Astronomers image the exploding fireball stage of a nova (Update)

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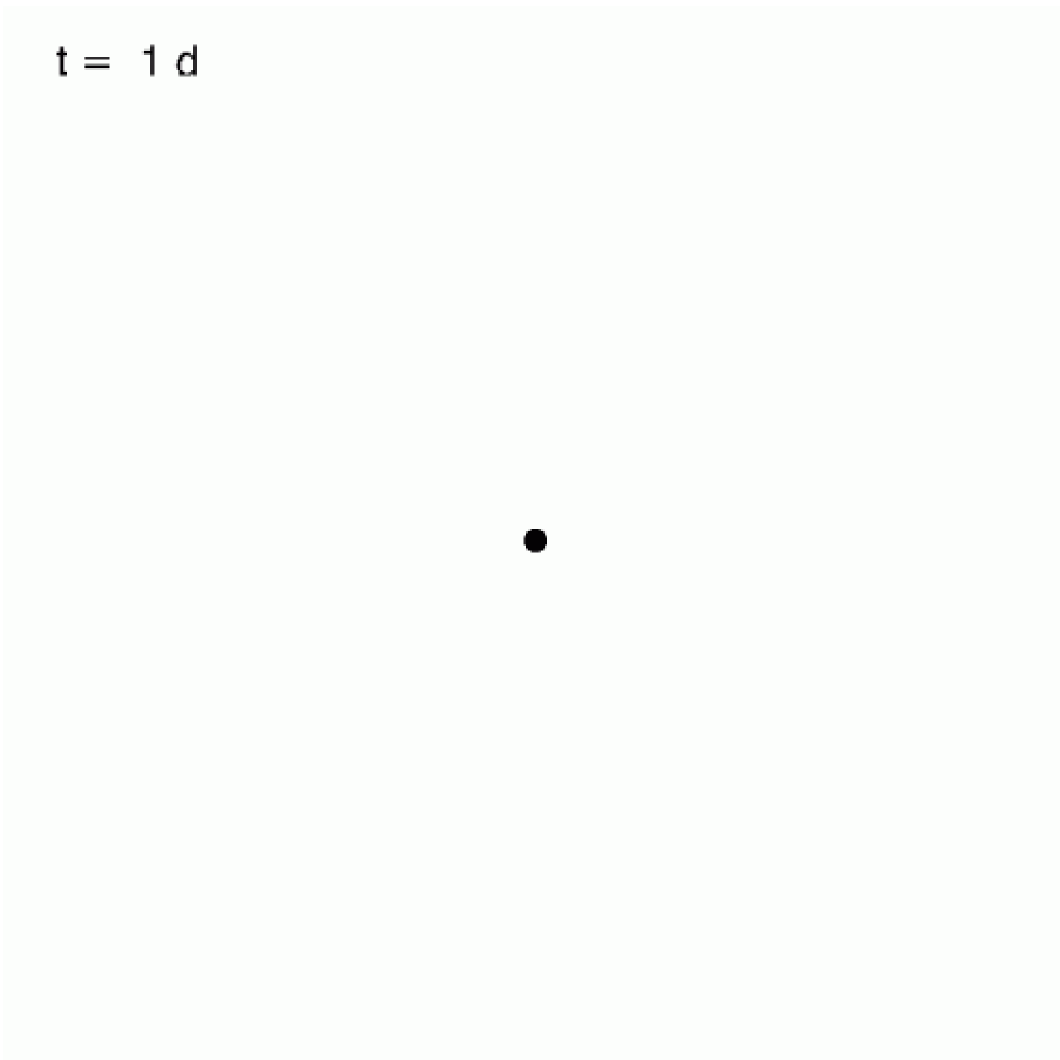

Animation of Fireball expansion

The first images of a nova during its early fireball stage—when it ejects material, and gases expand and cool—show that this activity is more complicated than predicted.

That is the conclusion, published in the current issue of *Nature*, from a research collaboration led by Georgia State University Astronomer Gail Schaefer that includes 37 researchers from 17 institutions. The researchers observed the expanding thermonuclear fireball from a nova that erupted last year in the constellation Delphinus.

"This is the first time astronomers have been able to witness an expanding fireball with such great detail, rather than as a tiny point of light way out in the galaxy," Schaefer said. "It was amazing to see the material expanding outward each day after the explosion."

A nova occurs after a thin layer of hydrogen builds up on the surface of a white dwarf—a highly evolved star with the mass of the sun packed into the volume of the Earth. A normal star accompanies the white dwarf in a binary star system, providing that hydrogen as the two stars orbit each other.

