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Energetics of magnetic reconnection from fluid to kinetic regimes

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Magnetic reconnection mediates the conversion of magnetic field energy into plasma kinetic energy through the production of bulk flows, heating, and the acceleration of energetic particles [1]. This process plays a critical role in the global evolution of magnetized plasma systems and the production of nonthermal particle distributions that are observed directly or through their radiation [2,3]. Bridging the gap between the microscopic diffusion regions where magnetic field topology changes occur and the global scales of realistic systems is a major challenge for reconnection models. Understanding the sacrifices in fidelity as the physical model is reduced from a kinetic Vlasov-Maxwell system to a simplified magnetohydrodynamic fluid is critical for the accurate modelling of large-scale realistic systems. Using fully kinetic particle-in-cell simulations with a Monte-Carlo Coulomb collision operator, we study the transition from collisionless to collisional reconnection for magnetic field strengths ranging from nonrelativistic to magnetically dominated. At sufficiently high collisionalities, we reproduce the Sweet-Parker scaling of reconnection rate with Lundquist number. In intermediate regimes, the collisionality significantly impacts plasmoid formation and particle acceleration. A detailed analysis of the generalized Ohm's law and self-consistent particle trajectories reveals the roles of ideal and non-ideal electric fields in particle energization. We discuss the implications of these results for modelling large-scale systems in space physics and astrophysics.

References:

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