Embedded Simulations of Collisionless Reconnection

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In this work, a new integrated approach is examined for modeling collisionless reconnection in large systems in which Hall-MHD calculations using both a full electron pressure tensor model and particle ions are embedded inside a MHD simulation so that the complex physics and more expensive computations are done only in a small region where higher fidelity is needed. The Hall-MHD calculations resolve the inner region to model correctly the ion inertial scale physics near the X point, including the decoupling of the ion and electron motions, the ion gyro-radius effects, and the reconnection electric field produced by the off-diagonal electron pressure tensor terms [1]. The effects of the off-diagonal terms in the ion pressure tensor, i.e., the ion gyro-radius corrections, are necessary in order to model correctly the ion out-of-plane motion; these effects can be modeled efficiently in a particle Hall-MHD simulation in which particle ions are used in a predictor/corrector manner to implement ion gyro-radius corrections. In the outer region of the embedded simulation, the MHD code calculates large-scale fields and one-fluid quantities and also provides appropriate boundary conditions for the two-fluid calculations done in inner region. We show that reconnection occurs due to electron viscous effects contained in the off-diagonal terms of the electron pressure tensor, and that the embedded simulations exhibit smooth transitions of plasma and field quantities between the MHD/Hall regions, with small-scale physics represented well in the thin current sheet and near the X point.

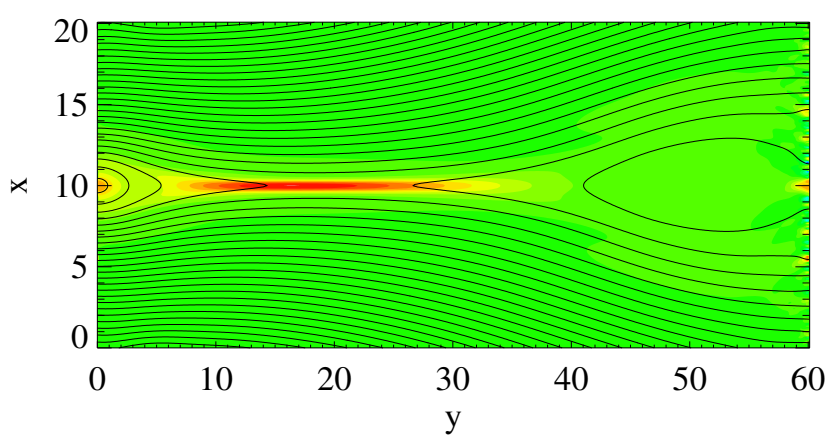

Figure 1: An embedded Hall-MHD/MHD simulation in which the inner Hall-MHD region extends from $x = 5.5$ to $x = 14.5$ and $y = 0$ to $y = 50$ (in units of the ion inertial scale $c/\omega_{\rm pi}$). Overlaid on the magnetic field lines in the simulation plane are color contours of the out-of-plane current density J_z during reconnection.

[1] L. Yin and D. Winske, Phys. Plasmas **10**, 1595 (2003).