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Hall current effects in dynamic magnetic reconnection solutions

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Abstract

The impact of Hall current contributions on flow driven planar magnetic merging solutions is investigated using both analytical and numerical approaches. The Hall current is important if the dimensionless Hall parameter (or normalized ion skin depth) satisfies $d_i > \eta$, where η is the inverse Lundquist number for the plasma. Analysis of a simplified 1D current sheet model shows that the Hall current initially manifests itself by inducing a non-reconnecting perpendicular "separator" component in the magnetic field. Only when the stronger condition $d_i^2 > \eta$ is satisfied does the Hall current affect the reconnecting planar field. These analytic predictions are tested by performing a series of numerical experiments in periodic geometry, using the full system of planar MHD equations. These results confirm that the nature of the merging changes dramatically when the Hall coupling satisfies $d_i^2 > \eta$. In line with the analytic treatment, the coupling provided by the Hall term leads to the emergence of multiple current layers that can enhance the global Ohmic dissipation at the expense of the reconnection rate. However, the details of the dissipation depend critically on the symmetries of the simulation, and when the merging is "head-on" (i.e., comprises four-fold symmetry) the reconnection rate can be enhanced. The 2D simulations also show that strong Hall currents eventually lead to the destruction of the typical quasi-one-dimensional current sheets found in the standard MHD model.

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