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Equations of State in Collisionless Reconnection

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Wind and Cluster spacecraft measurements of reconnecting current sheets in the Earth's magnetosphere show strong electron temperature anisotropy. This anisotropy is accounted for in a solution of the Vlasov equation recently derived for general reconnection geometries with magnetized electrons in the limit of fast transit time [1]. A necessary ingredient is an ion-scale parallel electric field, which maintains quasi-neutrality by regulating the electron density, traps a large fraction of thermal electrons, and heats electrons in the parallel direction. Based on the expression for the electron phase space density, equations of state provide a fluid closure that relates the parallel and perpendicular pressures to the density and magnetic field strength [2]. The resulting fluid model agrees well with fully kinetic simulations of guide-field reconnection, where the parallel electron temperature becomes several times greater than the perpendicular temperature. In addition, the equations of state relate features of the electron diffusion region that develop during anti-parallel reconnection to the upstream electron beta. They impose strong constraints on the electron Hall currents and magnetic fields. The equations of state are suitable for implementation in two-fluid or hybrid codes. Such codes could retain important electron kinetic effects in numerical models of large-scale collisionless plasmas, which lie beyond current computational limits in kinetic simulation.

[1] J. Egedal, W. Fox, N. Katz, et al., J. Geophys. Res. 113, A12207 (2008).
[2] A. Le, J. Egedal, et al., Phys. Rev. Lett. 102, 085001 (2009).