Study of slab magnetic reconnection by means of a self-adapting grid code based on the wavelet transform

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In a strong magnetized plasma, the local evolution of single helicity reconnection modes in the poloidal plane may be efficiently described in cartesian coordinates in a slab geometry (x, y), neglecting the z coordinate. The simplest model to describe the evolution of a magnetized plasma in this configuration and in the Alfvénic frequency range is provided by the two-field model equations (see e.g. [2]),

$$\frac{\partial F}{\partial t} + [\varphi, F] = \rho_s^2 [U, \psi] + \eta \nabla^2 (\psi - \psi_{eq}) \qquad F \equiv \psi - d_e^2 \nabla^2 \psi$$

$$\frac{\partial U}{\partial t} + [\varphi, U] = [\psi, \nabla^2 \psi] \qquad U \equiv \nabla^2 \varphi$$

The stream functions φ and ψ are related to the electromagnetic fields by $\mathbf{B}_{pol} = \nabla \psi \times \mathbf{e}_z$ and $\mathbf{E} = -\nabla \varphi - (1/c)\partial \psi/\partial t \, \mathbf{e}_z$, and to the plasma response by means of the $\mathbf{E} \times \mathbf{B}$-drift, which to the leading order represents the average plasma velocity in the poloidal plane. Among the characteristic parameters ρ_s (ion-sound Larmor radius), d_e (electron skin depth) and η (plasma resistivity), only the two latter may break the ideal preservation (linking theorem) of the magnetic topology, by thus triggering a reconnection process. However, the smallness of such parameters in the low collisional regimes encountered in fusion or astrophysical plasmas, implies that existing models for magnetic reconnection predict reconnection rates still too slow with respect to what is experimentally observed. **Computational limitations** have so far mostly constrained **numerical investigations of magnetic reconnection** to non-realistic multi-scale separations, whereas important effects may come into play, e.g. due to the separation of the ion and electron dynamics, or, as suggested by analogous studies in the whistler frequency regime ([3]) due to the transport of the equilibrium free energy from the macroscopic scales of the equilibrium shear length L to the small scales developing inside of the reconnection layer, which in real configurations are separated by some orders of magnitude.

The use of a **self-adapting grid code based on the wavelet transform** to study slab reconnection processes is pertinent due to the localization of the small scale nonlinear dynamics inside the reconnection layer, whose size scales with some power of d_e or η, depending on the regime. The integration is performed by means of a **Runge-Kutta fourth order scheme in time and a third order up-wind scheme** relying on compact finite differences in space. By using a self-adapting algorithm based on Adaptive Mesh Refinement technics with a wavelet based detection of areas of interest [4], the code allows to automatically refine along the dynamics which develop inside of the reconnection layer. There we locally let the space step decrease to $2^{-14}L$ for $500,000$ points in the (non-uniform) grid, yielding a 0.2% compression rate. We discuss the features of the numerical model and provide some preliminary examples of study of the nonlinear dynamics of magnetic reconnection for small values (i.e. $\ll 1$) of d_e/L and η.

Références

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