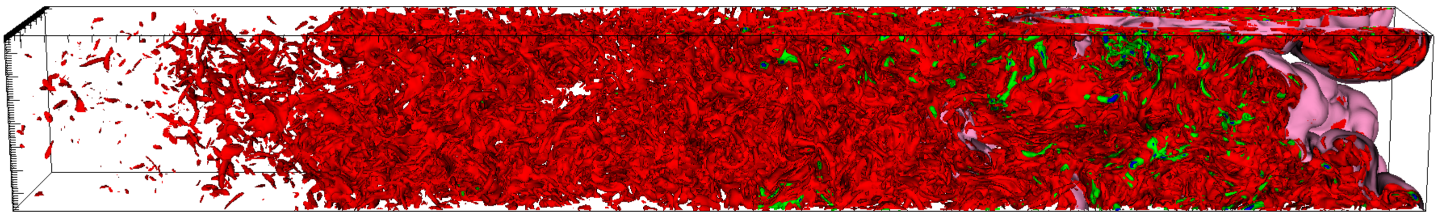
Turbulent Thermonuclear Flames in Type Ia Supernovae



Flame surface (pink) and isosurfaces of vorticity magnitude (red, green, blue increasing) for a turbulent, buoyancy-unstable flame propagating upwards (to the right as shown).

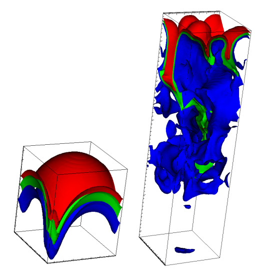
A Type Ia Supernova occurs when a white dwarf star slightly more massive than our sun is completely incinerated and the resulting processed elements are ejected into the interstellar medium. The decay of the unstable isotopes produced in the explosion, mostly ^{56}Ni, creates an extremely bright event. These supernovae show a remarkable regularity in the relationship between their brightness and duration that can be calibrated to determine their absolute brightness. This, along with their intrinsic brightness, makes Type Ia's excellent indicators for measuring cosmological distances. In addition, these explosions contribute much of the iron content of the solar system and is an essential ingredient in star formation.

The behavior of the turbulent nuclear flame which spreads through the star at the beginning of the dynamic phase of the runaway is one of the major physical uncertainties in modeling these explosions. The burning takes place in a flame front, a propagating sheet millimeters thick in which carbon and oxygen are fused to silicon- and then iron-group nuclides. The hot ash is less dense than the surrounding fuel, and therefore is driven upward by buoyancy. This accelerates the propagation of the flame front by creating strong turbulence which increases the surface area of the flame by indroducing ripples.

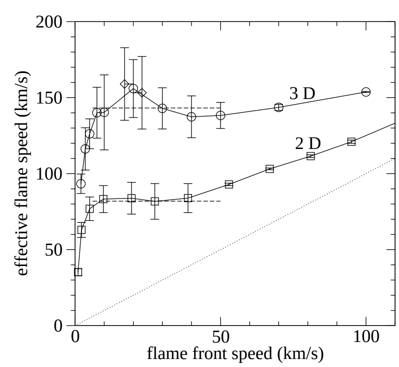
By performing high resolution simulations of buoyancy-driven flames in channels like that shown above, turbulence creation and turbulence-flame interaction are both captured in a realistic manner. These processes cannot be resolved with the necessary detail in a full-star explosion simulation. Therefore, simulation of the explosion proceeds by abstracting the essential features of the turbulent flame such as the rate at which it consumes fuel, so that large-scale behaviors relevant to the dynamics on the stellar scale are accurately captured.

Townsley, D. M., Asida, S., Jena, T., & Lamb, D. Q. "Simulating Self-Regulated Rayleigh-Taylor Driven Flames," in preparation

This work is supported by the NSF Physics Frontier Centers' Joint Institute for Nuclear Astrophysics under grant PHY 02-16783 and DOE under grant DE-FG 02-91ER 40606 and Contract B523820 to the ASC Alliances Center for Astrophysical Flashes.



Laminar (left) and turbulent (right) flame surfaces propagating upward.



Effective burning rate as a function of front propagation speed. In the flat region indicated, the burning rate is independent of the front speed, depending only on the strength of the buoyancy.

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