Earliest-yet observation of August SN2011fe supernova nails it: Destroyed star was white dwarf

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Last year's discovery of the nearest Type Ia supernova in decades – captured only 11 hours after it exploded – allowed astronomers to finally cinch the identity of the stars behind these explosions, which have become key measures of cosmic distance.

That supernova, called SN2011fe, and presumably most Type Ia supernovae were originally white dwarfs extremely dense and compact stars composed mostly of carbon and oxygen.

Now, thanks to a much earlier, fluke observation of SN2011fe by a small robotic telescope on the island of Mallorca, University of California, Berkeley, and Lawrence Berkeley National Laboratory (LBNL) astronomers can boost confidence even higher that Type Ia supernovae originate from white dwarfs.

"A fortuitous observation only four hours after we think the star exploded allowed us to put much more constraining limits on the size of the thing that blew up," said Joshua Bloom, UC Berkeley associate professor of astronomy and first author of a paper interpreting the observation that will appear in the Jan. 10 issue of the *Astrophysical Journal Letters*. "The size of the progenitor is so small and the density so high, it pretty much rules out any other reasonable or even fringe possibility. This is a direct confirmation that what blew up is a carbon-oxygen white dwarf."

In 1998, two research teams used Type Ia supernovae as standard candles to conclude that the expansion of the universe is accelerating, presumably fueled by a mysterious dark energy. That discovery earned three astrophysicists, including UC Berkeley and LBNL's Saul Perlmutter, the 2011 Nobel Prize in Physics.

Bloom will present his results on Wednesday, Jan. 11, during an 11:30 a.m. CST media briefing at the national meeting of the American Astronomical Society in Austin, Texas.

Smaller than a main sequence star

Bloom and his colleagues were coauthors of two papers published Dec. 15, 2011, in the journal Nature that concluded that SN2011fe's progenitor star was a compact object with a diameter less than one-tenth that of the sun. Based on the brightness of the explosion, which occurred 21 million light years away in the Pinwheel Galaxy (M101), and the fact that the explosive debris contained large amounts of carbon and oxygen, coauthor Peter Nugent of LBNL and his colleagues concluded that before it exploded, the star was almost certainly a carbon-oxygen white dwarf.

UC Berkeley astronomer Weidong Li and colleagues concluded the same thing based on the inability of the Hubble Space Telescope to detect any star at that spot before the supernova ignited.

White dwarfs are very dense stars about the size of the Earth that burned all their hydrogen and helium into carbon and oxygen before stopping fusion altogether, destined to cool slowly into dark cinders.

After the papers were submitted to *Nature* in early November, UC Berkeley and LBNL astronomers learned that the 17-inch PIRATE telescope on Mallorca, operated as a remote-controlled teaching telescope by The Open University in the U.K., had obtained a deep, wide-field image of the Pinwheel Galaxy (M101) only four hours after the explosion. Because the supernova was not visible in the PIRATE image, Bloom and his colleagues, including Nugent, were able to put an even more stringent upper limit on the early brightness of the supernova.

The new analysis concludes that the progenitor star had a diameter less than one-fiftieth that of the sun – 5 to 10 times smaller than last year's limit – which implies a density 100 to 1,000 times higher.

While the previous limits ruled out hydrogen-burning main sequence stars and red giants – the most likely alternatives to a white dwarf, said Ken J. Shen, an Einstein postdoctoral fellow at LBNL and UC Berkeley – they only "placed weak constraints on smaller stars that burn helium or carbon in their cores. Only with this new observation can we now rule these out."

Looking for light from the early shock wave

UC Berkeley's Daniel Kasen, an assistant professor of physics, and Shen used theoretical models of exploding stars to estimate how bright a star of a given size would be within hours of ignition from the glow of the supernova's expanding shock wave. The bigger the star, the brighter the glow from the shock. The non-detection of the supernova four hours after it exploded enabled Kasen, Shen, Bloom and their colleagues to rule out stars larger than a white dwarf.

"This is the first time we can really be confident about what is exploding," Shen said.

Their analysis relied on theories of how a carbon-oxygen white dwarf explodes. Presumably, the white dwarf acquires mass from its binary companion until the temperature and pressure in the core rises high enough to restart fusion reactions. This time, carbon and oxygen are fused into nickel and iron in a reaction that consumes the star within seconds, blowing it up like a runaway thermonuclear bomb, Kasen said.

The first light from the explosion should be from the glow of superheated gas as the debris from the star plows through surrounding gas and dust. No one has ever caught this shockwave glow from a Type Ia supernova because it's quite dim and drops off quickly, Kasen said. The light astronomers see is from the decay of radioactive elements created in the explosion, which can shine brightly for weeks afterward.

The inability to see SN2011fe four hours after the explosion, Kasen said, allowed the team to set much more stringent limits on the size of the progenitor star.

"The earlier you get on it (the supernova), or the nearer it is, the better your chance of actually seeing the glowing outflow from the shockwave," he said. "This is the closest we've gotten. If it had been 10 instead of 20 million light years from Earth, we might have seen something four hours after the explosion."

The PIRATE observation also narrowed the limits on the companion star published last month by Li and his colleagues. The diameter of the supernova's companion must be less than one-tenth that of the sun, ruling out red giant and normal main-sequence stars.

More information: ApJ Letters paper: dx.doi.org/10.1088/2041-8205/744/2/L17

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