§24. Anomalous Resistivity Due to Plasma Instabilities in an Ion-scale Current Sheet

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A three-dimensional particle simulation study [1] revealed that two kinds of plasma instabilities grow in an ion-scale current sheet in cases where no external driving source exists. First, the lower hybrid drift instability (LHDI) grows in the periphery of the current sheet. The lower hybrid drift mode, however, does not penetrate into the central high-β region of the current sheet because it undergoes strong damping there. Thus, it cannot be a direct cause of anomalous resistivity at the neutral sheet. After the nonlinear saturation of the LHDI, a drift kink instability (DKI) is triggered at the neutral sheet as a result of nonlinear deformation of the current sheet by the LHDI. The reconnection electric field grows at the neutral sheet in accordance with the excitation of the DKI. On the other hand, theoretical linear analysis [2] has suggested that the growth rate of the DKI decreases with the mass ratio, and becomes negligibly small for a real mass ratio.

To clarify the physical reason for the discrepancy between simulations and linear analysis, a series of two-dimensional particle simulations are performed for various mass ratios [3, 4]. Figure 1 shows the mass ratio dependence of the growth rate of kink modes, where the electron mass changes while the ion mass is fixed. The DKI is split into two modes with different wavelengths for a large mass ratio of m_i/m_e >100, i.e., a longer kink mode of kL~0.5 and a shorter kink mode of kL~1.7, where k is a typical wavenumber. Note that the longer kink mode maintains a constant growth rate (γ/ω_{ci}~0.2) even for a large mass ratio, while the rate decreases with mass ratio for the shorter kink mode.

A detailed analysis of simulation data [4, 5] discloses the following physical mechanism in the longer kink mode. The ion distribution is modified through an interaction between electrostatic fluctuation excited by the LHDI in the periphery and meandering ions with large orbit amplitude in the ion-scale current sheet. In this process, another peak is generated around the origin of velocity space (v=0) in addition to the initial shifted Maxwellian distribution, and thus the distribution changes to a two-component profile. The relative motion between the two ion components causes the growth of the longer kink mode, called the ion-ion kink mode, in the central region of the current sheet [2]. Therefore, the longer kink mode is almost independent of electron mass, ensuring that it can maintain the finite growth rate for a real mass ratio. The anomalous resistivity generated in this process, which is defined by the ratio of the electric field to the current density, is estimated to be about 0.1 of the Hall resistivity [3]. The generated electric field results in the penetration of magnetic flux into the dissipation region with a velocity nearly equal to that of the **E**×**B** drift associated with the generated electric field. The temporal evolution of the normalized reconnection rate is plotted in Fig. 2, where the normalized reconnection rate R_{rec} is defined by the penetration velocity into the ion dissipation region divided by the Alfvén velocity upstream. The reconnection rate is in the range of R_{rec} ~ 0.01−0.1, which is large enough to explain the magnetic reconnection phenomena observed in the magnetosphere and laboratory experiments.

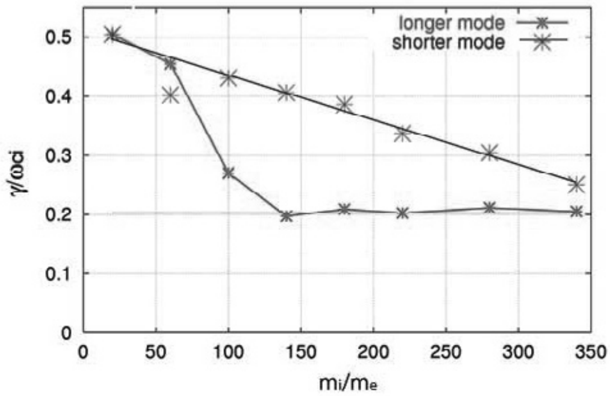

Fig. 1. Mass ratio dependence of the growth rate of the shorter (blue) and longer (red) kink modes, where the electron mass changes while the ion mass is fixed [4].

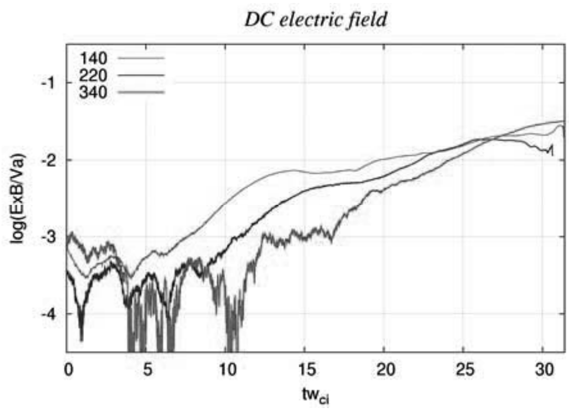

Fig. 2. Temporal evolution of normalized reconnection rate for mass ratio m_i/m_e =140 (green), 220 (blue), and 340 (red), where the electron mass changes while the ion mass is fixed [5].

1) R. Horiuchi and T. Sato, *Phys. Plasmas* **6** (1999), 4565.
2) W. Daughton, *Phys. Plasmas* **6** (1999), 1329.
3) T. Moritaka and R. Horiuchi, *Phys. Plasmas* **14** (2007), 102109.
4) T. Moritaka, and R. Horiuchi, *Phys. Plasmas* **15** (2008), 092114.
5) R. Horiuchi, et al, *Plasma and Fusion Research,* (2010) [in press].