COMPRESSIBLE MHD SOLVER FOR SPACE WEATHER APPLICATIONS

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Ideal Magnetohydrodynamics deals with a coupling between Euler's equations and Maxwell's equations. The MHD equations can be used as a simplified model for the simulation of the space weather, which results from the interaction of the solar wind with the magnetosphere of the earth. In particular we wish to model the supersonic flow of charged particles ejected from the sun, basically considered non relativistic, fully ionised and treated as a single fluid flow having infinite conductivity. This means that the influence of the electric field is negligible since the medium in which the particles are travelling is quasi neutral.

To solve the ideal MHD equations a 3D Godunov Finite Volume solver has been developed starting from EUPHORIA, a 3D Euler/Navier-Stokes solver previously developed at the Von Karman Institute.

A particular problem in the numerical treatment of the ideal MHD equations concerns the physical constraint that magnetic monopoles do not exist ($\nabla \cdot \mathbf{B} = 0$). This condition is not always exactly preserved after the discretization of the equations. Two strategies have been used to deal with the $\nabla \cdot \mathbf{B} = 0$ constraint.
The first one has been proposed by K. G. Powell and consists of adding a source term in the MHD equations. The second one has been proposed by G. Toth in order to avoid the non conservative formulation of the source term in the Powell approach. Instead of the source term, Toth has proposed a temporal and space averaging for the update of the magnetic field directly using the induction equation.

Both methods were validated, comparing the results obtained with the reference solutions shown in the original papers from both authors. These tests concern plasma interaction in shock tubes. Finally, a first attempt to model real fully 3D space weather situations was investigated with the simulation of supersonic flows carrying a magnetic field and blowing on a perfectly conducting sphere.

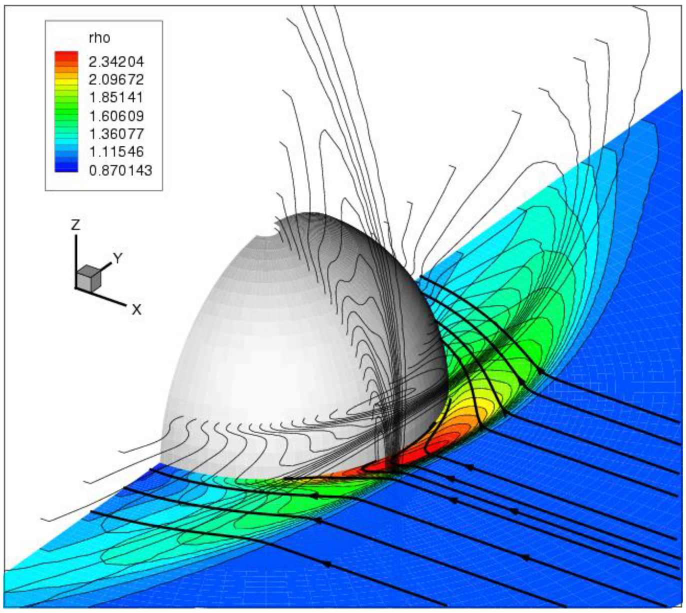

Figure 1: 3D flow visualisation of a magnetically dominated bow shock around a sphere. Density contour (thin solid) are shown for three different planes. Magnetic field lines (thick solid) are shown for the xy plane.