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Energetic electron acceleration by ion-scale magnetic islands in turbulent magnetic reconnection

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Magnetic reconnection is an important process in various collisionless plasma environments because it reconfigures the magnetic field and releases magnetic energy to accelerate charged particles. Its dynamics depend critically on the properties of the pre-reconnection current sheet. One property in particular, cross-sheet temperature inhomogeneity, is ubiquitous throughout the heliosphere. Figure 1 shows an example of such temperature inhomogeneity across the current sheet in Earth's magnetotail.[1]

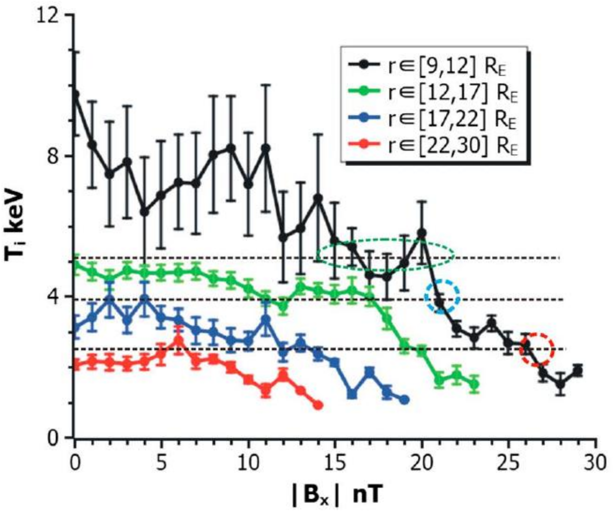

Fig. 1. Averaged profiles of ion temperature across Earth's magnetotail current sheet. $|B_x|\sim 0$ represents the center of the current sheet, $|B_x|\sim 30$ nT represents the boundaries of the current sheet. Different colors denote different radial distances from the Earth.

Using two-dimensional (2-D) particle-in-cell simulations, we show that such temperature inhomogeneity increases reconnection outflow speed, energy conversion efficiency, and secondary island formation rate.[2] We then further consider two cases with a long, thin current sheet, one with homogeneous temperature and one with inhomogeneous temperature across the current sheet. In the inhomogeneous temperature case, numerous secondary islands form continuously, which increases current sheet turbulence (with well-developed cascade power spectra) at large wavenumbers. Current density, energy conversion, dissipation, and acceleration of high-energy particles are also enhanced relative to the homogeneous temperature case.[3] Our results suggest that inhomogeneous temperature profiles, which are realistic, need to be incorporated into studies of turbulence and particle acceleration in collisionless magnetic reconnection.

A closer examination on the simulation results show that the ion-scale magnetic islands formed in the turbulent magnetic reconnection due to the temperature inhomogeneity can confine and accelerate electrons to high energies efficiently, causing the energetic electron energy flux to peak at the center of each islands. We use ARTEMIS spacecraft observations of turbulent reconnection outflows in Earth's magnetotail to reveal that peaks in the energetic electron energy flux are well correlated with bipolar signatures of reconnected magnetic field (see Fig. 2), which are indicative of ion-scale magnetic islands, providing observational evidence for this acceleration process.[4]

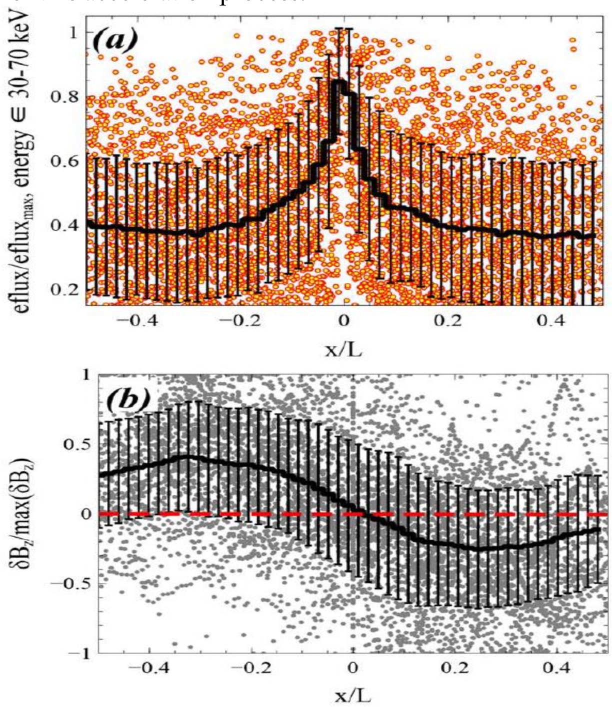

Fig. 2. Superposed epoch analysis of electron energy flux peak events. Averaged profiles of (a) normalized electron energy flux, and (b) magnetic field fluctuation.

References

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