NIF laboratory astrophysics experiments investigating the effects of a radiative shock on hydrodynamic instabilities

C.C. Kuranz[1*], H.-S. Park[2],C.M. Huntington[2], R.P. Drake[1], B.A. Remington[2], D. Klanantar[2] S. MacLaren[2], K.Raman[2], A.Miles[2], M. Trantham[2], J.L. Kline[3], K. Flippo[3], F.W. Doss[3], D. Shvarts[1,4]

[1] University of Michigan, Ann Arbor, MI, USA
[2] Lawrence Livermore National Laboratory, Livermore, CA, USA
[3] Los Alamos National Laboratory, Los Alamos, NM, USA
[4]Nuclear Research Center, Negev, Israel
*email: ckuranz@umich.edu

Energy-transport effects can alter the structure that develops as a supernova evolves into a supernova remnant. The Rayleigh Taylor instability is thought to produce structure at the interface between the stellar ejecta and the circumstellar matter, based on simple models and hydrodynamic simulations. When a blast wave emerges from an exploding star, it drives a forward shock into the circumstellar medium (CSM) and a reverse shock forms in the expanding stellar ejecta, creating a young supernova remnant (SNR). As mass accumulates in the shocked layers, the interface between these two shocks decelerates, becoming unstable to the Rayleigh Taylor (RT) instability. Simulations predict that RT produces structures at this interface, having a range of spatial scales. When the CSM is dense enough, as in the case of SN 1993J, the hot shocked matter can produce significant radiative fluxes that affect the emission from the SNR. Here we report experimental results from the National Ignition Facility to explore how large energy fluxes, which are present in supernovae such as SN 1993J, might affect this structure. The experiment used NIF to create a hydrodynamically material unstable interface subject to a high energy flux by the emergence of a blast wave into lower-density matter, in analogy to the SNR. We also preformed and with a low energy flux to compare the affect of the energy flux on the instability growth. We found that the Rayleigh-Taylor growth was reduced in the experiments with a high energy flux. In analyzing the comparison with SN 1993J, we discovered that the energy fluxes produced by heat conduction appear to be larger than the radiative energy fluxes, and large enough to have dramatic consequences. No reported astrophysical simulations have included radiation and heat conduction self-consistently in modeling supernova remnants and should be noted in understanding of young supernova remnants. We present data and simulations from Rayleigh-Taylor instability experiments in high- and low- energy flux experiments performed at the National Ignition Facility. We also will discuss the apparent, larger role of heat conduction when we closely examined the comparison between the experimental results, and the SNR observations and models.