ASTROPHYSICS

Closing In on the Cause of The Cosmos's Biggest Blasts

A flurry of new observations brings astronomers ever closer to understanding the cataclysmic explosions known as gamma ray bursts

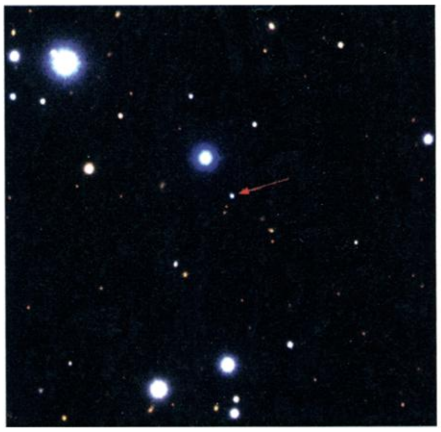
When a massive earthquake strikes, no sane seismologist would try to trace the rumble of a passing truck amid the noise of the aftershocks. But astronomers may have pulled off an equally challenging feat: detecting the glimmer of a supernova explosion in the fading afterglow of a titanic gamma ray burst (GRB). The new results support the popular idea that GRBs—the most energetic explosions in the universe—are the birth cries of black holes, the collapsed remnants of dying stars. "It is definitely strong evidence," says theorist Martin Rees of Cambridge University, U.K. A second team studying supernova debris near another GRB has strengthened the black hole connection, but its observations challenge the conventional wisdom on the sequence of events.

GRBs are brief, incredibly powerful flashes of high-energy radiation that astronomers detect in distant galaxies. According to the popular "collapsar" theory, a burst occurs when a star at least 10 or 20 times as massive as the sun collapses into a black hole, spewing jets of matter into space at close to the speed of light. At about the same time, the dying giant star blows away its outer layers in a more modest, though still enormous, supernova explosion. Because they are mainly powered by the slow decay of radioactive nickel, supernovas take days or weeks to reach their maximum brightness. Thus, the collapsar model predicts that astronomers should see a GRB first, followed by a temporary brightening of the fading afterglow of the burst, at the time the supernova reaches its peak brightness.

Ever since April 1998, when Dutch astronomers discovered a supernova at the exact spot where a GRB had been detected (*Science*, 19 June 1998, p. 1836), astronomers have been checking other bursts for such telltale supernova signatures. In a handful of cases, tentative "bumps" have been found in the light curves (brightness plots) of GRB afterglows, but the measurements have been too imprecise to be truly convincing or to rule out alternative explanations.

Recent observations with the Hubble Space Telescope, however, leave little doubt that the "bump" in the light curve is real. A team of astronomers led by Joshua Bloom of the California Institute of Technology in Pasadena used Hubble to study the afterglow of GRB 011121, which the Italian-Dutch x-ray satellite BeppoSAX detected on 21 November 2001. In an online paper submitted to *The Astrophysical Journal Letters*, Bloom and colleagues write that the brightness and the reddish color of the bump in the afterglow's light curve are "remarkably well described" by a supernova. The team concludes that the results serve as "compelling evidence for a massive star origin of … gamma ray bursts."

Other astronomers say they are impressed but want more. "This is by far the most detailed observation yet of a bump in an afterglow light curve," says Paul Vreeswijk of the University of Amsterdam, the Netherlands, "but I'd like to see a spectrum before I'm fully convinced that it was produced by a supernova." Stan Woosley of the University of California, Santa Cruz, the father of the collapsar theory, agrees. "We need a spectrum," he says. "This [bump] smells like gunpowder, but it is no smoking gun [yet]." And Rees adds that "it would be more important if we could infer the nature of the precursor star and check whether it was, for instance, especially massive."



Fleeting glory. A brief brightening in the afterglow of GRB 011121 (arrow) supports a link between gamma ray bursts and supernovas.

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A team led by James Reeves of the University of Leicester, U.K., has taken a step in that direction. Using the European Space Agency's orbiting XMM-Newton x-ray observatory, the researchers studied the afterglow of another GRB, GRB 011211, which BeppoSAX spotted on 11 December 2001. In this week's issue of *Nature*, Reeves and colleagues report that they have found the spectral signatures of silicon, sulfur, argon, magnesium, and calcium—heavy elements that massive stars produce by nuclear fusion and then eject into space during supernova explosions. From the x-ray spectra, the team concludes that the supernova debris forms a shell billions of kilometers in diameter, expanding at some 26,000 kilometers per second—87% of the speed of light. Ions detected in the debris peg its temperature at a sizzling 50 million degrees. Apparently, a massive giant star exploded as a supernova, and then a few days later the ejected shell was heated by the energetic radiation of a subsequent GRB.

This surprising order of events—first the supernova, then the GRB—is predicted by a two-stage theory of GRBs called the "supranova" model, which a minority of theorists prefer to the collapsar model. In the supranova model, the core of the exploded star first collapses into a dense neutron star, triggering a supernova. The GRB occurs later, when the neutron star further collapses into a black hole (*Science*, 3 November 2000, p. 926). In the original supranova model, the GRB occurs weeks or even months after the supernova explosion. The Hubble observations of GRB 011121 rule out that timing, Bloom and colleagues say, but they could accommodate a much shorter delay suggested by the XMM-Newton observations.

But Mario Vietri of the Third University of Rome, one of the original authors of the supranova model, says the long-delay model is still viable. Vietri points to another online paper, in which the Hubble team cites radio and infrared observations of GRB 011121 as evidence that the doomed star ejected large amounts of gas and dust in the final stages of its life. In that case, Vietri says, the suggestive bump in the afterglow light curve might be due to radiation from the GRB heating this dusty environment or reflecting off the dust. And if the bump is not due to a supernova, it's conceivable that the supernova explosion happened long before the GRB.

"More work needs to be done before they can dismiss the effects of dust and light echoes," says Vietri. Obtaining a high-resolution spectrum will do the job, says Woosley, "but this has been difficult to come by observationally." It may well take the help of a dedicated GRB satellite such as NASA's Swift, due to be launched in 2003, to solve the many mysteries that still litter the field of GRB research.

–GOVERT SCHILLING

Govert Schilling's book *Flash! The Hunt for the Biggest Explosions in the Universe* will be published this month by Cambridge University Press.