§28. Two-Scale Structure of the Current Layer Controlled by Meandering Motion during Steady-State Collisionless Driven Reconnection

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A steady two-scale structure of current layer is demonstrated in the collisionless driven reconnections without a guide field by means of two-dimensional full-particle simulations in an open system.1) The current density profile along the inflow direction consists of two parts as shown in Fig.1. One is a low shoulder controlled by the ion-meandering motion, which is a bouncing motion in a field reversal region. The other is a sharp peak caused mainly by the electron-meandering motion. The shoulder structure is clearly separated from the sharp peak for the case of a large mass ratio calculation Mi/Me=200 because the ratio of the ion-meandering orbit amplitude to the electron-meandering orbit amplitude is proportional to $(Mi/Me)^{1/4}$. Although the ion frozen-in constraint is broken within a distance of the ion skin depth the violation due to the ion inertia is weak compared to the strong violation caused by the ion-meandering motion. The violation of the electron frozen-in constraint caused by the electron-meandering motion is stronger than the violation due to the electron inertia, and thus the electron-meandering motion produces the reconnection electric field in the central region where the current has the sharp peak structure.

In order to clarify the roles of ion dynamics and electron dynamics on steady collisionless reconnection, we have carried out full-particle simulations of collisionless driven reconnection in an open system for a large mass ratio. Especially, we have examined the relationship between the violation mechanism of the frozen-in constraint of plasmas and the current layer structure in detail. We summarize our results as follows.

It is confirmed that the system relaxes into a steady state even in case of a large mass ratio Mi/Me=200 when the window size of driving field is small. The reconnection rate is balanced with flux input rate at the boundary in the steady state. This means that microscopic scale physics adjusts itself to macroscopic scale physics in order to realize the steady collisionless reconnection.

A steady two-scale structure consisting of a sharp peak and low shoulders is formed in the current density profile in the steady reconnection (Fig.1). The sharp peak is mainly controlled by the electron-meandering motion, while the ion-meandering motion creates shoulders of the current layer as shown in Fig.2. The formation of shoulder structure is deeply related to the facts that the local peaks of number density profile are formed at the average turning point of ion-meandering motion, and that the out-of-plane electron ExB drift is created by in-plane electrostatic field which is generated as a result of strong decoupling of ion motion from electron motion.

We have not observed any current density structure in the ion-skin-depth scale. This is because the violation of ion frozen-in constraint due to the ion inertia is weak compared with the one due to the ion-meandering motion. The electron frozen-in constraint is violated when electrons enter into the electron diffusion region within the electron skin depth. However, the violation of electron frozen-in constraint due to the electron inertia becomes negligibly small near the reconnection point. Instead, the electron pressure tensor term is balanced with the reconnection electric field at the X-point as suggested by previous studies. Thus, the electron-meandering motion, which contributes to the electron pressure tensor, is a dominant cause of steady collisionless reconnection at the neutral sheet in two-dimensional open system.

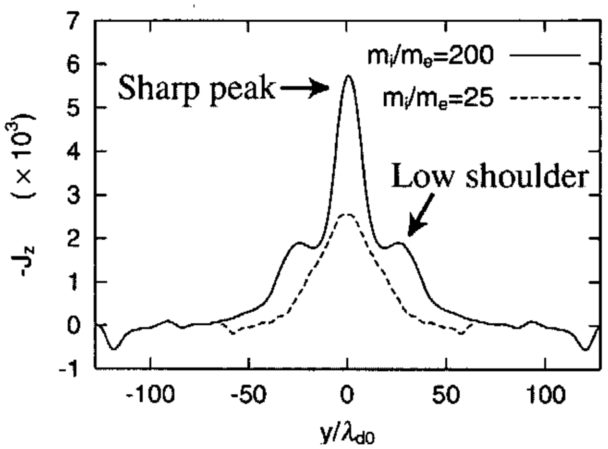

Fig. 1. The current density profile along the vertical line passing the X-point in the steady state for Mi/Me=200 and 25.

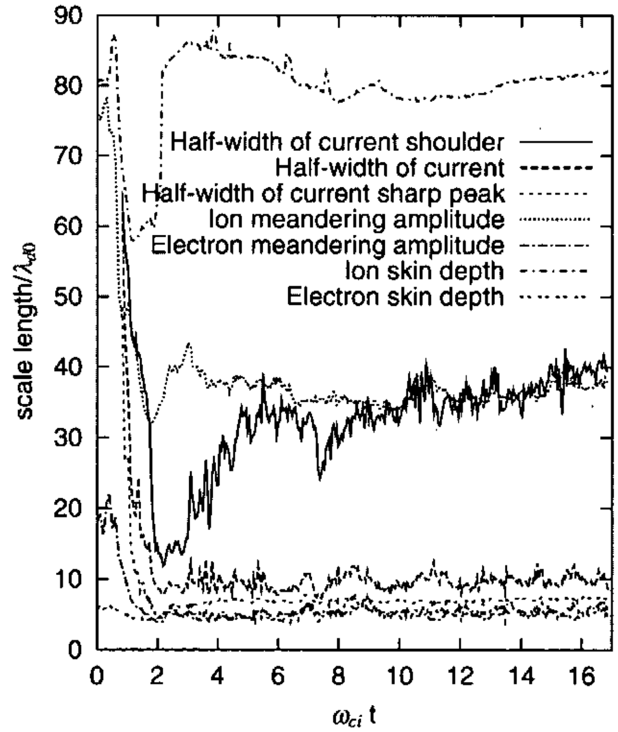

Fig. 2. The time evolutions of several scale lengths.

Reference

1) Ishizawa, A., et al.: Physics of Plasmas **11** (2004) 3579.