Dynamical Petscheck Reconnection

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Magnetic reconnection is the major mechanism for explosive energy liberation in various plasmas. However, the mechanism of fast reconnection in high magnetic Reynolds number (S) plasmas like the solar corona, in which $S>10^{10}$, is still unclear. The observations suggested that the reconnection rate in solar flares is as large as 10^{-2}, although the classical theory by Sweet (1958) and Parker (1963) predicted that the reconnection rate is limited by $S^{-1/2}$. While Petscheck (1964) proposed the fast reconnection model driven by slow mode shock, the previous simulation study suggested that the Petscheck-type reconnection is not stable in uniform resistivity and some anomalous resistivity or non-MHD effects are needed for fast reconnection.

In this paper, we developed the high-resolution magnetohydrodynamics (MHD) simulation of magnetic reconnection for the high-S ($S\textasciitilde10^4$-10^6) regime aiming at revealing the acceleration mechanism of magnetic reconnection in the MHD regime of uniform resistivity. We applied the HLLD Riemann solver developed by Miyoshi and Kusano (2005) to the high resolution two-dimensional MHD simulation of current sheet dynamics. The initial state is given by the Harris sheet equilibrium plus perturbation, and the uniform and constant resistivity model is adopted.

As a result, we found a new type of fast reconnection. When S is larger than 10^4, multiple X-line reconnection appears as a result of the secondary tearing instability and magnetic reconnection is accelerated through the formation of multiple plasmoids. Furthermore, we found that the electric current sheets between some particular magnetic island bifurcate to V-shape current layers and that the reconnection at the apex of bifurcated current layers is preferentially accelerated. The bifurcated current layers create slow mode shocks which more increase the reconnection rate up to about 0.05. The slow mode shocks are repeatedly created and dissolved corresponding to the formation and transportation of plasmoids. These results indicate that, even though resistivity is uniform, when the magnetic Reynolds number is high enough, the multiple X-line reconnection of Sweet-Parker current sheets (plasmoid reconnection) is switched to a new regime called "dynamical Petschek reconnection". The mechanism of transition from the conventional plasmoid reconnection to the dynamical Petscheck reconnection will be discussed.

Keywords: reconnection, Petscheck reconnection, MHD, simulation, slow mode shock