§3. Multi-Hierarchy Simulation of Collisionless Driven Reconnection in an Open System

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Collisionless magnetic reconnection is one of the fundamental processes in which energy is converted from magnetic field energy to kinetic energy. It plays an essential role in the rapid energy release in laboratory fusion device and astrophysical plasmas. Furthermore, magnetic reconnection has an aspect of cross-hierarchy phenomenon. For comprehension of magnetic reconnection process as a multi-hierarchy phenomenon, we have developed the multi-hierarchy simulation model which solves macroscopic and microscopic physics simultaneously and self-consistently.

Our multi-hierarchy model is based on the domain decomposition method. The simulation domain is divided into macro- and micro-hierarchies, and different algorithms are used in the different domains. The physics in the macro-hierarchy (MHD domain) is calculated by the MHD algorithm, and the dynamics in the micro-hierarchy (PIC domain) is expressed by the PIC algorithm. Between two hierarchies, the interface domain with a finite width is inserted, where physical quantities in the macro-hierarchy and micro-hierarchy are exchanged. We call this method “hand-shaking scheme”.

In order to examine validity of hand-shaking scheme between two hierarchies in our multi-hierarchy model, we simulated the propagation of linear Alfvén wave in the uniform magnetic field. Waves were observed to propagate smoothly in the multi-hierarchy simulation box [1]. Furthermore, multi-hierarchy simulations of plasma injection were performed. It was confirmed that plasma continuously and smoothly flowed from the MHD to PIC domains across the magnetic field [2, 3]. In 2009, using two-hierarchy-connected model in the upstream direction with periodic condition in the downstream direction, we succeeded in the first demonstration of multi-hierarchy simulation on magnetic reconnection (In Fig. 1, we show the magnetic field lines in the (x, y) plane) [4].

Recently we have improved our multi-hierarchy model where open boundary condition is applied in the downstream direction. Magnetic reconnection is driven in the same way as the first model. Figure 2 displays the magnetic field lines in the (x, y) plane. Plasma flows come from MHD to PIC domains and drive magnetic reconnection at the center in the PIC domain. The magnetic field lines are smoothly connected between two hierarchies. We confirmed that the magnetic reconnection phenomena found in our multi-hierarchy model exhibit true physics, by comparing them with pure PIC simulation results.

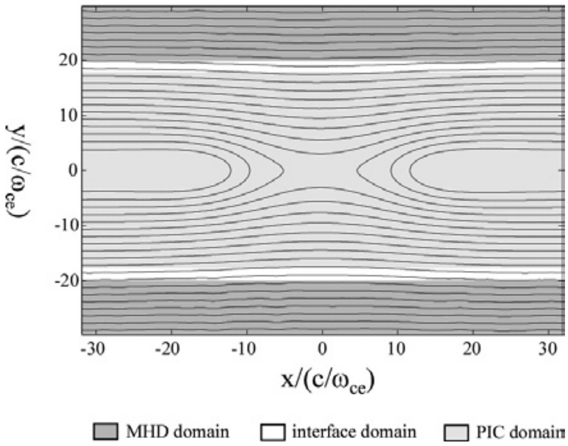

Fig. 1: Magnetic field lines in multi-hierarchy simulation for a periodic boundary condition in the downstream direction (x).

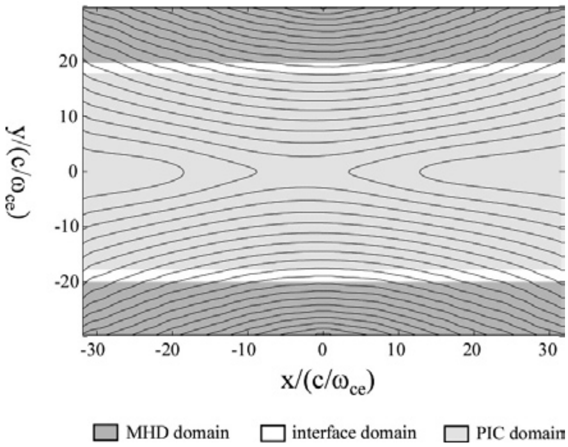

Fig. 2: Magnetic field lines in multi-hierarchy simulation for an open boundary condition in the downstream direction (x).

1) S. Usami, H. Ohtani, R. Horiuchi, and M. Den, Comm. in Comput. Phys. **4** (2008) 537.
2) S. Usami, H. Ohtani, R. Horiuchi, and M. Den, J. Plasma Fusion Res. **85** (2009) 585.
3) S. Usami, H. Ohtani, R. Horiuchi, and M. Den, Comm. in Comput. Phys. in press.
4) S. Usami, H. Ohtani, R. Horiuchi, and M. Den, Plasma Fusion Res. **4** (2009) 049.