TEMPLE UNIVERSITY
Department of Mathematics

Applied Mathematics and Scientific Computing Seminar

Room 617 Wachman Hall

Wednesday, 20 January 2010, 4:00 p.m.

An Asymptotic Preserving Hybrid Godunov Method for Radiation Hydrodynamics

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Abstract.

From a mathematical perspective, radiation hydrodynamics can be thought of as a system of hyperbolic balance laws with dual multiscale behavior (multiscale behavior in the hyperbolic wave speeds as well as multiscale behavior in the source term relaxation). However, these dual behaviors are quite different and cause breakdowns in monotonicity and stability, respectively, while influencing the temporal resolution of the problem. These considerations are taken into account when designing a robust algorithm.

This talk presents a hybrid Godunov method for one-dimensional radiation hydrodynamics that is asymptotically preserving and uniformly well behaved from the photon free streaming (hyperbolic) limit through the weak equilibrium diffusion (parabolic) limit and to the strong equilibrium diffusion (hyperbolic) limit. The method incorporates a backward Euler upwinding scheme for the radiation energy density E_r and flux F_r as well as a modified Godunov scheme for the material density ρ, momentum m, and energy density E.

The backward Euler scheme is first-order accurate and uses an implicit HLLE flux function to temporally advance the radiation components according to the material flow scale. The modified Godunov scheme is second-order accurate and directly couples stiff source term effects to the hyperbolic structure of the system of conservation laws. This Godunov technique is composed of a predictor step that is based on Duhamel's principle and a corrector step that is based on Picard iteration. The Godunov scheme is explicit on the material flow scale but is unsplit and fully couples matter and radiation without invoking a diffusion-type approximation for radiation hydrodynamics. This technique derives from earlier work by Miniati & Colella 2007. Numerical tests demonstrate that the method is stable, robust, and accurate across various parameter regimes.