[구SF-03] A Relativistic Magnetohydrodynamic Code Based on an Upwind Scheme

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Building a relativistic magnetohydrodynamic (RMHD) code based on upwind schemes has been a challenging project, because of the absence of analytic expressions of eigenvalues and eigenvectors. We found analytic expressions of eigenvalues and eigenvectors for adiabatic RMHD flows which are relatively simple and manageable. Especially, our eigenvectors can handle all degenerate points. Using these analytic forms, we built a code based on the total variation diminishing (TVD) scheme, and successfully performed one-dimensional shock tube tests.

[구SF-04] Study of the Kinetic Effects on Relativistic Unmagnetized Shocks using 3D PIC Simulations

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Shocks are ubiquitous in astrophysical plasmas: bow shocks are formed by the interaction of solar wind with planetary magnetic fields, and supernova explosions and jets produce shocks in interstellar and intergalactic spaces. The global morphologies of these shocks are usually described by a set of magnetohydrodynamic (MHD) equations which tacitly assumes local thermal equilibrium, and the resulting Rankine-Hugoniot shock jump conditions are applied to obtain the relationship between the upstream and downstream physical quantities. While thermal equilibrium can be achieved easily in collisional fluids, it is generally believed that collisions are infrequent in astrophysical settings. In fact, shock widths are much smaller than collisional mean free paths and a variety of kinetic phenomena are seen at the shock fronts according to in situ observations of planetary shocks. Hence, both the MHD and kinetic equations have been adopted in theoretical and numerical studies to describe different aspects of the physical phenomena associated with astrophysical shocks. In this paper, we present the results of 3D relativistic particle-in-cell (PIC) simulations for ion-electron plasmas, with focus on the shock structures: when a jet propagates into an unmagnetized ambient plasma, a shock forms in the nonlinear stage of the Weibel instability. As the shock shows the structures that resemble those predicted in MHD systems, we compare the results with those predicted in the MHD shocks. We also discuss the thermalization processes of the upstream flows based on the time evolutions of the phase space and the velocity distribution, as well as the wave spectra analyses.