Rapid supernova could be new class of exploding star

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Artist's impression of an AM-CVn star system, where helium flows from one star, a helium white dwarf (upper right), onto another, piling up in an accretion disk around a small, dense primary star. Helium from the disk eventually falls onto the star, forming a shell that may end up exploding as a Type .Ia (point one A) supernova.

(PhysOrg.com) -- An unusual supernova rediscovered in seven-year-old data may be the first example of a new type of exploding star, possibly from a binary star system where helium flows from one white dwarf onto another and detonates in a thermonuclear explosion.

In a paper first published online Nov. 5 in the journal *Science Express*, University of California, Berkeley, and Lawrence Berkeley National Laboratory (LBNL) astronomer Dovi Poznanski and his colleagues describe the outburst, dubbed SN 2002bj, and why they believe it is a new type of explosion.

"This is the fastest evolving supernova we have ever seen," said Poznanski, a UC Berkeley post-doctoral fellow who recently joined LBNL's Computational Cosmology Center. "It was three to four times faster than a standard supernova, basically disappearing within 20 days. Its brightness just dropped like a rock."

This rapid drop, coupled with the supernova's faintness, the strong signature of helium in the spectrum of the explosion, the absence of hydrogen, and the possible presence of vanadium - an element never previously identified in supernova spectra - points toward helium detonation on a white dwarf, the astronomers said.

"We think this may well be a new physical explosion mechanism, not just a minor variation of ones already known," said co-author Alex Filippenko, UC Berkeley professor of astronomy. "This supernova is qualitatively different from the complete disruption of a white dwarf, known as a Type Ia supernova, or the collapse of an iron core and rebound of the surrounding material, so-called 'core-collapse supernovae.'"

Co-author Joshua Bloom, UC Berkeley associate professor of astronomy, also views SN 2002bj as a "new beast" quite different from the two well-known classes of supernovae.

"We have seen great diversity in those two main supernova mechanisms, but even within that diversity, observationally, there is a limited range of variation spectrally and in how events evolve in time," he said. "This object (SN 2002bj) falls outside that range."

The supernova was detected in 2002 in the galaxy NGC 1821, in the constellation Lepus, by Filippenko's Katzman Automatic Imaging Telescope (KAIT) at Lick Observatory near San Jose as well as by amateur astronomers. Due to an unfortunate alignment of circumstances, the supernova was erroneously classified by the astronomical community as a common Type II supernova and filed away.

In June, Poznanski happened upon the spectrum while searching for Type II supernovae he hopes to use as distance indicators to confirm the accelerating expansion of the universe. When he carefully examined a high-quality spectrum of SN 2002bj, he realized that the supernova was not a Type II at all, but an unusual kind of supernova more akin to a Type Ia.

The spectrum had been obtained seven days after its discovery by Filippenko and Douglas Leonard, at the time a UC Berkeley graduate student, now an assistant professor of astronomy at San Diego State University, using the Keck I telescope.

"Its classification was a mistake, which is understandable given the conditions of the data. But, of course, a redress of old data with fresh eyes is not usually this fruitful," Leonard said.

The exploding star SN 2002bj in the galaxy NGC 1821, captured by the Katzman Automated Imaging Telescope at Lick Observatory on Feb. 28, 2002. Using KAIT, the Lick Observatory Supernova Search (LOSS) has found and imaged about 800 supernovae in the past 10 years.

Pulling out follow-up images made by KAIT, Poznanski and UC Berkeley graduate student Mohan Ganeshalingam found that the brightness of SN 2002bj dropped off so rapidly that the supernova disappeared 20 days after its discovery. An image of that area of the sky taken seven days prior to its discovery showed no supernova, so it had brightened and dimmed into obscurity in less than 27 days, whereas most supernovae brighten and dim over three to four months.

Searching through thousands of supernovae spectra, Poznanski and graduate student Ryan Chornock - now a post-doctoral fellow at Harvard University - could find none that had such an awkward composition, but they did come across a theory of fast but faint supernovae that seemed to fit.

Proposed by Lars Bildsten and colleagues - Bildsten is a professor of physics at the Kavli Institute for Theoretical Physics at UC Santa

Barbara - the theory involves AM Canum Venaticorum (AM CVn) binary systems, which are composed of two white dwarfs, one of which is primarily made of helium that is being slowly pulled by gravity onto its companion. White dwarfs are the remnants of stars that burned their hydrogen down to carbon and oxygen or, in some particular cases, to helium.

In a 2007 Astrophysical Journal Letters paper, Bildsten and colleagues proposed that in AM CVn systems, when enough helium has been accumulated on the surface of the primary white dwarf, an explosion will occur that can "power a faint … and rapidly rising (few days) thermonuclear supernova."

Christopher Stubbs, chair of the Department of Physics at Harvard University, jokingly dubbed it a ".Ia" (point one A) supernova, because it is one-tenth as bright for one-tenth the time as a Type Ia supernova, and the name stuck.

Filippenko noted that this explosion is nothing like a regular Type Ia explosion because the white dwarf survives the detonation of the helium shell. In fact, it has similarities to both a nova and a supernova. Novas occur when matter - primarily hydrogen - falls onto a star and accumulates in a shell that can flare up as brief thermonuclear explosions. SN 2002bj is a "super" nova, generating about 1,000 times the energy of a standard nova, he said.

The explosion would have created heavy elements such as chromium, which decays to vanadium and thence to titanium. Thus, absorption lines of vanadium could be expected, Poznanski said.

Filippenko noted that the past few years have "yielded a bonanza of weird supernovae."

"A lot of us who have studied supernovae for several decades are amazed at the quality and quantity of data coming in recently, showing interesting new subclasses or even strange new physical classes of supernovae," he said. "It whets my appetite for what else we might find out there with these large, wide-sky surveys like the Palomar Transient Factory, Dark Energy Survey and the Large Synoptic Survey Telescope. KAIT has discovered about 800 supernovae, but these new surveys will find thousands or hundreds of thousands of supernovae."

Poznanski, too, is expecting the current Palomar Transient Factory, which uses a wide-field camera to search the sky daily for new objects, to find more supernovae like SN 2002bj. The factory is a project led by Shri Kulkarni, professor of astronomy at the California Institute of Technology (Caltech), and involves many of the co-authors on the Science Express paper, including Peter Nugent, co-leader of the Computational Cosmology Center at LBNL, who runs the search for transients.

"The Palomar survey will be able to find many rare objects, like SN 2002bj, by scanning huge parts of the sky and not limit itself to the big, bright and nearby galaxies," Poznanski said.

Source: University of California - Berkeley (news : web)

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