Impact of electromagnetic turbulence in the reconnection layer: Large-scale 3D kinetic simulations and analytical model for effective magnetic dissipation

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Abstract

Most of the plasma fluid equations have employed the electrical resistivity to generate the magnetic dissipation required for magnetic reconnection to occur in a collisionless plasma. However, there has been no clear evidence that such a model is indeed appropriate in the reconnection diffusion region in terms of the kinetic physics. The present study demonstrates that, using a large-scale 3D kinetic simulation and analytical analysis, the spatial distribution of the non-ideal electric field is consistent with the dissipation due to the viscosity rather than the resistivity, when electromagnetic (EM) turbulence is dominant in the electron diffusion region (EDR). The effective viscosity is caused by the EM turbulence that is driven by the flow shear instabilities leading to the electron momentum transport across the EDR. The result suggests a fundamental modification of the fluid equations using the resistivity in the Ohm's law. In contrast, for the 2D current sheet without significant turbulence activity, the non-ideal field profile does not obey the simple form based on the viscosity. A general form of the of non-ideal electric field in 2D and 3D current sheets appropriate for fluid simulations is presented.

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