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

E. Deriaz[1], D. Del Sarto[1], M Ottaviani[2]

[1] Institute Jean Lamour UMR 7198, Université de Lorraine, Nancy, France
[2] CEA-IRFM,F-13108 Saint-Paul-lez-Durance, France

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 $(x, y)$, the neglected $z$ coordinate corresponding to negligible curvature effects along the toroidal 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 $\varphi$ and $\psi$ 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 $\rho_s$ (ion-sound Larmor radius), $d_e$ (electron skin depth) and $\eta$ (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 econcountered in fusion or astrophysical plasmas, implies that existing models for magnetic reconnection predict reconnection rates still too slow with respect to what experimentally observed. Mechanisms to account for this discrepancy are therefore sought, and in some regimes indications have been recently given of the occurrence of a nonlinear acceleration of the reconnection rate (see [3]). 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 (which is for example responsible of the transition to the whistler regime −see e.g. [4]), or, as suggested by analogous studies in the whistler frequency regime [5], 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 transforms" 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 $\eta$, 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 [6] with a wavelet based detection of areas of interest [7], the code allows an automatic fine refinement while following the nonlinear dynamics which develops inside of the reconnection layer. There we locally let the space step decrease to $2^{-14}L$ for $500,000$ points in total, 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 $\eta$.

# References


[1] M. Yamada, R. Kulsrud, H. Ji, *Rev. Mod. Phys.* **82**, 603 (2010).

[2] F. Porcelli, D. Borgogno, F. Califano, D. Grasso, M. Ottaviani, F. Pegoraro *Plasma Phys. Controll. Fusion* **44**, B389 (2002).

[3] A. Biancalani, B. Scott, *Europhys. Lett.* **97**, 112901 (2012).

[4] D. Biskamp, E. Schwarz, J.F. Drake, *Phys. Plasmas* **4**, 1002 (1997).

[5] N. Attico, F. Califano, F. Pegoraro, *Phys. Plasmas* **7**, 2381 (2000).

[6] R. Teyssier, *Astronomy & Astrophysics* **385**, 337 (2002).

[7] E. Deriaz et V. Perrier, *SIAM Multiscale Modeling and Simulation*, **7**(3) 1101–1129 (2008).