Fast magnetic reconnection supported by sporadic small-scale Petschek-type shocks

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Magnetic reconnection is a process to change the connectivity of magnetic fields and works as a mechanism of explosive energy conversion from magnetic to kinetic and thermal energy of plasma and particles. Energy conversion during solar flare, magnetospheric substorm and Tokamak disruption is thought to be caused by magnetic reconnection. Furthermore, magnetic reconnection is considered to play an important role also on many astrophysical phenomena.
One of the largest problems of theories on magnetic reconnection using magnetohydrodynamic (MHD) approximation is that the efficiency of energy conversion is far smaller than that of observations in space or laboratory plasma. A recent outstanding theory of MHD magnetic reconnection that may solve this "fast reconnection problem" is plasmoid reconnection theory. In plasmoid reconnection, reconnection is accelerated accompanied with a formation of plasmoids (magnetic islands). The reason of the acceleration, however, is not yet understood enough.
In this study, we conducted large-scale numerical simulations to elucidate the mechanism of fast reconnection supported by plasmoids. We used MHD equations with spatially uniform resistivity. At first, "global model" numerical simulation that includes a large system of whole current sheet exhibiting magnetic reconnection is performed. We revealed that reconnection region structure with shock planes, which is called Petschek-type structure, repeatedly appears together with plasmoids and reconnection is accelerated.
Next, we conducted "local model" numerical simulation, which models the region where Petschek-type structure appeared in the global model numerical simulation. Using this simulation, we revealed the condition that Petschek-type structure is reproduced. The condition is existence of plasma flow along the interface of antiparallel magnetic fields. Because of the growth of plasmoids in this plasma flow, the structure of magnetic diffusion region is restricted and fast reconnection with Petschek-type structure realizes.
According to these numerical simulations, "Dynamical Petschek Reconnection" model is proposed in this presentation. The flow along the interface, which is necessary to realize Petschek-type structure, spontaneously forms as out-flow of reconnection before the formation of plasmoids. This model, accordingly, can explain the fast reconnection as a result of self-consistent evolution of reconnecting current sheet. Petschek-type reconnection regions form repeatedly with the formation and coalescence of plasmoids, and the reconnection in this model shows highly dynamic temporal evolution. Observation of solar flare also suggests such a short-time variation, which is consistent with our Dynamical Petschek Reconnection theory. Furthermore, according to our theory, shock plane will appear around reconnection region, which is a candidate of acceleration process of high energy particle accompanied by solar flare.
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