An all-Mach semi-implicit finite volume method for magnetically-dominated MHD

R. Dematte, A. Farmakalides, S.T. Millmore and N. Nikiforakis

Laboratory for Scientific Computing, University of Cambridge (aaf37@cam.ac.uk)

In this work we present a novel conservative, semi-implicit, finite-volume scheme for the time-dependent, visco-resistive magneto-hydrodynamics system of equations in multiple space dimensions. The scheme is based on a flux-vector splitting approach, where the original system is split into two subsystems: one containing the advective terms (advective subsystem) and the other containing the rest (pressure subsystem). The former is discretised explicitly while the latter is treated implicitly. As a consequence, the pressure subsystem accounts for the Alfvén and magnetosonic waves, and the complete scheme is constrained by a mild CFL stability condition which depends only on the advective flow velocity. Since the magnetosonic waves are treated implicitly, this scheme is well suited for low Mach-number flows and for the incompressible limit of the MHD equations. Since the Alfvén waves are also treated implicitly, the scheme is also well suited for high beta (ratio of magnetic to gas pressure) flows, typically found in fusion applications. The algorithm is validated by means of several benchmark problems for high and low Mach-number flows, as well as a novel case-study where the flow Mach-number varies time-dependently from a near steady-state to supersonic. This will allow to capture seamlessly the evolution of the flow-field from sustained equilibrium to locally unstable (ELMs) and severe (VDEs) events in tokamak reactors.

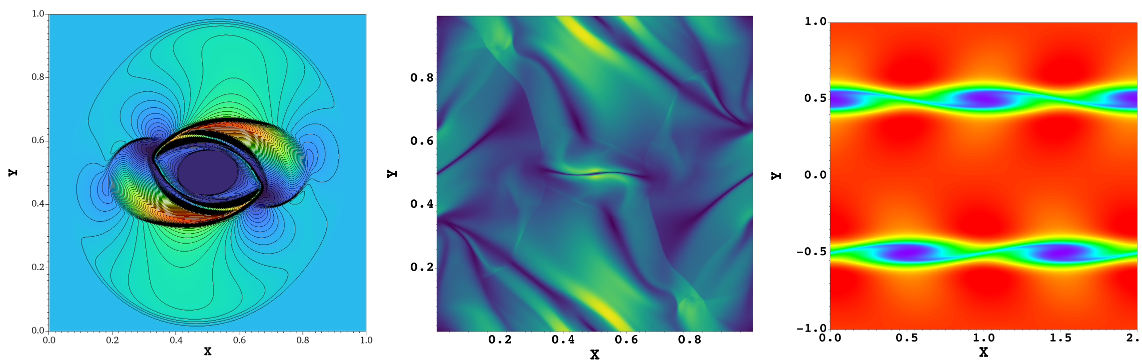

Figure 1: Validation test cases for both high and low Mach-number flow regimes. From left to right - MHD rotor, Orszag-Tang vortex, VRMHD Kelvin-Helmholtz instability.

References

[1] D.S. Balsara, G. I. Montecinos, and E.F. Toro, Journal of Computational Physics **311**, (2016)