Turbulent Flames in Type Ia Supernovae

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Type Ia supernovae (SNe Ia) are the biggest thermonuclear explosions in the universe. They are thought to arise when a white dwarf star gradually accretes matter from a binary partner, and grows to approximately 1.4 solar masses. At this point, the carbon/oxygen core of the star begins to undergo rapid thermonuclear burning, eventually resulting in an explosion.

These thermonuclear flames are of the order of centimeters thick, embedded in a star that is thousands of kilometers across. Therefore, simulations of SNe Ia are not able to capture the full range of scales from first principles, necessitating the use of numerical models, which need to account for the complex interactions of the chemistry with the turbulent convective motions within the star.

Laminar burning velocities for thermonuclear flames are extremely small relative to the sound speed in the star, making detailed studies of turbulence flame interactions intractable using compressible flow simulations. A low Mach number algorithm is used to study the detailed evolution of planar flame sheets propagating through a three-dimensional turbulent background. The use of a low Mach number adaptive algorithm allows us to accurately resolve the thermal structure of the flame and capture the inviscid energy cascade, while implicitly incorporating energy dissipation at the grid-scale.

The focus of these simulations is the detailed microphysics of turbulence/flame interactions across a range of conditions from the flamelet regime to the distributed burning regime, with the aim of formulating a turbulent flame model for large scale simulations that is grounded in physics.