§21. Generation of Anomalous Resistivity in Current Sheets Controlled by Ion Dynamics

Moritaka, T. (Nagoya Univ.), Horiuchi, R., Ohtani, H.

Collisionless magnetic reconnection is one of the fundamental physical processes controlling dynamic phenomena in high temperature and low density plasmas. Anomalous resistivity can violate frozen-in condition at the reconnection region and cause fast-type magnetic reconnection in such systems. One cause of the anomalous resistivity is current-driven instabilities which grow in current sheets perpendicular to the anti-parallel magnetic fields. The roles of electron and ion dynamics on the current sheet evolution are investigated in order to clarify the generation process of the anomalous resistivity in ion scale current sheets observed in the magnetosphere and in laboratories. A series of particle simulations have been performed in which mass ratios are varied over a wide range in two ways. The first corresponds to the case when the "electron mass" is varied. The initial equilibrium and ion distribution function are completely fixed while parameters related to the electron dynamics are varied according to the mass ratio. The second corresponds to the case when the "ion mass" is varied i.e., parameters which determine the electron dynamics are all fixed.

It is found that the lower hybrid drift instability (LHDI), which grows at the periphery of the current sheet, causes two types of the particle diffusion. One takes place in the LHDI region and is controlled only by the ion dynamics, and the other takes place in the vicinity of the neutral sheet and is controlled mainly by the electron dynamics. The particle diffusion near the neutral sheet leads to the formation of two-peak structure of the electron velocity profile (Fig.1). On the other hand, magnetic kink modes in the vicinity of the neutral sheet are observed to grow after the saturation phase of the LHDI. When the mass ratio is sufficiently high, the kink modes are classified into two modes, a shorter wavelength mode ($k\sqrt{\rho_e L} \sim 0.5$, comparable to the electron meandering scale) and a longer wavelength mode ($kL \sim 0.5$, comparable to the current sheet / ion meandering scale). The growth rate of the longer kink mode varies according to the ion mass and is independent of the electron mass, while that of the shorter kink mode is determined only by the electron mass. For high mass ratio, anomalous resistivity is generated mainly by the longer mode[1] and the resultant DC electric field reaches the same saturation level independently of the electron mass.

In the present simulations, we have found two processes which are controlled only by the ion dynamics (the outward diffusion in the periphery due to the LHDI and the growth of the longer kink mode at the neutral sheet). These processes are related to each other through the meandering ions which move about between the neutral sheet and the periphery. The influence of the outside diffusion to the neutral sheet is characterized by the anisotropic modification of the ion distribution function. The relationship between the ion temperature anisotropy and the growth rate of the longer mode is in good agreement with the linear theory of the ion-ion kink mode[2] in the high mass ratio cases (Fig.2). Under the influence of the outside diffusion, the ion temperature anisotropy at the neutral sheet reaches the same value and the ion-ion kink mode is destabilized independently of the electron dynamics. In this way, anomalous resistivity due to the longer kink mode is considered to be generated commonly in ion-scale current sheets even for the real mass ratio.

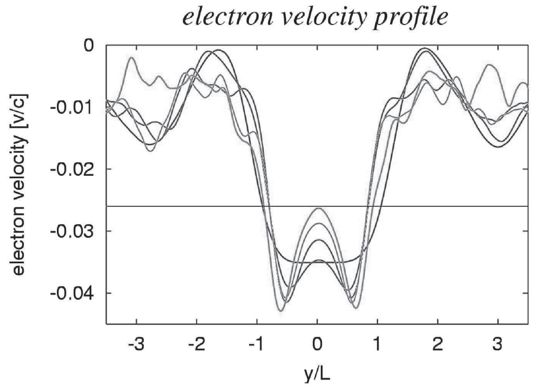

Figure 1: Spatial profiles of electron velocity v_{ex} at the saturation phase of LHDI. Each lines denote the simulation results for different electron masses.

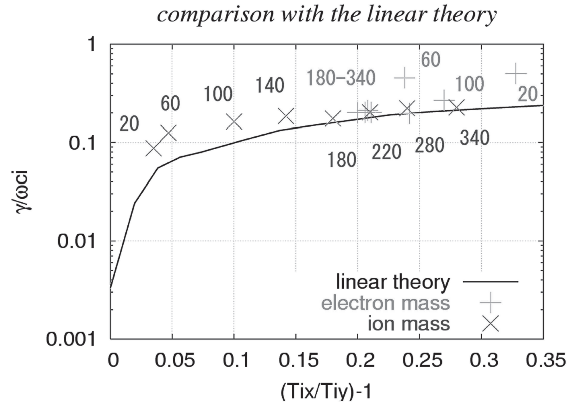

Figure 2: Relationship between the growth rate of the longer mode and the ion temperature anisotropy. The crosses (+) denote the simulation results in varing electron mass and numbers in the figure denote mass ratio for each run. The diagonal crosses (×) denote those in varing ion mass. Solid line represents the theoretical relationship of the ion-ion kink mode[2]

1) T.Moritaka et al, Phys.Plasmas , **14**, 102109(2007)
2) W.Daughton, Phys.Plasmas, **6**, 1329(1999)