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Multiscale dynamics of collisionless magnetic reconnection based on large-scale kinetic simulations

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Magnetic reconnection is a natural energy converter which allows explosive energy release of the magnetic field energy into plasma kinetic energy. The reconnection process is essentially multiscale. The magnetic dissipation driving reconnection takes place in a localized region formed around the x-line, while it has a significant impact on large-scale dynamics of the planetary magnetosphere, leading to global change of the field line configuration and global plasma convection. In collisionless plasma, the dissipation (i.e. the effective resistivity) around the x-line is caused by the electron momentum transport due to the Speiser-type motion and/or wave-particle interactions. The corresponding dissipation region is scaled by the electron kinetic scales. On the other hand, it has been believed that the large-scale dynamics beyond the ion kinetic scales can be well described in the MHD framework. However, there is no guarantee that this hypothesis is still valid in collisionless plasma where the binary collision is negligible. In fact, it is poorly understood how the kinetic process in the dissipation region connects to the large-scale process of collisionless reconnection.

The current study has investigated the processes connecting the electron dynamics in the dissipation region with even the large-scale dynamics in the downstream region, by means of the PIC simulation with the adaptive mesh refinement. The simulations in 2D and 3D systems suggest that (1) the large-scale dynamics of collisionless reconnection may not obey the MHD equations, and (2) the cross-field scale of the outflow jet (such as BBFs) is determined by the electron dynamics in the dissipation region. These results indicate the importance of the kinetic processes even in large-scale dynamics beyond the ion kinetic scales in collisionless magnetic reconnection.