運動論リコネクションにおける輸送係数の計測
Measurement of transport coefficients in collisionless magnetic reconnection

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Magnetic reconnection is an essential process in the space plasma environments such as a solar flare and a magnetospheric substorm. Numerous studies have been devoted to clarify the observed rapid energy release rate far beyond the Ohmic dissipation. Especially, Birn et al. (2001) and the collaboration works have compared numerical solutions of the reconnection with various plasma models, and concluded that kinetic processes play a key role for fast reconnection. The conventional resistive MHD model with uniform resistivity fails to reproduce the fast reconnection as is observed in kinetic models. In order to solve the discrepancy between the MHD and kinetic models, we test a dissipative MHD model including the viscosity and the thermal conductivity as well as the resistivity (Minoshima et al. 2016). We find that transport processes of fluid quantities play an important role for fast reconnection in the MHD regime. Especially, the cross-field transport of the outflow momentum facilitates the coupling between the magnetic field and the vortex. In contrast, the resistive MHD reconnection tends to limit small-scale eddies within the current sheet, because it assumes a magnetic Prandtl number to be zero. This might be one of reasons for relatively slow reconnection in the resistive MHD model.
In order to verify the above scenario, we perform a Vlasov simulation of two-dimensional collisionless magnetic reconnection. We then compare the result with the fluid model to measure effective transport coefficients. The reconnection is kept fast even with the ion-to-electron mass ratio of unity, indicating that the Hall effect is not a necessary condition for fast reconnection. The solution of the Vlasov simulation is well approximated by the two-fluid equation and the generalized Ohm's law including full pressure tensor terms. The magnetic diffusion region is localized, and the reconnection electric field is sustained by the off-diagonal term of the pressure tensor and the inertia term. The outflow jet is accelerated by the Lorentz force, and is balanced with the off-diagonal term of the pressure tensor. This term behaves as a shear stress that transfers the outflow momentum from the neutral line across the magnetic field. The orbit analysis shows that the corresponding particles cross the neutral line partly and gain energy from the motional electric field. This is a resemblance to the diffusive transport process. The effective viscosity coefficient is measured from the simulation data, and it is widely distributed in the outflow region. The value is comparable to or larger than the effective resistivity that peaks at the center of the diffusion region. The result indicates the effective magnetic Prandtl number larger than unity in the collisionless reconnection, and agrees with the dissipative MHD reconnection scenario.

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