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Roles of plasmoid instability in magnetic reconnection and magnetohydrodynamic turbulence[1]

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The ubiquitous thin current sheets in high-Lundquist-number space and astrophysical plasmas are known to be unstable to the plasmoid instability, which disrupts current sheets to form smaller structures such as flux ropes and secondary current sheets. The plasmoid instability thus plays a significant role in magnetic reconnection and magnetohydrodynamic (MHD) turbulence. In the presence of a large-scale magnetic field, the three-dimensional plasmoid instability can lead to self-generated turbulence within the reconnection layer without the need of external forcing. We show that this turbulent state in a highly inhomogeneous reconnection layer does not conform to the classic Goldreich-Sridhar (GS) theory.[1] Most notably, (1) the scale-dependent anisotropy predicted by GS is not observed, and (2) the turbulence energy spectrum is steeper with a power-law index approximately -2.2 rather than -5/3. Similar steepening of the energy spectrum is also observed in 2D homogeneous MHD turbulence at small scales.[2] We clarify the roles of seed noise on the condition of current sheet disruption.[3] This key ingredient enables us to develop a self-consistent theory of plasmoid-mediated MHD turbulence, where the turbulence fluctuation at smaller scales provides the seed noise to disrupt current sheets at larger scales.[4] In addition to these theoretical developments, we will present evidence of the plasmoid instability in solar observations, as well as new results from models beyond resistive MHD, including the Hall effect. [1] Huang, Y.-M. and Bhattacharjee, A., Astrophys. J. 818, 20 (2016) [2] Dong, C., Wang, L., Huang, Y.-M., Comisso, L., and Bhattacharjee A., Phys. Rev. Lett. 121, 165101 (2018) [3] Huang, Y.-M., Comisso, L., and Bhattacharjee, A., Astrophys. J. 849, 75 (2017) [4] Comisso, L., Huang, Y.-M., Lingam, M., Hirvijoki, E., and Bhattacharjee, A., Astrophys. J. 854, 103 (2018).

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