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Effects of Turbulence on Relativistic Magnetic Reconnection in Poynting-Dominated Plasmas

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The concern with the effects of turbulence on magnetic reconnection in magnetohydrodynamic (MHD) scale is now growing. It has been shown that in most case 2-dimensional current sheet evolves into the so-called 'plasmoid-chain' in which the sheet is filled with plasmoids and results in fast-reconnection [1]. However, in real situations, the current sheet should have a 3-dimensional structure, and the plasmoid-chain is expected to evolve into 3-dimensional turbulence. And the effects of 3-dimensional turbulence become an open question [2].

In this work, the evolution of a current sheet in a turbulent flow is modeled using three-dimensional resistive relativistic MHD (RRMHD). The initial current sheet was modeled by the relativistic Harris sheet with constant temperature. The evolution of the plasma is calculated using a three- dimensional RRMHD scheme [3], which solves the full RRMHD equations in a conservative fashion using the constrained transport algorithm. The resistivity, η, was assumed to be constant. We set the periodic boundary condition in the y-direction, and the free boundary condition the x- and z-direction. In our model, we drive a divergence-free 3-velocity field with a flat power spectrum, and an electric field determined consistently around current sheet center [4].

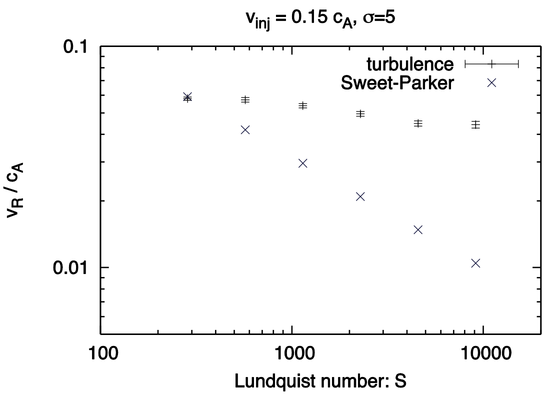

Figure 1 Lundquist number dependence, [5].

Figure 1 shows our numerical results of the reconnection rate dependence on the plasma Lundquist number, $S=L c_A/\eta$. The background plasma is assumed to be Poynting-dominated, that is, $\sigma=B^2/4\pi wc^2\gamma^2$, is larger than unity, where B is the magnetic field, w is the relativistic enthalpy, c is the light velocity, and γ is the Lorentz factor. This clearly shows that the reconnection rate becomes independent of the Lundquist number even in the relativistic plasma case[5], similarly to the non-relativistic case [2,4].

Figure 2 is the reconnection rate in terms of the injection velocity of turbulence. In the weaker turbulence region, it shows the reconnection rate grows with the strength of the turbulence similarly to the non-relativistic case[2,4]. However, in the trans-Alfvénic region, the reconnection rate starts to decrease with the injection velocity. We have found that this is due to a relativistic effect, that is, the enhancement of mode conversion from Alfvén mode to fast mode[5,6], which results in the decrease of exhaust region's size expanded by Alfvén mode turbulence [2]

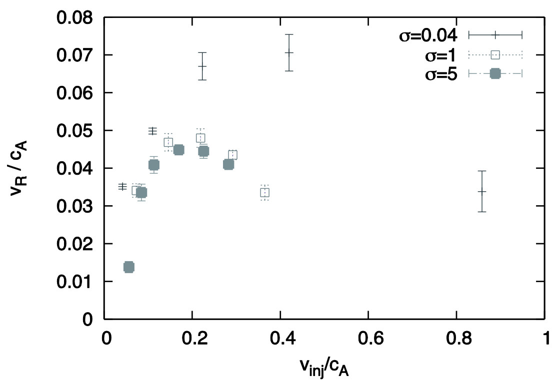

Figure 2 Dependence on strength of turbulence [5].

In this work, we found the turbulence can be responsible for the fast reconnection even in relativistic plasmas. The reconnection rate becomes independent of the resistivity, and increase with the strength of turbulence up to a certain value of strength. We also found a relativistic effect enhances the mode conversion from Alfvén mode to fast mode in trans-Alfvénic turbulence regime. Although the origin of strong turbulence remains unknown in this work, our recent work indicates that current sheet can generate a sufficiently strong turbulence via several instabilities, such as tearing mode.

References

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