DPP19-2019-001279

Abstract for an Invited Paper
for the DPP19 Meeting of
the American Physical Society

The Collisonal-Collisionless Phase Transition in Partially Ionized Magnetic Reconnection[1]

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Magnetic reconnection is the fundamental process responsible for topological rearrangement of fieldlines and an important process in nearly all magnetized plasmas. While commonly studied in fully ionized plasmas, neutrals are important in many astrophysical environments such as the solar chromosphere or interstellar medium, but comparatively little attention has been given towards understanding reconnection physics in partially ionized systems. In particular, the transition from slow, collisional reconnection to fast, collisionless reconnection is not well understood. Analytic models have predicted that, when neutrals are present, this transition occurs when the current sheet thickness reaches the total inertial length (defined with the total mass density), but multi-fluid simulations have not seen this effect. In this work, fully kinetic, particle-in-cell simulations of weakly-collisional, partially ionized magnetic reconnection are performed. The transition from collisional to collisionless reconnection is found to occur when the current sheet thins below the ion-inertial length (defined by only the ion mass density). Within the collisionless regime, and in sufficiently large systems, the peak reconnection rate scales with the total Alfvn speed in agreement with experimental results. Neutral viscosity is important and plays a significant role in momentum transport through the ion diffusion region. To clarify the role of kinetic and collisionless effects, well-matched fluid simulations are compared with the particle-in-cell simulations. Finally, the fully ionized case is studied within the context of phase-transition theory. By identifying good order parameters, the transition is shown to consist of both a second-order phase transition at the ion-scale and an additional, first-order transition at the electron scale.

[1]This work was funded by the Basic Plasma Science Program from DOE Office of Fusion Energy Sciences under contract number DE-AC02-09CH11466 and from NASA under grant number NNH15AB29I.