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磁気リコネクション研究をめざした多階層シミュレーションモデルの開発
Development of Multi-Hierarchy Simulation Model for Magnetic Reconnection Studies

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Collisionless magnetic reconnection is one of the fundamental processes in which magnetic field energy is converted to kinetic energy. It plays an essential role in the rapid energy release in laboratory fusion device and astrophysical plasmas such as solar flare. Also magnetic reconnection has an aspect of typical complex phenomenon controlled by multiple spatiotemporal scale physics. In order to understand the entire picture of magnetic reconnection as a multi-hierarchy phenomenon, we have developed a multi-hierarchy simulation model which solves macroscopic and microscopic physics simultaneously and self-consistently. In our multi-hierarchy model, the physics in the macro-hierarchy is calculated by the MHD (fluid) algorithm, and the dynamics in the micro-hierarchy is expressed by the PIC (particle) algorithm [1].

Ishizawa et al. had found a hierarchical structure in the upstream direction of magnetic reconnection quantitatively [2]. The characteristic spatial and temporal scales depend on the distance from the neutral sheet. Kinetic effects play crucial roles within the ion meandering scale from the neutral sheet, while plasma behavior can be expressed by the one-fluid framework outside the ion inertia length.

Based on the feature described above, the method that different algorithms are used in different domains is quite effective for magnetic reconnection studies. We call this method “domain decomposition method”. In 2009, with the hierarchy-interlocking model in the upstream direction, we have successfully demonstrated multi-hierarchy simulations of magnetic reconnection [3].

Aiming to apply our multi-hierarchy model to a larger system of magnetic reconnection, we develop the hierarchy-interlocking model in the downstream direction. Using this model, we perform a multi-hierarchy simulation in which one-fluid plasma flow with a Maxwellian velocity distribution propagates from PIC to MHD domains. Figure 1 shows the profile of plasma mass density. We can see that plasmas are smoothly and continuously injected from PIC to MHD domains via the interface domain. Now, we are constructing a two-dimensional hierarchy-interlocking model, in other words a hierarchy-interlocking model in the upstream and downstream directions as shown in Fig. 2 and are examining it physical reliability.

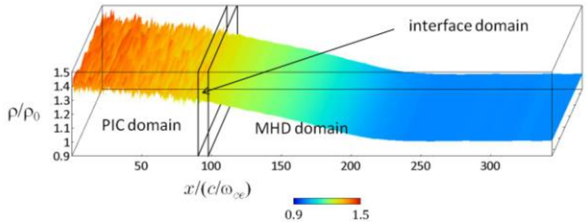

Fig. 1: Spatial profile of plasma mass density by the hierarchy-interlocking model in the downstream direction.

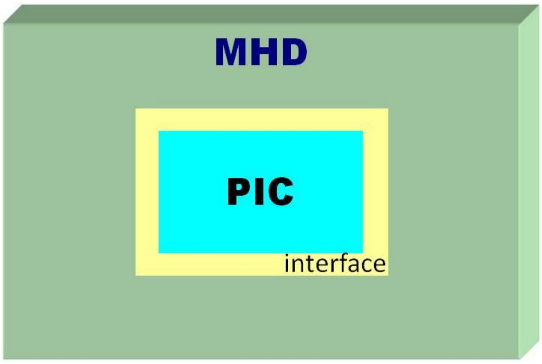

Fig. 2: Schematic diagram of the two-dimensional hierarchy-interlocking model.

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