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

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Abstract

Magnetic reconnection is a process of changing the connectivity of magnetic field lines, and thought to play a core role in explosive energy conversion of solar flares. According to the Sweet-Parker theory, it is, however, difficult to conduct magnetic reconnection efficiently in highly conductive plasma of the solar corona. Petschek proposed another reconnection theory, in which small magnetic diffusion region realizes efficient reconnection with the energy conversion occurring in slow mode MHD shocks. However, recent numerical simulations suggest that Petschek reconnection is not stable in a system with spatially uniform resistivity. Some mechanism such as anomalous resistivity or kinetic physics is needed to sustain the localized diffusion region. It is, therefor, not clear yet how fast reconnection realizes in the actual parameter of the solar corona.
In order to answer to this question, we perform resistive 2D MHD simulation in a large system with a high spatial resolution, and find that slow mode MHD shocks predicted by Petschek spontaneously form even under a uniform resistivity (Shibayama et al. 2015, PoP). In this process, fast motion of large plasmoids in the current sheet play a role of localizing the diffusion region, and slow mode shocks form in front of the moving plasmoids. These plasmoids enhance magnetic reconnection intermittently and repeatedly. As a result, the reconnection rate increases up to 0.02, which is high enough to explain the time-scale of solar flares. Furthermore, our simulation suggests that the obtained reconnection rate doesn’t depend on the Lundquist number. This is due to a similarity in the evolution of plasmoid.

Reference : Shibayama et al., Physics of Plasmas, 22, 100706 (2015)