A tiny flame shines light on supernovae explosions

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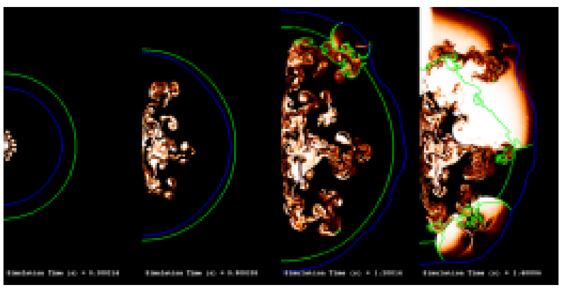

This figure shows four snapshots in time as the flame propagates initially subsonically outward reaching a specified density (green) at which point the flame transitions to a detonation. Shown in color is a reaction progress variable describing the burning of nuclear statistical quasi-equilibrium (NSQE) products to nuclear statistical equilibrium (NSE) products. The blue contour marks the separation between the previously convective core and the isothermal outer layer. Note that the scale of the right-most figure is larger than the other three.

Starting from the behavior of small flames in the laboratory, a team of researchers has gained new insights into the titanic forces that drive Type Ia supernova explosions. These stellar explosions are important tools for studying the evolution of the universe, so a better understanding of how they behave would help answer some of the fundamental questions in astronomy.

Type Ia supernovae form when a white dwarf star – the left-over cinder of a star like our Sun – accumulates so much mass from a companion star that it reignites its collapsed stellar furnace and detonates, briefly outshining all other stars in its host galaxy. Because these stellar explosions have a characteristic brightness, astronomers use them to calculate cosmic distances. (It was by studying Type Ia supernovae that two independent research teams determined that the expansion of the Universe was accelerating, earning them the 2011 Nobel Prize in Physics).

To better understand the complex conditions driving this type of supernova, the researchers performed new 3-D calculations of the turbulence that is thought to push a slow-burning flame past its limits, causing a rapid detonation -- the so-called deflagration-to-detonation transition (DDT). How this transition might occur is hotly debated, and these calculations provide insights into what is happening at the moment when the white dwarf star makes this spectacular transition to supernova. "Turbulence properties inferred from these simulations provides insight into the DDT process, if it occurs," said Aaron Jackson, currently an NRC Research Associate working in the Laboratory for Computational Physics and Fluid Dynamics at the Naval Research Laboratory in Washington, D.C. At the time of this research, Jackson was a graduate student at Stony Brook University on Long Island, New York.

Jackson and his colleagues Dean Townsley from the University of Alabama at Tuscaloosa, and Alan Calder also of Stony Brook, will present their data at the American Physical Society's (APS) Division of Fluid Dynamics (DFD) meeting in Baltimore, Nov. 20-22, 2011.

While the deflagration-detonation transition mechanism is still not well understood, a prevailing hypothesis in the astrophysics community is that if turbulence is intense enough, DDT will occur. Extreme turbulent intensities inferred in the white dwarf from the researchers' simulations suggest DDT is likely, but the lack of knowledge about the process allows a large range of outcomes from the explosion. Matching simulations to observed supernovae can identify likely conditions for DDT.

"There are a few options for how to simulate how they [supernovae] might work, each of which has different advantages and disadvantages," said Townsley. "Our goal is to provide a more realistic simulation of how a given supernova scenario will perform, but that is a long-term goal and involves many different improvements that are still in progress."

The researchers speculate that this better understanding of the physical underpinnings of the explosion mechanism will give us more confidence in using Type Ia supernovae as standard candles, and may yield more precise distance estimates.

More information: The talk, "Turbulence and Combustion in Type Ia Supernovae," is on Tuesday, Nov. 22, 2011. Abstract: absimage.aps.org/image/MWS_DFD11-2011-001839.pdf

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