Mixing of density inhomogeneities in compressible flows

Abstract

Mixing of fluids with density inhomogeneities in compressible flows plays a critical role in many high-speed and high-energy applications, including inertial confinement fusion, supersonic combustion, and shock-driven instabilities. Unlike passive scalar mixing, active scalar mixing involves two-way coupling between species concentration, density, and the velocity field, giving rise to nonlinear transport mechanisms that fundamentally alter mixing dynamics. This dissertation investigates active scalar mixing in compressible flows, with a particular emphasis on level-2 mixing, where density gradients directly influence flow evolution. Fourier pseudospectral direct numerical simulations (DNS) are employed to study the mixing dynamics of two non-reacting species across diffusion-dominated, turbulence-driven, and shock-driven regimes. Density variations are introduced through molecular-weight differences and characterized using the Atwood number (At), enabling systematic comparison between lighter and heavier mixtures.