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HOT ON THE TRAIL OF NATURE'S EXOTIC FLASHERS

MINNEAPOLIS, MINN. - Astronomers have uncovered tantalizing insight into the origin of short gamma-ray bursts, a mysterious class of high-energy transients that have eluded detail study until now. Unlike their long-duration cousins, which are known to arise when massive young stars die, short bursts appear to occur when old, dense neutron stars collide. The evidence for this distinct progenitor population heralds the opening of a new chapter into the study of Nature's most exotic explosions.

At the heart of the results is the discovery that a new short gamma-ray burst called GRB 050509b, found by Swift, was positioned (to an accuracy of about 0.5% the size of the full Moon) near a bright, old galaxy called an elliptical galaxy. It was the first short GRB pin-pointed on the sky to that precision.

Unlike spiral galaxies like the Milky Way, which contain many young as well as old stars, elliptical galaxies have expended almost all of their gaseous mass used as the 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 GRB to an old galaxy implicates such dead stars as the likely culprits.

"Before now, all GRBs had been associated with the death of young stars," said Joshua Bloom, assistant professor of astronomy at the University of California, Berkeley, and lead author of the study. "Instead, it could be that in GRB 050509b we witnessed the violent coalescence of two neutron stars. It'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," explained Bloom.

In 1993, Russell Hulse and Joseph Taylor won the Nobel prize in Physics 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 GRBs could be produced when stars such as these collide.

In the last few hours of Mother's Day, May 8, 2005, astronomers were alerted to the new short burst position and Bloom's 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: about 2.7 billion light years from Earth.

Prof. Jason X. Prochaska at the University of California, Santa Cruz, who coordinated the Keck spectroscopy effort, said "The distance to that elliptical galaxy just leapt out, so the real question became whether it was indeed the host of the GRB."

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 Penn State University 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."

Professor of astronomy Alex Filippenko, a Berkeley colleague of Bloom's who also contributed to the study, concurs: "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 GRBs come from mergers of neutron stars, or from neutron-star/black-hole mergers."

For those who believe alternative models for short burst production - such as from the explosion of a single massive star or a star quake on an isolated highly magnetized neutron star - there is still some hope. 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 GRB was not associated with the giant elliptical galaxy and so could have been associated with a younger stellar population well beyond the elliptical.

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 GRB 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 but one class lasting longer than 2 seconds and the other lasting less than 2 seconds. GRB 050509b, with a duration of only 30 milliseconds, falls squarely in the short duration category. Until 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 GRB are in principle available: the binding energy of the orbiting debris, and the spin energy of the black hole. Dr. Enrico Ramirez-Ruiz, at the Institute for Advanced Study in Princeton, NJ, explained that “compact binary mergers provide huge energy reservoirs and would yield a natural explanation for the shortest time scales observed in GRBs.”

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.

Dr. Jonathan Granot, at the Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, explained that "GRB 050509b appears significantly less energetic compared to long-soft GRBs, no matter what its distance was to Earth." Nevertheless, short and long GRBs appear to have a similarly high efficiency for their gamma-ray emission, suggesting a similar emission mechanism. "The next few short bursts should go a long way towards filling in the missing pieces."

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 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.

The group reporting results consists of Bloom, Prochaska, Filippenko, Foley, Ramirez-Ruiz, Granot, and Sigurdsson as well as Drs. Dave Pooley and Saurabh Jha (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, Dr. Kevin Hurley (UC Berkeley), Cullen Blake, Dr. Emilio Falco, Jenny Greene, Dr. W. Michael Wood-Vasey (Harvard-Smithsonian Center for Astrophysics), Prof. Aaron Barth (UC Irvine), Prof. Lori Lubin, Dr. Roy Gal (UC Davis), Dr. Mike Gladders, Dr. Luis Ho (Carnegie Observatories), Dr. Hsiao-Wen Chen (Massachusetts Institute of Technology), Ben Koester (Univ. of Michigan), and Dr. Gordon Squires (California Institute of Technology).

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ADDITIONAL RESOURCES:

* Submitted paper to the Astrophysical Journal:
http://arxiv.org/abs/astro-ph/0505480
* NASA/Swift Web link for GRB 050509b:
http://tinyurl.com/9ojme
* Press link at UC Berkeley:
http://astro.berkeley.edu/~jbloom/grb050509b