§23. Development of Multi-hierarchy Simulation Model for Magnetic Reconnection Studies

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Magnetic reconnection is controlled by multi-hierarchy physics. The change in magnetic field topology is global phenomenon, while microscopic kinetic process is needed to trigger magnetic reconnection. Namely, MHD model is not applicable to the vicinity of reconnection point. Therefore, the full understanding of magnetic reconnection needs a (three-dimensional) multi-hierarchy model which can deal with both microscopic and macroscopic physics consistently and simultaneously [1].

Our multi-hierarchy model is based on the domain division method, and thus is composed of two hierarchies: micro and macro hierarchies. The neighborhood of reconnection points is micro hierarchy, where microscopic kinetic effects play important roles. Dynamics in this system are solved by particle (PIC) simulation [2]. Let us call the domain PIC domain. On the other hand, the surrounding of PIC domain is macro hierarchy, and is described by ideal MHD simulation [3], since non-ideal effects leading to the generation of electric resistivity are assumed to be produced by microscopic process in PIC domain.

In order to interlock PIC and MHD domains smoothly, the Interface domain which has a finite width is inserted between PIC and MHD domains. The physics in the Interface domain is calculated by both PIC and MHD simulations. Physical quantity $Q(x,y,z)$ in the Interface domain is given as the value interpolated as follows

$$Q(x,y,z) = a\, Q_{\mathrm{MHD}}\, (x,y,z) + (1\text{-}a)\, Q_{\mathrm{PIC}}\, (x,y,z),$$

where a parameter a is the function of x, y, and z, and Q_{MHD} and Q_{PIC} stand for the values of physical quantity Q obtained from MHD and PIC simulations, respectively.

In order to examine applicability of our multi-hierarchy model, we perform simulation of propagation of one-dimensional linear waves in the simulation box as shown in Fig. 1 [4]. PIC domain is located at the center of the box. MHD domains are at both sides of PIC domain. There exist the Interface domains between MHD and PIC domains. The right MHD domain is connected to the left MHD domain by the periodic boundary condition.

Figure 2 demonstrates the propagation of Alfvén wave, where spatial profiles of x component of fluid velocity v_x are plotted at the various times. We can see small noises only in PIC domain. They are caused by thermal fluctuation. The propagation speed is observed to be the Alfvén speed. The wave smoothly propagates in the right direction through Interface domains from MHD to PIC domains, and *vice versa.*

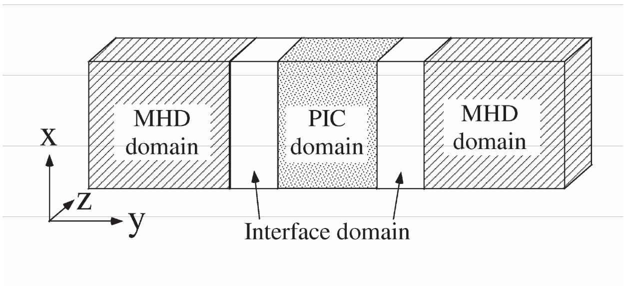

Fig. 1: Simulation box for numerical test of the multi-hierarchy model. One-dimensional waves propagate in the y direction.

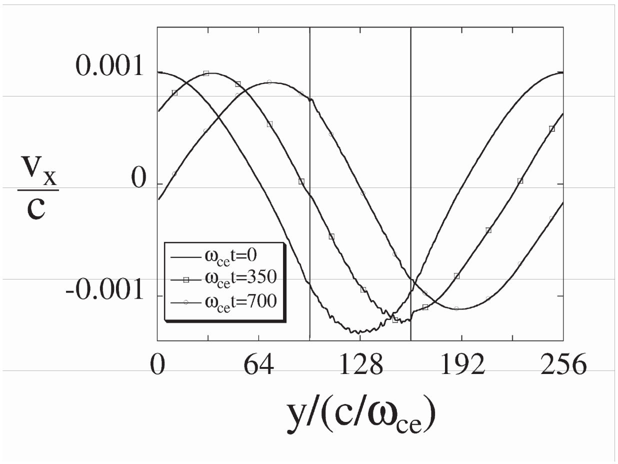

Fig. 2: Spatial profiles of fluid velocity v_x at the various times. Alfvén wave smoothly propagates in the multi-hierarchy box.

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