Self-generation of Magnetic Fields in Discontinuous Plasmas

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Abstract

Hydrodynamic instabilities play an important role in the evolution of astrophysical systems. The Rayleigh-Taylor instability (RTI), for example, occurs when a dense fluid is accelerated against a light fluid, producing well known finger-like structures and material mixing. In the case of supernova (SN) explosions, RTI occurs when a blast wave moves through materials of varying densities, such as layers of hydrogen and helium. Scientists have attempted to investigate this system experimentally in a laboratory setting. In our supernova Rayleigh-Taylor mixing experiment on the Omega laser (Kuranz et al. 2010) we accomplished this by using a laser to irradiate a target and drive a blast wave through material which has been designed to mimic the H/He interface in a core-collapse supernova progenitor envelope. The experimental results differed from simulation outcomes, most notably by revealing suppressed RT mushroom-cap formation and significantly more extended RT spikes.

In this computational study, we consider the effects of magnetic fields and thermal conductivity on RTI. It is known that a misalignment of temperature and electron density gradients can generate a

magnetic field from zero-field initial conditions (the Biermann Battery effect). This field can then be modified due to complex interactions between ions and electrons in the plasma. Magnetic field and thermal conductivity are known to modify RTI growth and thus may account for the observed differences between computer models and experimental results. To this end, we implemented and verified generalized Ohm's law and anisotropic thermal conduction using the Braginskii formulation in the FLASH-based Proteus code. We present verification results of our implementation and preliminary results in application to the RTI problem under high-energy density conditions.