Godunov method for Riemann problem with non-conservative product: Simulation of non-equilibrium plasmas for magnetic reconnection

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The ability to model, simulate and predict magnetic reconnection (MR) is a stumbling block in order to predict space weather and geomagnetic storms. Some fundamental aspects of MR are not yet well understood. A thermal non-equilibrium plasma model is used for describing the sun chromosphere [1]. However the model contains non-conservative terms. Theses terms naturally appear in the derivation using a multi-scale Chapman-Enskog expansion.
A possible remedy to this problem is to replace, without a sound physical basis, the equation of the internal energy of electron by an equation of entropy for electron [2]. These methods are working well for regular solutions or for problems where the diffusion is strong enough to compensate the non-conservative term. However, the sun chromosphere involves strong dynamics and shocks [3]. When dealing with shock waves or Alfvén wave, it is necessary to develop numerical tools to be able to capture the proper dynamics of the system.
The Riemann problem has been studied and a Riemann solver has been developped for the convective part of the system of equations describing the thermal non-equilibrium plasma. This solver is based on finite volume Godunov scheme in order to resolve discontinuity and avoid spurious oscillations. We focus on 1D finite volume simulations of Riemann problems where the jump conditions are computed using travelling waves. The effect of the non-conservative term on the jump conditions and Riemann simulations has been studied and compared with other methods. Through these developments, the key relationships between governing equations, numerical strategy and solar physics are pointed out.

Références

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