The normal star sheds a small amount of its mass through a stream onto the white dwarf's surface that gradually builds up a hydrogen "ocean." When that ocean is perhaps 200 meters (~650 feet) deep, the white dwarf's enormous surface gravity produces a pressure at the bottom of the hydrogen layer sufficient to trigger thermonuclear fusion, essentially a stellar H-bomb. Over ensuing weeks, the nova slowly fades as the fireball expands, cools and dissipates. Surprisingly, this seeming cataclysm on the white dwarf's surface has no real effect on the star or its companion, and the flow of material resumes so that the detonation will likely repeat at a future date.

Because these objects are generally very far from the sun and faint until the explosion occurs, they do not appear on classical star maps. Instead, a "new" star suddenly appears where none was before.

The famous 16th century Danish astronomer Tycho Brahe described this sudden appearance of stars in his 1572 book De Stella Nova, and the Latin nova for "new" became attached to this phenomenon, which also manifests itself through far more energetic processes that are destructive of the exploding star in a supernova.

Nova Delphinus lights up

Last year, on Aug. 14, the Japanese amateur astronomer Koichi Itagaki discovered a "new" star, promptly named Nova Delphinus 2013. Within 15 hours of discovery and within 24 hours of actual explosion, the NSF-funded Center for High Angular Resolution Astronomy (CHARA) and its Georgia State University astronomers pointed array telescopes, located at historic Mount Wilson Observatory in the San Gabriel Mountains of Southern California, toward Nova Del 2013 to image the fireball and measure it. They measured the nova on a total of 27 nights over two months; the first measurement represents the earliest size yet obtained for a nova event.

The CHARA facility uses optical interferometry principles to combine light from six telescopes to create images with very high resolution, equivalent to that of a telescope with a diameter of more than 300 meters. This makes it capable of seeing details far smaller in angular extent than traditional telescopes on the ground or in space. To put it in perspective, it can resolve imagery the size of a U.S nickel on the top of the Eiffel tower in Paris from the distance of Los Angeles, Calif.

"Since novae can dim rapidly after their outburst, having sufficient brightness and resolution at the critical times is very challenging," said collaborator Dipankar Banerjee from the Indian Physical Research

Laboratory. "CHARA is one of the few instruments in the world that can do this."

CHARA's measurement of angular expansion rate of the nova, combined with measurements of the expansion velocity from independent spectroscopic observations, allowed researchers to determine distance to the star. Nova Del 2013 was found to be 14,800 light years from the sun. This means that, while we witnessed this explosion here on Earth last August, it actually took place nearly 15,000 years ago.

Knowing the nova's distance along with its angular size allows astronomers to determine the fireball's physical size at different times of observation. During the first observation on Aug. 15, the fireball was roughly the size of Earth's orbit. Two days later, it was already the size of Mars' orbit, and by day 12, the fireball surface would extend out to Jupiter's orbit. When last measured 43 days after detonation, it had expanded nearly 20-fold to nearly the size of Neptune's orbit. But it was the thermonuclear explosion back on the white dwarf's surface that fueled this remarkable expansion rate of more than 600 kilometers-per-second (over 1.3 million miles per hour).

Catch a flying elliptical nova fireball

The University of Michigan Infrared Beam Combiner (MIRC), an instrument that combines all six telescopes of the CHARA Array simultaneously, created the nova fireball's first images and showed that the explosion was not precisely spherical, and that the fireball actually had an ellipticity of 13 percent. This will help astronomers understand how material is ejected from a white dwarf during this kind of explosion.

"One remaining mystery here is how the shape of the explosion changed so much over just a few days," said John Monnier, MIRC principal investigator. "I can't wait for the next big nova to happen soon to see what more we can learn about this dramatic process."

The CHARA observations also showed that fireball outer layers became more diffuse and transparent as it expanded. After about 30 days, researchers saw evidence for a brightening in outer layers, potentially caused by dust grains forming in cooler, clumpy structures that emitted light at infrared wavelengths.

"This result is a dramatic illustration of the powerful new capability provided by optical interferometry," said Jim Neff, NSF astronomy program officer. "And it also highlights the importance of rapid communication and cooperation among astronomers worldwide, both amateur and professional."

It has been almost 350 years since Carthusian monk Pere Dom Anthelme discovered the first true nova in the constellation of Vulpecula in 1670. Since then thousands of novae have been discovered, but it is only in the last decade or so that it has become possible to image the earliest stages of the explosion due to interferometry's high resolution. The new CHARA measurements follow the expansion of Nova Del 2013 from its very early relatively compact stages until the fireball was nearly the size of our solar system. Studying how the structure of the nova changed at the earliest stages brings new insights to theoretical models of novae eruptions.

More information: The expanding fireball of Nova Delphini 2013, *Nature*, dx.doi.org/10.1038/nature13834

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