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Electron physics near the X-line in asymmetric magnetic reconnection

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In order to study the inner workings of magnetic reconnection in space, NASA has recently launched Magnetospheric Multiscale (MMS) spacecraft. MMS have made electron-scale measurements of reconnection at the Earth's dayside magnetopause (Burch et al. 2016 *Science*), and then the spacecraft have recently started to observe magnetotail reconnection sites (Torbert et al. 2018). To better understand these observations, there is a strong demand for numerical modeling of magnetic reconnection by means of particle-in-cell (PIC) simulations.

In this talk, we overview our recent studies on asymmetric magnetic reconnection at the dayside magnetopause, by means of 2-D PIC simulations. We explore electron-physics signatures in characteristic regions surrounding the X line. On the magnetospheric side of the X line, the normal electric field enhances the electron meandering motion from the magnetosheath side. The motion leads to a crescent-shaped component in the electron velocity distribution functions (VDFs), in agreement with MMS observations. On the magnetosheath side of the X line, the magnetic field line is stretched in the third dimension, and then its curvature radius is comparable with typical electron Larmor radius. The electron motion becomes nonadiabatic, and then the electron ideal condition is no longer satisfied. This is also the case for the middle of the outflow regions.

The out-of-plane "guide field" gives a different picture by suppressing these nonadiabatic effects. The electrons from the magnetosheath and the magnetosphere coexist in the boundary layer, however, the two populations are separate in the velocity space. We find that such an effect is highlighted by the information (Shannon) entropy of the electron VDFs. We will discuss the spatial profile of the entropy in reconnection systems and its implications in fundamental physics of magnetic reconnection.

Reference:

[1] S. Zenitani, H. Hasegawa, and T. Nagai, *Electron dynamics surrounding the X line in asymmetric magnetic reconnection*, J. Geophys. Res. Space Physics, **122**, 7396, doi:10.1002/2017JA023969

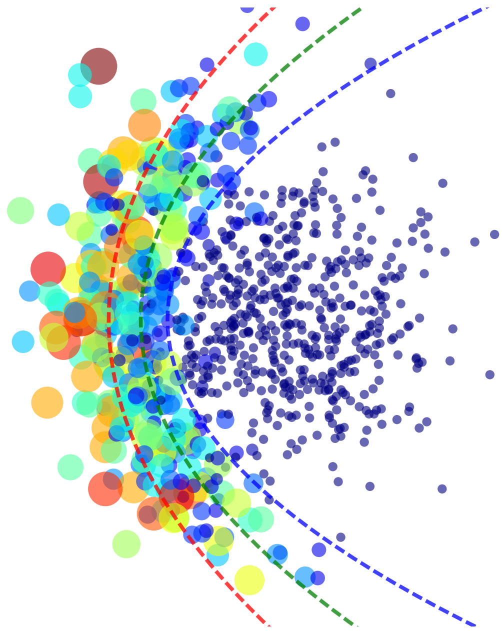

Figure 1. 2-D electron velocity distribution near the X-line in our PIC simulation [1]. The color and size of the symbol stands for the crossing numbers of the field reversal during a certain time interval. The dashed curves indicate theoretical conditions for the sheath-origin electrons.