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Towards a New Understanding of Collisionless Magnetic Reconnection

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A central cornerstone of modern concepts regarding fast magnetic reconnection has been the expectation that the non-ideal electron region remains localized on the electron scale. Based on this understanding, it has been widely argued that the reconnection rate is controlled by the ions in a manner that is insensitive to the specific details of the electron physics. This picture implies that a single x-line will lead to steady reconnection with an open geometry similar to the Petscheck model. These expectations were largely based on two-fluid simulations and small-scale kinetic simulations with periodic boundary conditions. Recently, this problem was re-examined using 2D fully kinetic simulations with open boundary conditions [1] as well as the largest periodic simulations ever considered. In contrast to previous expectations, both of these approaches demonstrate that the length of the electron diffusion region expands in time to form a highly elongated current layer with a width on the electron scale but a length that can exceed tens of ion inertial lengths. These non-ideal electron layers exhibit multiple scales in the outflow direction[2] with an inner region characterized by strong out-of-plane current and an outer region marked by a collimated electron jet. The formation of these highly elongated layers involves a competition between the outward convection of magnetic flux with the non-ideal terms arising from the divergence of the electron pressure tensor. Although it is possible to setup a balance over limited durations, the resulting layers are always highly elongated. Over longer time scales, these layers are unstable to the formation of secondary magnetic islands leading to a reconnection process that is inherently time-dependent. These results point to a very different picture regarding the essential physics of reconnection since both the reconnection rate and time dependence are sensitive to the details of the electron physics.

[1]Daughton, Scudder and Karimabadi, *Phys. Plasmas* **13**, 072101,2006
[2]Karimabadi, Daughton and Scudder, *Geophys. Res. Lett.* **34**, L13104, 2007