Behind the big flash

Calculations reveal new explanation of supernova explosions

Type Ia supernovae are playing a leading role in revealing the history of the Universe. As cosmic distance markers, Type Ia supernovae, combined with other observations, led to the discovery of the mysterious dark energy that is accelerating the expansion of the Universe. These supernovae also play an important role in the chemical evolution of the Universe, fusing carbon and oxygen atoms into heavier elements such as magnesium, silicon, sulfur, iron, and nickel.

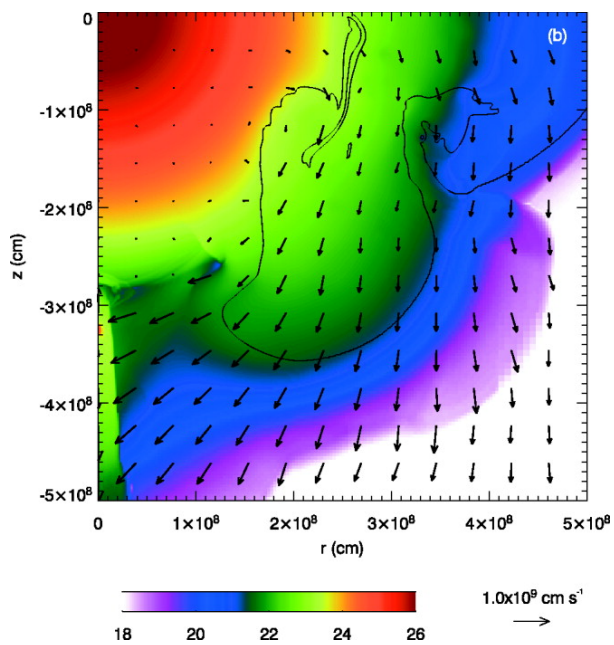
Understanding Type Ia supernovae in more detail will provide answers to many cosmological questions. But one of the most basic questions about the supernovae themselves remains unanswered: How do they explode?

Details on how the explosion might be initiated have emerged from the unprecedented full-star simulations created by a research project running on NERSC computers, "Thermonuclear Supernovae: Stellar Explosions in Three Dimensions," led by Tomasz Plewa of the Center for Astrophysical Thermonuclear Flashes at the University of Chicago and the Nicolaus Copernicus Astronomical Center in Warsaw.

The simulations that Plewa and his colleague Timur Linde ran on NERSC's Seaborg computer, using 3.2 million processor hours, investigated the birth of the thermonuclear flame, an essential part of an unexpected scenario that the researchers call "gravitationally confined detonation." In this scenario, the explosion begins with burning at a point slightly off-center in the core of the star, which results in the formation of a buoyancy-driven bubble of hot material. This bubble rushes outward at transonic speeds and breaks through the stellar surface. Confined by the star's gravity, the burning shock wave races around the surface of the star, pushing the fuel-rich outer layers ahead of it like a thermonuclear tsunami.

This flood of nuclear fuel converges at the point opposite the bubble breakout, forming a conical compressed region bounded by the shock (see figure). The crashing waves of matter carry enough mass and energy to trigger a detonation just above the stellar surface, resulting in a supernova explosion that incinerates the progenitor star.

This model accounts for a number of typical characteristics observed in Type Ia supernovae, including the layered structure of the ejected matter and the asymmetry of the explosion.



This quarter cross section shows the density evolution of the surface flood across the lower portion of the star 2.005 seconds after ignition. The conical compressed region is the bright green strip in the lower left; the high-pressure detonation point is the red spot just below -3×10^8.

Berkeley Lab Computing Sciences

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