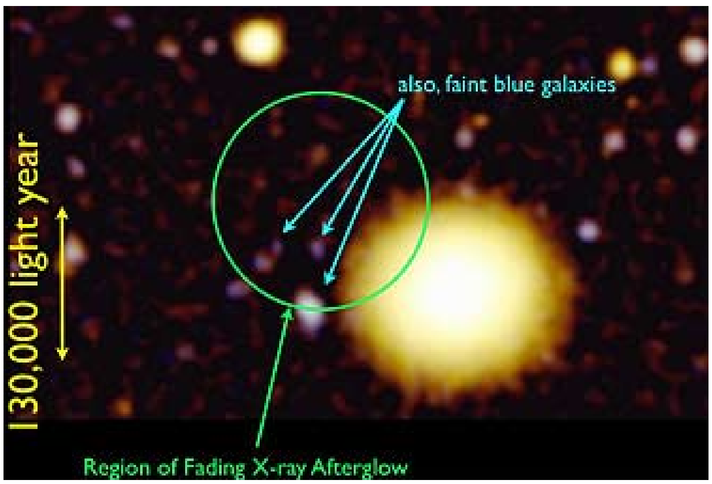
Astronomers hot on the trail of nature's exotic flashers

May 31 2005



Astronomers have uncovered tantalizing insights into the origin of short gamma-ray bursts â€" mysterious, split-second high-energy flashes that have eluded detailed study until now.
Unlike their long-duration cousins, which are known to arise when massive young stars die, short bursts are thought to occur when old, dense neutron stars collide.

Image: A Keck Observatory photo of the massive elliptical galaxy near which a split-second burst of gamma rays was detected on May 8, presumably produced by the merger of two neutron stars. The green circle indicates the region from which an X-ray afterglow was observed (not *seen in this visible-light image). Astronomers concluded that the burst came from the elliptical galaxy, a region of old stars, including many neutron stars, although several faint blue galaxies also occur along the line of sight. (Photo by Joshua Bloom/UC Berkeley)*

New evidence supports this distinct progenitor population, heralding the opening of a new chapter in the study of natureâ€™s most exotic explosions, according to Joshua Bloom, assistant professor of astronomy at the University of California, Berkeley, and lead author of the study.

The observations leading to this inference are being reported this week at a meeting of the American Astronomical Society and have been detailed in a paper submitted to The Astrophysical Journal.

At the heart of the results is the discovery that a new short gamma-ray burst called GRB 050509b, found by the Swift satellite earlier this month, was positioned near a bright, old galaxy called an elliptical galaxy. It is the first short gamma-ray burst pinpointed on the sky to high precision, about 0.5% the size of the full moon.

Unlike spiral galaxies such as the Milky Way, which contain many young as well as old stars, elliptical galaxies have expended almost all of their gaseous mass as fuel to build new stars. This means that elliptical galaxies are comprised mostly of very old stars and compact remnants of dead stars, such as neutron stars, black holes and white dwarfs.

Connecting a short gamma-ray burst to an old galaxy implicates such dead stars as the likely source of short gamma-ray bursts.

"Before now, all gamma-ray bursts had been associated with the death of young stars,â€? Bloom said. â€œInstead, it could be that in GRB 050509b we witnessed the violent coalescence of two neutron stars. Itâ€™s a preview, in a distant galaxy, to what will happen to the Hulse-

Taylor binary neutron star system in our own galaxy a billion years from now."

Russell Hulse and Joseph Taylor won the Nobel prize in Physics in 1993 for their 1974 discovery of a double neutron star binary in the Milky Way Galaxy, showing that the decay of the orbit was consistent with predictions from Einstein's Theory of General Relativity. Since then, there has been much speculation that some gamma-ray bursts could be produced when stars such as these collide.

In the last few hours of Mother's Day, May 8, 2005, astronomers around the world were alerted to a new short burst position. Bloom and his team quickly began to take images with telescopes in Arizona. Upon realizing that the burst had come from near an elliptical galaxy, they quickly secured a distance to that galaxy with the Keck II telescope in Hawaii, pegging it at about 2.7 billion light years from Earth.

"The distance to that elliptical galaxy just leapt out, so the real question became whether it was indeed the host of the gamma-ray burst." said Jason X. Prochaska, assistant professor of astronomy and astrophysics at the University of California, Santa Cruz, who coordinated the Keck spectroscopy effort.

As the data began to pour in, Bloom and his collaborators noticed a striking resemblance to predictions of the neutron star merger hypothesis for short gamma-ray bursts. The distance of the gamma-ray burst from the galaxy, the type of the galaxy and the distance from Earth were all in line with simulations of neutron star merger models completed years ago.

