§21. Formation of Electron Dissipation Region and its Role in Collisionless Driven Reconnection

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The dynamical evolution of collisionless driven reconnection is investigated by using the simulation code ("PASMO") developed for a microscopic open system which is surrounded by external macroscopic system [1,2,3]. The analysis is focus on the formation of electron dissipation region and its structure.

The electron dissipation region is formed in the center of current layer through electron kinetic effects. When magnetic reconnection starts, the Lorentz force associated with reconnection electric field and the reconnected magnetic field accelerates the electrons towards the downstream. Accordingly, the length of fast electrons outflow region increases with time until the system reaches a steady state. It is found from the detailed analysis that magnetic energy at the inflow region is converted mainly into the kinetic energy of electron outflow in the downstream through collisionless reconnection. Thus, the relation

$$V_e = \sqrt{\frac{B_x^2}{4\pi m_e n_{e,out}}} \qquad (1)$$

holds in a steady state. Figure 1 shows the profile of electron outflow velocity along the outflow direction. The observed maximum velocity is about 0.45c, which is in good agreement with the electron Alfven velocity 0.425c defined in Eq. (1).

Ion becomes unmagnetized inside ion meandering scale, while electrons remain magnetized [1,4]. The driving electric field works strongly on magnetized electrons and makes electron and ion motions different. Thus, in-plane electrostatic field is generated as a result of charge separation. The electrostatic field, in turn, makes the strong out-of-plane electron current though **EXB** drift [1].

The inward magnetized electron motion carries magnetic flux towards the electron dissipation region. Because magnetic pressure becomes maximum at the edge of electron dissipation region, it pushes electrons into this region from the outside. The electron-rich region is formed inside this region, while ion-rich region is outside the region. The in-plane electrostatic field becomes maximum at the edge, which is balanced with the magnetic pressure force. If the half-width of electron dissipation region is given by the electron skin depth d_e, the force-balance equation is rewritten as

$$\left\langle \left| \frac{n_i - n_e}{n_e} \right| \right\rangle = \frac{1}{2}\frac{V_{e,Alfven}^2}{c^2}, \qquad (2)$$

where the bracket <> stands for the volume average over the electron dissipation region. Figure 2 demonstrates the simulation results where the electron Alfven velocity is about 0.5 at the edge and the normalized charge density is about 0.12. Thus, it is confirmed from the simulation that this relation holds with a high accuracy.

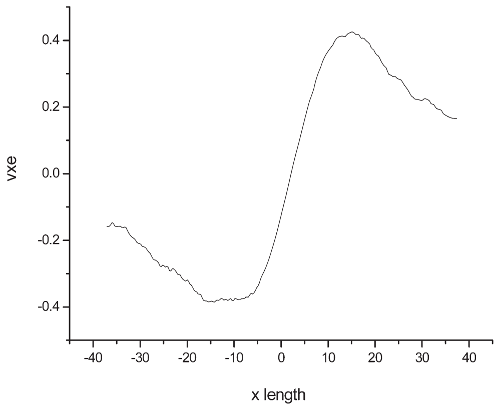

Fig. 1. Spatial profile of electron outflow velocity along the outflow direction in a steady state.

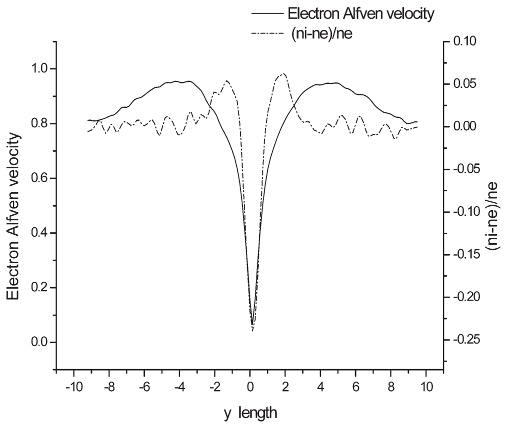

Fig. 2. Spatial profiles of electron Alfven velocity and normalized charge density along the inflow direction in a steady state.

Reference

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