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Thermonuclear Supernovae on Supercomputers

Abstract: Thermonuclear supernovae are some of the most spectacular explosive events in the Universe, converting about a solar mass of C/O-rich white dwarf material into intermediate mass (Si, Ca, etc) and iron-group (Fe, Ni, etc) elements in roughly a second. The kinetic energy imparted by the blast wave to the plasma is enough to unbind the entire white dwarf, which expels enriched material into the surrounding interstellar space at mildly relativistic speeds ($< 0.1c$). The fact that the majority of thermonuclear supernovae explode with similarly-shaped lightcurves allows them to be used as standardizable distance indicators; this enabled a Nobel Prize in 2011 by showing that the Universe's expansion is accelerating. In spite of their observational standardization, we still don't know the exact progenitor systems for these explosions as archival data has not shown a direct detection of the progenitor, but only placed constraints on particular models. I will discuss some of my recent work with collaborators on simulating the so-called "Single-Degenerate, Chandrasekhar-Mass" (MCh) model, whereby accretion of material onto a white dwarf from a non-degenerate companion star heats and compresses the core of the white dwarf to the point of carbon fusion. I will emphasize the different computational techniques one uses to study the problem from end-to-end, including the difficulty of linking each phase of the evolution. In particular, I will show the results of our linking the low Mach number convective evolution resulting from core carbon fusion to the evolution of a turbulent thermonuclear flame as it burns its way toward the surface of the white dwarf. These high-resolution simulations are at the forefront of three-dimensional thermonuclear supernova modeling, especially for the MCh model, but still leave room for improvement both in terms of the nuclear physics and models of turbulence-flame interactions.