Leading theories of cosmic explosions contradicted in a flash

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Satellite that could help solve mystery to be deactivated in September

Observations of a cosmic explosion detected on Feb. 15 by two NASA satellites have thrown into doubt one popular explanation for such explosions and have also seriously weakened the argument for yet another, according to University of Chicago astrophysicist Don Lamb. But solving the mystery any time soon may be forestalled by plans to shut down one of the satellites in September.

The explosion in question is a powerful burst of X-rays called an X-ray flash that was observed by NASA's Swift and High Energy Transient Explorer-2 satellites. X-ray flashes seem to be related to gamma-ray bursts, the most powerful explosions in the universe. "No one understands this relationship at all. It's a complete mystery," said Lamb, the Louis Block Professor in Astronomy & Astrophysics at the University of Chicago and a member of the HETE-2 science team.

Lamb will present some ideas on the relationship of X-ray flashes to gamma-ray bursts on May 31 during a meeting of the American Astronomical Society in Minneapolis. The co-authors of his paper are Tim Donaghy, a Ph.D. student in physics, and Carlo Graziani, Senior Research Associate in Astronomy & Astrophysics, both at the University of Chicago.

Discovered in 1969, Gamma-ray bursts last anywhere from fractions of a second to many minutes and pack the output of as many as 1,000 exploding stars. They occur almost daily, come from any direction in the sky, and are followed by afterglows that are visible for a few days at X-ray and optical wavelengths.

Discovered in 2000, X-ray flashes seem to form the less powerful end of a continuum of cosmic explosions that progresses to X-ray rich gamma-ray bursts and then culminates in gamma-ray bursts proper. All three phenomena occur in approximately equal numbers.

"We think that regular gamma-ray bursts are all produced by the collapse of massive stars and probably the creation of black holes," Lamb said. "I personally think it's essentially a certainty that X-ray flashes are produced by the same kind of event."

But exactly how that occurs remains a matter of speculation. One possibility is that a varying rotation rate of the collapsed core of these massive stars produces different opening angles of the jets emitted from the bursts. "Maybe sometimes they're rotating rapidly and you get narrow jets and other times they're rotating less rapidly and you get wider X-ray rich jets and sometimes they're rotating still more slowly and you get very broad jets that produce the X-ray flashes," Lamb explained.

The Feb. 15 X-ray flash, designated XRF 050215b, has yielded the best data ever on this phenomenon, thanks to the joint observations of the two NASA satellites. The next-best data come from a flash known as XRF 020427, detected in April 2002 by the Italian BeppoSAX satellite. Three characteristics of both flashes conflict with a popular theory that X-ray flashes are gamma-ray bursts as viewed from slightly off to the side of the jet instead of head on.

First, according to the popular theory, scientists expected the energy levels of an X-ray flash's afterglow to connect smoothly on a gradient with the energy of the burst itself. Second, they expected the afterglow to fade fast. And third, they expected the afterglow to be faint when compared to the original burst.

These expectations all follow from Albert Einstein's theory of special relativity, but none of them have panned out. Scientists apparently cannot rely on special relativity to explain X-ray flashes, Lamb said.

The satellite observations also conflict with the theory that the shape of the jets from a gamma-ray burst are universal, but only look different because of the viewing angle. Based on this theory, scientists would have predicted that the afterglow of the Feb. 15 X-ray flash afterglow would have faded within a day or so following the initial burst. But the afterglow showed now signs of fading even five days following the burst.

One theory suggests that all three types of explosions contain the same amount of energy, but that the opening angle of the jet emitted from the explosions defines their apparent brightness.

In this scenario, narrow jets produce the gamma-ray bursts, wider jets result in X-ray rich gamma-ray bursts, and the broadest lead to X-ray flashes. Lamb and many others view this theory as a possibility. "There's a lot of people who don't or are not at all sure," he said.

The question could probably be settled within the next few years with more burst observations conducted jointly between the Swift and HETE-2 satellites, which measure slightly different properties of the phenomena. But NASA plans to discontinue the HETE-2 mission this September.

NASA would somehow need to find an additional $1.5 million annually to keep HETE-2 operating. "It's not the best budgetary climate to try to pull this thing off," Lamb said. But if NASA somehow manages to do it, "The HETE mission would leverage the science that Swift could do by a significant amount," he said.

Link: The HETE-2 Satellite

Source: University of Chicago