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Plasmoid-dominated Turbulent Reconnection in a Low-β Plasma: MHD simulations and code developments

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In magnetohydrodynamics (MHD), magnetic reconnection has long been discussed by Sweet-Parker (S-P) and Petschek models. It was recently found that a laminar S-P reconnection evolves to plasmoid-dominated turbulent reconnection in a large-scale system. The reconnection rate during the plasmoid-dominated stage is known to be 0.01, regardless of other parameters. Plasma β in the inflow region is extremely low around reconnection sites in a solar corona. However, despite its importance in a corona, many aspects of the plasmoid-dominated reconnection in the low-β regime remain unexplored, partly because of numerical difficulties.

We study basic properties of plasmoid-dominated turbulent reconnection in a low-β background plasma [1], by means of large-scale MHD simulations. We have found that the system becomes highly complex due to repeated formation of plasmoids and normal shocks [2]. The average reconnection rate gradually increases in the β<1 regime, in contrast to popular results. We attribute this to compressible effects. Based on a compressible Sweet-Parker theory, we have proposed a scaling law for the reconnection rate. This prediction was verified by a numerical survey in the 2-D parameter space. We also discuss the influence of the initial plasma-sheet models. We have made our simulation code, OpenMHD, publicly available [3,4]. The code is written in Fortran 90 and is parallelized by MPI-3 and OpenMP. Recently we have ported the code to NVIDIA GPUs using CUDA Fortran language. The GPU version runs 40 times faster than the CPU-only version per a node on our 8-core workstation. As of 2021, more than 10 papers were published in academic journals, by using OpenMHD code.

References:
[1] S. Zenitani & T. Miyoshi, *Plasmoid-dominated Turbulent Reconnection in a Low-β Plasma*, Astrophys. J. Lett. **894**, L7 (2020)
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[3] S. Zenitani, *Magnetohydrodynamic structure of a plasmoid in fast reconnection in low-beta plasmas: Shock-shock interactions*, Physics of Plasmas **22**, 032114 (2015)
[4] https://github.com/zenitani/OpenMHD

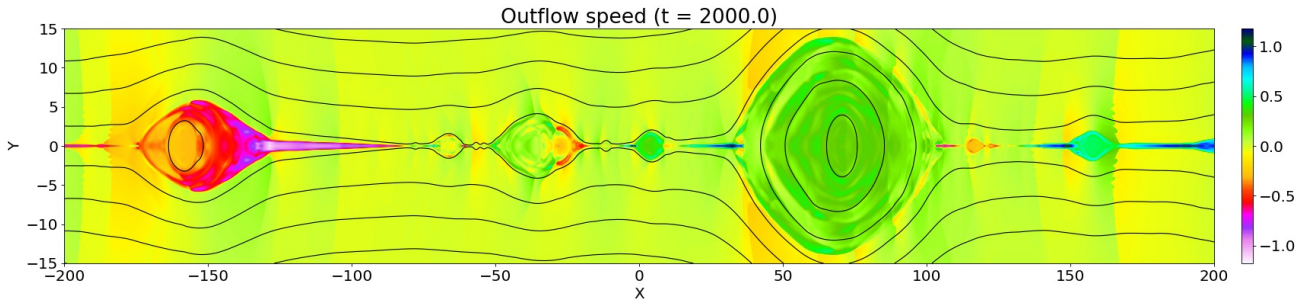

Figure 1. Horizontal plasma velocity (v_x) at a well-developed stage of plasmoid-dominated reconnection [1].