§21. Collisionless Driven Reconnection in Three-dimensional Thin Current Sheet

Horiuchi, R., Ohtani, H., Ishizawa, A.

Magnetic reconnection is controlled by multi-scale physics from microscopic physics, which leads to the generation of electric resistivity, through macroscopic physics which determines global plasma transport and global change of field topology. In order to clarify magnetic reconnection as multi-scale physics we have developed an open boundary model for particle simulation [1,2]. In this model the interaction between macro system and micro system is expressed by the plasma inflow and outflow through the system boundary.

A microscopic reconnection process is solved by means of an explicit electromagnetic particle simulation. A macroscopic process is introduced into this model as boundary conditions. A floating condition is used at the downstream boundary so that the plasma flow can move in and out freely through the boundary. The frozen-in condition, \( \mathbf{E} + \mathbf{v} \times \mathbf{B} = 0 \) \((s=1,e)\), is assumed at the upstream boundary [1,2,3]. Thus, the plasma inflows can be symmetrically driven from two upstream boundaries by imposing the external electric field in the \( z \) direction. The ion and electron number fluxes are assumed to be always the same at the upstream and downstream boundaries so as to keep the total charge neutrality.

Triggering mechanism of collisionless driven reconnection and its dynamical behavior in an open system are examined by using the developed EM particle simulation code. It is found that there are two causes to violate frozen-in constraint and trigger collisionless reconnection. One is anomalous resistivity created by the DKI, and the other is originated by stochastic particle motion near the neutral sheet, which is expressed by off-diagonal components of pressure tensor term in two-fluid MHD as

\[
n_j (E + v_j \times B) = \frac{m_j}{q_j} n_j \left( \frac{\partial}{\partial t} v_j + (v_j \cdot \nabla) v_j \right) + \frac{1}{q_j} \nabla \cdot \mathbf{P} + \frac{1}{q_j} \nabla P
\]

By expanding each term into the DC and wavy components, we examine the roles of plasma instabilities and particle kinetic effects in Collisionless reconnection.

Figures 1 and 2 show the spatial profiles of non-ideal terms for electrons and ions when a low-frequency electromagnetic instability, called drift-kink instability (DKI), develops fully at the central region of current sheet. The reconnection point is located at the position \( y=0 \). The electric field becomes almost uniform in the quasi-steady state.

The reconnection electric field (solid line) is sustained by the ion pressure tensor originating from stochastic particle orbit (dashed line) in the ion current layer (Fig. 2). On the other hand, the wavy component has a strong peak near the reconnection point, and balanced with the reconnection electric field in the electron case. In other words, anomalous resistivity created by the DKI is a main cause of the reconnection electric field in the electron current layer (Fig. 1). This result corresponds to the fact that the growth of the DKI is suppressed by three-dimensional effect and it grows just inside an electron current layer.

Fig. 1. Spatial profiles of non-ideal terms for electrons in the DKI phase.

Fig. 2. Spatial profiles of non-ideal terms for ions in the DKI phase.

Reference