Radiative Shock Solutions

Robert B. Lowrie
Los Alamos National Laboratory, Computational Physics and Methods Group (CCS-2), MS D413, Los Alamos, NM 87544 USA

Radiation hydrodynamics (RHD) is nonlinear and analytic solutions are rare. This talk will describe semi-analytic solutions of planar radiative shock waves for equilibrium and nonequilibrium diffusion radiation models. We will also compare these solutions with results from a finite-volume simulation code. These are the first semi-analytic solutions we know of for high-energy density, radiation hydrodynamics.

By "semi-analytic," we mean that the solution requires the numerical integration of nonlinear ordinary-differential equations (ODEs). The errors in this procedure are easy to control, so that these solutions may be used for simulation code verification. Moreover, the ODEs offer new insight into the shock structure and physics of these shocks. For example, previous work has assumed that the material temperature reaches its maximum on the downstream side of the embedded hydrodynamic shock (Zel'dovich spike). We show that in certain cases, the temperature may actually continue to increase after the hydrodynamic shock and reaches its maximum at a specific value of the local Mach number.

The semi-analytic solutions may be used to verify RHD simulation codes. Radiative shocks are very demanding for a code to compute, because the extent of the radiation precursor may be orders-of-magnitude larger than the relaxation region downstream of the Zel'dovich spike. Adaptive-mesh refinement (AMR) is necessary to resolve efficiently the multiple length scales in the problem. We will quantitatively compare results from the RAGE AMR code with our semi-analytic solution. As an example of the utility of AMR, using a 2:1 refinement ratio between mesh levels, RAGE requires 13 levels of mesh refinement in order to adequately resolve a certain Mach 5 radiative shock. The AMR mesh uses 967 mesh cells, as opposed to the 245,760 mesh cells required for the equivalent equally-spaced mesh.