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Collisionless reconnection in presence of a guide field

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Abstract

The aim of the Geospace Environment Modeling (GEM) magnetic reconnection challenge [1] was to understand the physics of fast magnetic reconnection in high β plasmas. The procedure adopted in the challenge was to investigate a standard 2-dimensional configuration based on a Harris current sheet. The GEM challenge project revealed that the primary mechanism which enables the break of the frozen-in conditions is given by the non-gyrotropic electron pressure terms. The reconnection rate is then enhanced thanks to the Hall term which gives rise to the whistler dynamics.

In the present work, we extend the simulation results by adding a guide field in order to study reconnection in low β plasmas.

The implicit Particle-in-Cell code CELESTE3D is used for this purpose. The implicit moment method is used to handle effectively multiple time and length scales processes: the relevant time and length scales are resolved while effectively averaging over faster time scales (e.g., electron plasma frequency) and shorter length scales (e.g., Debye length). The practical consequence is the ability to handle realistic mass ratios and to simulate macroscopic systems while retaining a kinetic description of both ions and electrons. In a previous work, we have applied CELESTE3D to investigate reconnection in high β plasmas, showing the ability to consider the physical mass ratio of 1836 [2].

Using simulations, we study how the reconnection rate scales with the guide field and the mass ratio. In general, the mass ratio has little importance on the reconnection rate, while the guide field diminishes it and decreases the reconnection saturation level. The ion and electron motion is strongly influenced by the presence of the guide field, which makes possible for ions and electrons to drift along directions otherwise not possible. In presence of a guide field, the whistler dynamics is suppressed, and thus the Hall effect and the quadrupolar structure of the guide field related to it vanish. The whistler dynamics is replaced by the Kinetic Alfvén Dynamics and the ion sound radius takes the place of the ion inertial length as the length scale of interest.

[1] J. Birn et al., J. Geophys. Res. 106, 3715 (2001).
[2] P.Ricci, G. Lapenta, J.U. Brackbill, Geophys. Res. Lett., 29, 10.1029/2002GL015314 (2002).