

## §24. Plasma Instabilities and Anomalous Resistivity in the Current Sheet

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Magnetic reconnection can lead to topological change of magnetic field and fast energy conversion from magnetic field to particles and is widely believed as a fundamental process of the energetically active phenomena observed in the solar corona, the geomagnetic tail and fusion plasma. Instead of binary collisions, microscopic nonideal effect can dissipate magnetic field energy and cause collisionless magnetic reconnection in these systems.

A variety of microscopic plasma instabilities which can excite in the current sheet have so far been studied by linear analyses. It is important to clarify how the excitation of these instability causes non-ideal effect and collisionless magnetic reconnection. In this paper we investigate microscopic effect in collisionless magnetic reconnection by examining the force balance equation when these instabilities grow.

The simulation is carried out by using 2+1/2 dimensional explicit electromagnetic particle simulation code. We adopt the Harris type equilibrium with the antiparallel magnetic field configuration. Periodic and fixed boundary conditions are imposed in equilibrium current direction and along the gradient of magnetic field. The force balance expressed by two-fluid equation is examined using the particle simulation result. The relationship between non-ideal effect created by microscopic plasma instabilities and the generation of electric field is investigated based on this force balance equation.

In the early phase of the development of current sheet, the electromagnetic wave is excited at the periphery of the current sheet. The spectrum of this wave agrees with the linear analysis of LHDI<sup>1)</sup>. Fig.1(top) shows the structure of magnetic field and the force balance at the phase of LHDI. The nonlinear coupling of the perturbations of the electric field and particle density  $\tilde{n}\tilde{\mathbf{E}}$  contributes the outward flow of particle  $\langle \mathbf{v} \rangle$  in the periphery of the current sheet. This outward flow results in the deformation of the equilibrium current sheet profile such as the localization of current density and magnetic flux. The change of the meandering orbit across the neutral sheet by this particle transport leads to the particle acceleration by the pressure tensor term in neutral sheet. But average electric field in the neutral sheet or magnetic flux reduction are not found in this phase.

After the saturation of LHDI, the growth of the longer electromagnetic wave is observed at the

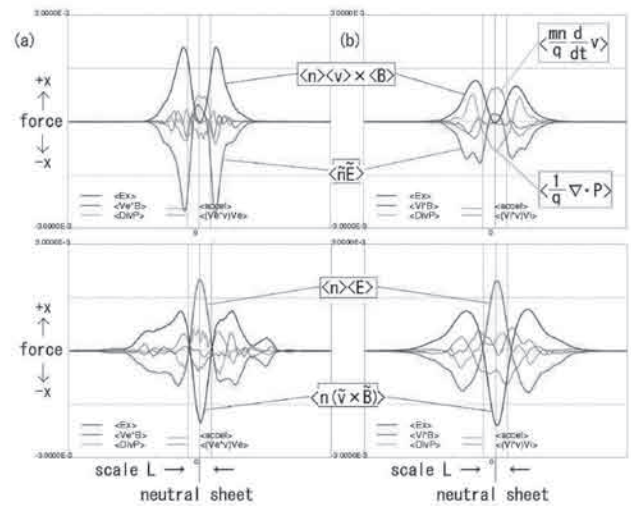


Figure 1: The spatial profile of force balance of electron (a) and ion (b); LHDI phase (top) and DKI phase (bottom)

neutral sheet<sup>2)3)</sup>. This wave has good agreement with linear analysis of DKI<sup>4)</sup>. The average electric field  $\langle \mathbf{E} \rangle$  appears and current density dissipates at neutral sheet. The reduction of total magnetic flux consistent with the DC electric field is found in this phase. Fig.1(bottom) shows the magnetic field and the force balance at the phase of DKI. The force balance at the neutral sheet is changed by the excitation of DKI at the center of current sheet. The fluctuations of magnetic field and current density form the finite wavy component  $\langle \tilde{\mathbf{u}}_j \times \tilde{\mathbf{B}} \rangle$  in Lorentz force term, and this term balances the average electric field. The anomalous resistivity examined from the damping rate of equilibrium current is the same order of the effective resistivity examined from DC electric field. The interaction between the fluctuation of magnetic field and microscopic plasma flow dissipates the momentum of particles and creates anomalous resistivity.

While the magnetic flux is re-distributed in the phase of LHDI, anomalous resistivity and magnetic flux reduction are generated through the nonlinear wave-particle interaction in the DKI phase. It is concluded that the DKI play an important role in creating anomalous resistivity and triggering collisionless magnetic reconnection.

### References

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