"The pieces of the puzzle seemed to start adding up, it was almost too concordant with theory," said Steinn Sigurdsson, professor of astronomy at Pennsylvania State University (Penn State) and co-author of the paper.

Because the Swift position of the burst is also consistent with a number of much fainter blue galaxies, the team relied on relative probabilities to argue for a connection to the elliptical galaxy.

Bloom put it bluntly: "It's been like CSI: Universe. We got a load of evidence for the merger hypothesis but no smoking gun yet."

UC Berkeley colleague Alex Filippenko, a professor of astronomy who also contributed to the study, concurred. "Additional objects of this type will need to be found before the evidence can be considered conclusive, but this is certainly an intriguing hint that at least some short-duration gamma-ray bursts come from mergers of neutron stars, or from neutron-star/black-hole mergers."

Bloom noted that there is still hope for those who believe alternative models for the production of short bursts, such as the explosion of single massive stars or star quakes on isolated, highly magnetized neutron stars. The authors reckon there is at most a few percent chance, similar to the chance of hitting your number on a Roulette wheel, that the gamma-ray burst was not associated with the giant elliptical galaxy and so could have been associated with a younger stellar population well beyond the elliptical.

UC Berkeley graduate student Ryan Foley, who analyzed the faint blue background galaxies, noted that, "Even if the association with the elliptical is wrong, all of the other possible associations are even farther away. So, we have probably uncovered the first direct evidence that short bursts arise from outside of our galaxy."

A large variety of gamma-ray burst durations are known, from a few milliseconds to thousands of seconds. Since 1993, two populations of gamma-ray bursters have been recognized, each with largely different spectra. One population lasts longer than 2 seconds and the other, the short gamma-ray bursts, last less than 2 seconds. GRB 050509b, with a duration of only 30 milliseconds, falls squarely in the short duration category. Until GRB 050509b, no short burst had been rapidly positioned on the sky to a precision necessary to pinpoint to a specific galaxy.

When a neutron star binary coalesces, the rapidly spinning merged system is expected to form a spinning black hole, orbited momentarily by a torus of neutron-density matter. Two large reservoirs of energy to produce the gamma-ray burst are in principle available: the binding energy of the orbiting debris, and the spin energy of the black hole.

"Compact binary mergers provide huge energy reservoirs and would yield a natural explanation for the shortest time scales observed in gamma-ray bursts," explained Enrico Ramirez-Ruiz, an astronomer at the Institute for Advanced Study in Princeton, New Jersey.

Neutron stars are the most dense objects of normal matter in the universe, supported against gravitational collapse by subatomic forces. They have a mass greater than the sun but occupy a volume smaller than 15 miles across. Most neutron stars are created when a large star dies as a supernova. In rare cases, when two large stars are born together as a binary, both remnant neutron stars could remain bound in orbit together, and in some cases, one of the neutron stars could collapse to a black hole before the second supernova if it accretes matter from the other star. Regardless of the end product, a bound pair of neutron stars or a black hole/neutron star binary system will eventually collide as the orbits decay due to the emission of gravitational radiation.

Jonathan Granot, a post-doctoral fellow at the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University, explained that, â€œGRB 050509b appears significantly less energetic compared to long-soft gamma-ray bursts, no matter what its distance was to Earth.â€?

Nevertheless, short and long gamma-ray bursts appear to have a similarly high efficiency for their gamma-ray emission, suggesting a similar emission mechanism. â€œThe next few short bursts should go a long way towards filling in the missing pieces.â€?

The results are based on new data from a NASA satellite called Swift and a bevy of ground-based telescopes, including the world's largest, the Keck 10-meter telescopes.

The group reporting results consists of Bloom, Prochaska, Filippenko, Foley, Ramirez-Ruiz, Granot and Sigurdsson, as well as Drs. Dave Pooley and Saurabh Jha of UC Berkeley, who worked on the X-ray imaging analysis and galaxy association probabilities, respectively. The complete publication team includes Michael Cooper, Dr. Joe Hennanwi, Dr. Weidong Li, Daniel Perley, Brian Gerke, Dr. Jeffrey Newman and Dr. Kevin Hurley of UC Berkeley; Cullen Blake, Dr. Emilio Falco, Jenny Greene and Dr. W. Michael Wood-Vasey of the Harvard-Smithsonian Center for Astrophysics; Prof. Aaron Barth of UC Irvine; Prof. Lori Lubin and Dr. Roy Gal of UC Davis; Dr. Mike Gladders and Dr. Luis Ho of the Carnegie Observatories; Dr. Hsiao-Wen Chen of the Massachusetts Institute of Technology; Ben Koester of the University of Michigan; and Dr. Gordon Squires of the California Institute of Technology.

Link: The Astrophysical Journal paper

Source: UC Berkeley Department of Astronomy (By Joshua Bloom)