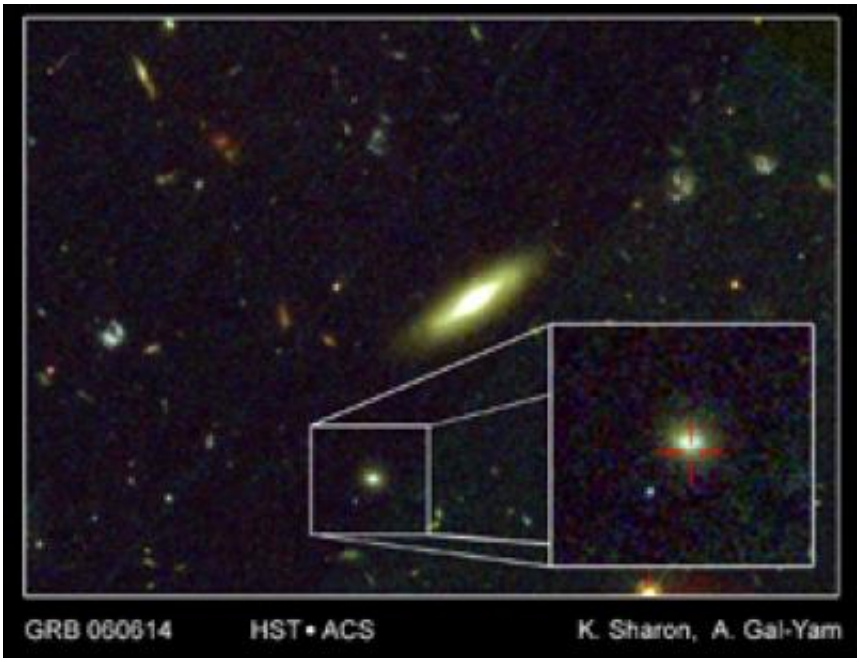
Astronomers discover new kind of black-hole explosion

December 20 2006



Hubble Space Telescope image of the host galaxy of the the "hybrid gamma-ray burst" GRB 060614 (centered in the small box). This galaxy, which has about 1 percent the mass of the Milky Way, is 1.6 billion light years away in the constellation Indus. The location of the gamma-ray burst within the galaxy is indicated by the red cross hairs. The sensitivity of these Hubble images is what enabled astronomers to rule out the possibility that this burst was produced in a supernova-like explosion of a massive star. Since all other long-duration bursts observed with Hubble have shown supernovae, this result has surprised astronomers, suggesting that they may be seeing a new type of black hole explosion. Credit: K. Sharon & A. Gal-Yam, Caltech

Scientists have discovered what appears to be a new kind of cosmic explosion -- a "hybrid gamma-ray burst" -- which will be the subject of four articles to be published in the journal *Nature* on 21 December 2006.

The burst was discovered with NASA's Swift satellite on 14 June 2006, and has since been studied with over a dozen telescopes, including the Hubble Space Telescope and large ground-based observatories.

"Gamma-ray bursts are the most powerful explosions in the Universe, yet they are random and fleeting, never appearing in the same place twice. The only way to study them in detail is to observe them as quickly as possible with the most powerful telescopes we have," explains Derek Fox, assistant professor of astronomy and astrophysics at Penn State. Fox is an author of one of the *Nature* papers, which presents ground-based and Hubble Space Telescope observations of the fading afterglow of the hybrid gamma-ray burst in optical light. "This burst -- unlike all other long gamma-ray bursts we have seen at close distance -- was not accompanied by a supernova, for reasons we do not yet fully understand." Fox is the Principal Investigator of one of the Hubble Space Telescope programs that contributed data on the hybrid gamma-ray burst.

As with other gamma-ray bursts, this hybrid burst is likely signaling the birth of a new black hole. It is unclear, however, what kind of object or objects exploded or merged to create the black hole or, perhaps, something even more bizarre. The hybrid burst exhibits properties of the two known classes of gamma-ray bursts, characterized as "long" and "short," yet has other features that cannot be explained.

Long gamma-ray bursts are longer than two seconds and appear to be from the core collapse of a massive star, forming a black hole. Most of these bursts come from the edge of the visible universe. Short gamma-ray bursts, which are under two seconds and often last just a few

milliseconds, appear to result from the merger of two neutron stars or a neutron star with a black hole, which subsequently creates a new or bigger black hole.

"We have lots of data on this burst and have dedicated lots of observation time to it, and we just can't figure out what exploded," said Neil Gehrels of NASA Goddard Space Flight Center, lead author on one of the *Nature* reports. "All the data seem to point to a new but perhaps not-so-uncommon kind of cosmic explosion." The hybrid burst, called GRB 060614 after the date it was detected, was 1.6 billion light years away in the constellation Indus. Penn State astrophysicists John Nousek and Peter Mészáros are coauthors of the paper led by Gehrels, which describes the discovery and observation of this burst with the Swift satellite. This paper demonstrates that the burst -- despite its 102-second-long emission -- exhibits some characteristics expected from short bursts that are less than a second long. But the burst lacked the hallmark of a supernova, or star explosion, commonly seen shortly after long bursts. Also, the burst's host galaxy has a low star-formation rate with few stars massive enough to produce long gamma-ray bursts and supernovae.

"This burst was close enough to detect a supernova if it existed," said Avishay Gal-Yam of Caltech, lead author on another Nature report, "but even Hubble didn't see anything." Co-author Derek Fox of Penn State adds: "We have been tracking these bursts regularly with Hubble, and only a short burst would be expected to disappear like this. It was a huge surprise when we looked at these data and found nothing there."

Certain properties of the recent 060614 burst suggest that this new burst behaved more like a short burst from a merger of stars than a long burst from a single collapsing star. But no previous theoretical model of mergers can support a sustained release of gamma-ray energy for 102 seconds. However, this new burst, which was eight times more luminous than other unquestioned short bursts, has spawned a new theoretical

paradigm that will be published in a paper in the Astrophysical Journal. This paper was co-authored by scientists at Goddard and Penn State, including Penn State's Mészáros and David Burrows, lead scientist for Swift's X-ray telescope, and was led by Bing Zhang, a former research associate at Penn State who now is at the University of Nevada at Las Vegas.

"We used a well-known scaling relation between the peak energy of the spectra and the apparent luminosity, which this burst appears to obey, to scale down this burst's luminosity to a value comparable to that of other short bursts," Mészáros says. By showing that a "scaled down" version of this burst looks a lot like a short burst, the paper provides independent evidence for associating it with the short-burst population. "It may be that many -- or perhaps all -- bursts that normally would have been classified as short, have a longer-lasting and dimmer emission of lower-energy gamma-rays, which becomes more prominent when they are as luminous as this very bright burst," he explains. "If so, the new puzzle is to understand what gives rise to these dimmer and longer-lasting emissions -- and this puzzle is in virtually uncharted territory."

While scientists remain undecided on whether this was a long short burst from a merger or a long burst from a star explosion that, for some unknown reason, did not produce a supernova, most conclude that some new process must be at play: either the model of mergers creating second-long bursts needs a major overhaul, or the progenitor star from an explosion is intrinsically different from the kind that makes supernovae.

Source: Penn State