乱流磁気リコネクションでの乱流拡散・輸送・ダイナモ効果

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Turbulent diffusion, transport, and dynamo effects in turbulent magnetic reconnection

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Magnetic reconnection is a ubiquitous phenomenon and, at the same time, has unique nature that magnetic field energy is explosively converted into kinetic and thermal energy of plasmas. In the phenomena such as solar flares and the magnetospheric substorm, it is believed that magnetic reconnection takes the central role due to its fast energy release. In spite of many notable theoretical and numerical studies, it is still challenging to explain the fast energy conversion in magnetic reconnection particularly for a high magnetic Reynolds number. Recently, turbulence has attracted much attention on this problem. For example, it is suggested from the theoretical viewpoint of homogeneous anisotropic MHD turbulence that reconnection rate does not depend on the electric resistivity but rather on the property of turbulence [1]. Another study suggests that turbulence transport effects, which are related to the enhancement of turbulent energy and cross-helicity (statistical variables that characterize MHD turbulence), change the global structure and enhance the reconnection rate based on the theory of inhomogeneous MHD turbulence [2].

So far, we developed a MHD turbulence simulation code motivated by the above theoretical study [2], and investigated the effect of turbulence in the two-dimensional system. In the simulation model, equations of turbulent field are solved in addition to the ordinal MHD equations, and mean and turbulent fields develop by interacting with each other. Then, it was shown that the localized turbulent diffusion dramatically enhances the reconnection rate and the cross-helicity could contribute to such localization. In the present study, we discuss the role of turbulence in a fully three-dimensional system. In the 3D case, in addition to 2D signatures (the turbulent diffusion and the cross-helicity effects), mean field helicity could also contribute to dynamics of magnetic reconnection (so called alpha dynamo effect [3]). We take into account such a helical effect in our simulation model, and investigate the signature of 3D turbulent magnetic reconnection. Namely, in magnetic reconnection, large helical structures are related to presence or absence of the guide magnetic field. In the simulation results, reconnection shows a 2D-like signature in the case of no guide field reconnection. However, in the case of guide field reconnection, it is shown that helicity effects affect the development of turbulent energy and cross-helicity, and contribute to dynamics of turbulent magnetic reconnection. In this presentation, we introduce such a helical effect and discuss its role in the 3D turbulent magnetic reconnection.

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