.

ASTROPHYSICS

Cosmic blasts hint at inner magnetars

A twist in the plot for the Universe's most powerful explosions suggests a detour en route to forming a black hole.

BY EUGENIE SAMUEL REICH

Powerful, mysterious and brief, γ -ray bursts are the flash bulbs of the cosmos. The brightest bursts outshine a million galaxies, then fade within minutes or hours. Only an extraordinarily energetic and localized event could generate such a brilliant flash. Most γ -ray bursts (GRBs) are thought to be triggered by the collapse or merger of stars to form black holes.

Until now, the short timescales and considerable variation among GRBs have made it hard to understand the physical processes at work. But recent observations from NASA's Fermi Gamma-ray Space Telescope, launched in 2008, and the Swift satellite, launched in 2004 and still going strong, have allowed astronomers to unpick the details of the explosions. Each mission has now detected more than 500 bursts, and results presented this week at the Gamma Ray Bursts 2010 Conference in Annapolis, Maryland, have added a twist to the standard fireball-to-black-hole plot.

The new findings point to the formation of magnetars, highly magnetized and rapidly spinning neutron stars, at the heart of GRBs. Although several magnetars have been observed within the Milky Way, their role as possible causes of GRB emissions has been largely ignored, says Neil Gehrels, an

experimental physicist who works with data from Swift at the NASA Goddard Space Flight Center in Greenbelt, Maryland. "Now it's a new hot topic," he says.

A GRB consists of an initial high-energy γ -ray and X-ray signal, called the prompt emission, followed by an afterglow of X-rays. 'Long' GRBs, which last for more than two seconds, are thought to be triggered when a massive star runs out of fuel and collapses. Jets of material rushing out of the collapsed object generate searchlight beams of radiation, which are visible from Earth if the jet is pointing in the right direction.

The supporting evidence for magnetars comes at the end of the prompt emission. In most cases, this fades rapidly. However, in 2007, Paul O'Brien at the University of Leicester, UK, and his colleagues reported on a GRB seen by Swift in which the X-ray emission held steady for hundreds of seconds before beginning its decline¹. Such a signal had been predicted by theorists² as the signature of a magnetar that forms within the GRB maelstrom and, for a while, spins fast enough to resist shrinking into a black hole (see 'Profile of a magnetar').

Brian Metzger at Princeton University in New Jersey, who is working on the theory of magnetars, says that the emission from the formation of a black hole would be expected to flicker as the amount of material falling in from the

collapsed star varies. By contrast, the emission from a magnetar is caused by material flung from its surface by a rotation rate that can be as much as one thousand per second, collimated by a magnetic field up to one quadrillion times that of Earth. Both the rotation rate and the magnetic field are expected to remain fairly constant for several hundred seconds before the magnetar spins down and finally collapses into a black hole.

One example was not enough to persuade everybody, says O'Brien, although "people were curious about it". But a sample of ten such cases³ makes the magnetar scenario much more plausible, says Metzger. "The black-hole model is still the more popular, but I think people consider both models as distinct possibilities," he says. Not all GRBs show the resulting plateau in X-ray emission, but they might still involve the formation of magnetars whose signature is swamped by the X-rays produced when the jets interact with gas surrounding the original star, says O'Brien.

Dissection of GRBs isn't just throwing up possible magnetars. At this week's meeting, Sylvain Guiriec at the University of Alabama in Huntsville presented the first detection of a long-predicted thermal component of the emission for GRB100724B, observed on 24 July 2010.

The thermal component is a measure of the black-body radiation that makes it possible to estimate the temperature of the explosion's photosphere, the apparent surface of the expanding fireball, which Guiriec says is about 44 million kelvin. The tricky part was distinguishing the thermal signature from radiation emitted by the jets. Guiriec spent two years surveying objects observed by the Fermi telescope before finding one for which the separation happened to be easy. He analysed another 40 rather more ambiguous bursts in the same way. Guiriec says this is the first time that astrophysicists can claim to have related a portion of the prompt emission to the physical model of the burst. "We were scared we'd be scooped," he says.

The next step will be to subtract the thermal emission from that of the entire GRB to help to explain the physical mechanisms that underlie the rest of the signal. Guiriec's first attempt to do so suggests that the standard picture is missing some important magnetic effects.

Gehrels says that future work is likely to focus on flashes from the demise of massive stars at the edge of the visible Universe, allowing astronomers to glean direct information about what the first stars to form were like. Both the European Space Agency's Cosmic Vision programme and NASA's Explorer programme, with respective deadlines of December 2010 and February 2011, are expecting proposals for GRB missions. ■

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2. Zhang, B. & Mészáros, P. *Astrophys. J.* **552**, L35–L38 (2001).
3. Lyons, N. *et al. Mon. Not. R. Astron. Soc.* **402**, 705–712 (2010).