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Experimental demonstration of collisionless plasmoids at the electron scale during high Lundquist number magnetic reconnection.[1]

JOSEPH OLSON, University of Wisconsin-Madison

The dynamics of magnetic reconnection can vary greatly depending on the collisionality of the plasma. While resistivity alone provides force balance during collisional reconnection, it cannot account for the reconnection rate during collisionless reconnection. As the collisionality decreases, kinetic processes, such as electron pressure anisotropy[2] can develop unimpeded and provide pressure balance across the current sheet[3]. Recent PIC simulations have shown that more unique structures, driven by pressure anisotropy, can develop only if the electrons do not collide as they traverse the reconnection region[4]. More precisely, this collisionless regime exists when the characteristic Lundquist number is above $S > 10\epsilon(m_i/m_e)L/d_i$ (for anti-parallel reconnection), where $\epsilon < 1$ is an experimental scale factor and L is the system size. The Terrestrial Reconnection EXperiment (TREX) has been specifically designed to operate in this regime, where the Lundquist number is set by the applied reconnection drive. Early experiments in low collisional plasmas with $S \sim 10^3$ showed evidence of magnetic island formation (plasmoids) occurring below characteristic ion length scales[5]. The experiments demonstrate that the plasmoid instability is still active for relatively small system size compared to predictions from either extended MHD or fully kinetic PIC simulations. Furthermore, in recent experiments with $S > 10^4$, we document a transition to a regime where the current sheet shrinks to the electron scale, $\delta_J \sim 2-4c/\omega_{pe}$, consistent with results from kinetic simulations showing that such electron layers are related to strong pressure anisotropy.

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