§8. Two-Step Evolution of Collisionless Driven Magnetic Reconnection

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Driven magnetic reconnection in a collisionless plasma is investigated by means of a $2\frac{1}{2}$ dimensional particle simulation [1,2]. A plasma is initially in a magnetohydrodynamic equilibrium with the Harris-type magnetic configuration. A driving plasma flow is supplied into a system through the boundary of a simulation domain by the $\mathbf{E} \times \mathbf{B}$ drift motion. The current layer is compressed by the convergent plasma flow and its spatial scale length changes with time. After some period the system dynamically evolves into a kinetic regime in which the finite Larmor radius effect plays an important role.

Figure 1 shows the temporal evolution of the electric field along the equilibrium current at the reconnection point. It is found that there are two temporal phases in the evolution of magnetic reconnection in accordance with the dynamical evolution of the current layer (Fig. 2), i.e., (1) the slow reconnection phase in which the current layer is compressed as thin as the orbit amplitude of an ion meandering motion (" ion current layer "), and (2) the fast reconnection phase in which the electron current is concentrated into the narrow region with the spatial scale comparable to the orbit amplitude of an electron meandering motion (" electron current layer "). The growth rate of the electric field in the slow reconnection phase is $\gamma_g \approx 0.103\omega_{ci}$ while that in the fast reconnection phase is $\gamma_g \approx 0.013\omega_{ce}$, where ω_{ce} and ω_{ci} are the electron cyclotron frequency and the ion cyclotron frequency.

The temporal evolution of magnetic reconnection scales as $E_0^{-1/2} M_i^{1/4}$ and the maximum reconnection rate is roughly in proportion to E_0, where E_0 is the driving electric field and M_i is the ion mass. This scaling law can be explained by the model that the dynamic evolution of magnetic reconnection is controlled by the physics of the ion current layer, but not the physics of the electron current layer. It is also found that the ion heating takes place inside the ion current layer due to the finite ion Larmor radius effect while the electron heating takes place inside the electron current layer due to the finite electron Larmor radius effect, and the ion temperature becomes two or more times as high as the electron temperature.

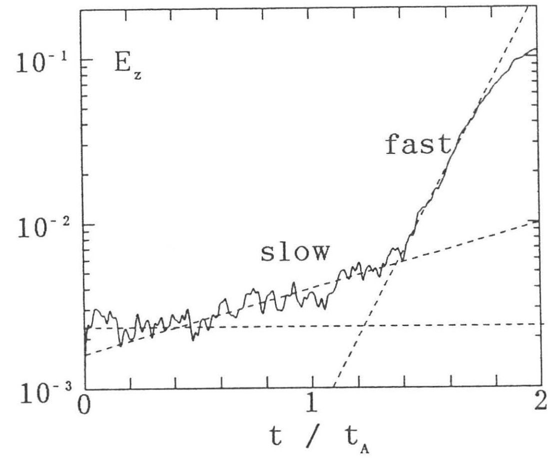

Fig. 1. Temporal evolution of the reconnection electric field.

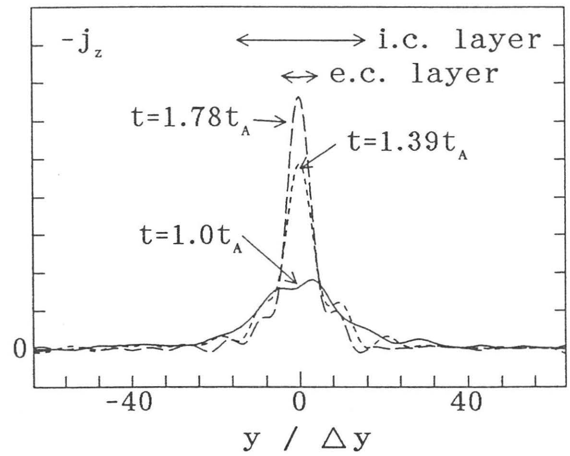

Fig. 2. Spatial profiles of the current density at three different times.

References

1) R. Horiuchi and T. Sato, NIFS-233, 1993.
2) R. Horiuchi and T. Sato, NIFS-284, 1994.