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An Entropy Stable Three Dimensional Ideal MHD Solver with Guaranteed Positive Pressure

Authors : Andrew R. Winters, Gregor J. Gassner

Abstract : A high-order numerical magentohydrodynamics (MHD) solver built upon a non-linear entropy stable numerical flux function that supports eight traveling wave solutions will be described. The method is designed to treat the divergence-free constraint on the magnetic field in a similar fashion to a hyperbolic divergence cleaning technique. The solver is especially well-suited for flows involving strong discontinuities due to its strong stability without the need to enforce artificial low density or energy limits. Furthermore, a new formulation of the numerical algorithm to guarantee positivity of the pressure during the simulation is described and presented. By construction, the solver conserves mass, momentum, and energy and is entropy stable. High spatial order is obtained through the use of a third order limiting technique. High temporal order is achieved by utilizing the family of strong stability preserving (SSP) Runge-Kutta methods. Main attributes of the solver are presented as well as details on an implementation of the new solver into the multi-physics, multi-scale simulation code FLASH. The accuracy, robustness, and computational efficiency is demonstrated with a variety of numerical tests. Comparisons are also made between the new solver and existing methods already present in FLASH framework.

Keywords : entropy stability, finite volume scheme, magnetohydrodynamics, pressure positivity
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