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Influence of Coulomb Collisions on the Dynamics of Magnetic Reconnection in Space and Laboratory Plasmas

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Magnetic reconnection is the process of a rapid change in the magnetic field topology, frequently associated with a conversion of magnetic energy into various forms of plasma kinetic energy. Many systems of interest, such as the solar corona and laboratory experiments, operate in the parameter regimes inaccessible to both collisionless and fluid models, where the collisional mean free path is comparable to the characteristic scale lengths of interest and/or the reconnection electric field is of the order of the runaway field. In this work, fully kinetic simulations with a Monte-Carlo treatment of Landau collision integral are used to analyze two problems in reconnection under such conditions. Made practical by the recent progress in computing capabilities, this powerful simulation technique allows a seamless transition from collisionless to fully collisional regimes. First, we present simulations with boundary conditions [1] mimicking the Magnetic Reconnection eXperiment (MRX). A thorough comparison of the structure of the electron reconnection layer between the experiment and the simulations allows the relative roles of the collisional dissipation and that of the collisionless effects in MRX to be quantified. Ultimately, this provides important insights into a possible role of 3D current-aligned instabilities and helps bridge the gap between a small laboratory experiment and much larger systems in Nature. As a second example, we discuss the transition between the collisional and the kinetic reconnection regimes. In relatively short systems with Lundquist number below $S \sim 10^3$ the transition, signified by a rapid increase in the reconnection rate, occurs at the temperature that corresponds to the width of the Sweet-Parker current sheet $\delta_{\rm SP} \sim d_i$, where d_i is the ion inertial length. In larger systems $S > 10^3$, the transition is observed at significantly lower temperatures than are expected from a simple criterion $\delta_{\rm SP} \sim d_i$. In particular, the Sweet-Parker current sheet is found to be unstable against a tearing-like instability that leads to a significant modulation of the current sheet thickness [2]. The transition is achieved when the *minimum* thickness of the current sheet falls below d_i. These results may have strong implications for reconnection in the solar corona, since many of the existing models are based on the premise that the Sweet-Parker scaling is relevant at practically important $S \sim 10^{12}$ and neglect the influence of secondary islands in estimating the transition to kinetic scales.

[1] S. Dorfman et al. Phys. Plasmas **15**, 102107 (2008)

[2] W. Daughton et al. *"Transition from Collisional to Kinetic Regimes in Large-Scale Reconnection Layers"*, to appear in Phys. Rev. Letters

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