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Scaling of reconnection and stability of current sheets in large systems

A. Bhattacharjee

Space Science Center, University of New Hampshire, Durham, NH 03824, USA

The scaling of collisionless reconnection in large systems is a subject of great interest in space and astrophysical plasmas. We have carried out a sequence of 2D simulations using the same initial conditions for large systems using resistive MHD, Hall MHD and fully kinetic particle-in-cell models. It is shown that the dynamics of thin current sheets is sensitive to the mechanism that breaks field lines (spatially uniform resistivity, electron inertia, and/or electron pressure tensor), and that velocity shear along the thin current sheets plays an important role in controlling their geometry and stability. In the resistive MHD model, the long thin current sheet spanning Y-points becomes near-explosively unstable to secondary tearing, producing plasmoids copiously. In resistive Hall MHD, the nonlinear dynamics changes qualitatively, as the Y-points contract spontaneously to form X-points thwarting the secondary tearing instabilities seen in the resistive MHD study. A steady state is eventually realized due to a balance between the spatial gradients of the current density and the velocity shear. Hall MHD simulations in which electron inertia breaks field lines as well as PIC simulations show a very different dynamics, exhibiting the tendency to form extended thin current sheets and secondary tearing instabilities. We address the issue of scaling in all three models, especially the dependence on system size and the dissipation mechanism, and discuss the relevance of these results to solar flares and magnetospheric substorms.