High-Speed Fluid Dynamics in Magnetic Reconnection in a Low-β Plasma

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In the solar corona, in the planetary magnetosphere, and in other astrophysical settings, magnetic reconnection often occurs in a low-β plasma, in which the magnetic pressure is higher than the plasma pressure. Surprisingly, much less is known about low-β reconnection, partially due to numerical difficulties and partially due to lack of attention. Recently, new features of low-β reconnection were reported in magnetohydrodynamic (MHD) simulations with shock-capturing codes. Zenitani et al. [1,2] discovered new normal shocks and a repeated shock-reflection near a magnetic island (plasmoid) at the reconnection jet front.

In this work, we extend our previous researches on the plasmoid structure in low-β reconnection. Using a high-accuracy HLLD code [3], shocks, discontinuities, and their intersections are resolved and clarified in unprecedented detail. Figure 1 is a snapshot of the reconnection-plasmoid system in run 1 in Ref. [4]. The color indicates vertical MHD velocities. There are two triangle-trains, as indicated by the white circles. They correspond to shock-reflections in a supersonic jet, the so-called "shock diamonds." The right ones are over-expanded shock-diamonds in front of the plasmoid. The left ones are under-expanded shock-diamonds, hidden inside the reconnection jet. In addition, contact discontinuities and a slow expansion fan from shock-crossing points are found. All these structures are summarized in the 2015 edition of the "plasmoid diagram" (Figure 2).

From the physics viewpoint, these structures are outcome of high-speed fluid effects or compressible fluid effects. High-speed fluid dynamics plays an important role in a low-β plasma, because an Alfvénic reconnection jet easily becomes transonic or supersonic. Underlying mechanisms are similar to those in aerospace engineering and in astrophysical jet physics. Since the mechanisms are common, similar shocks and shock-dissipation will take place in plasmoid-dominated turbulent reconnection. We have a prospect that the high-speed effects will be important in various astrophysical MHD systems, in which Alfvén speed becomes supersonic.

The simulation code for Ref. [4] is publicly available at arXiv:1503.01920. Fortran 90 files are archived in a gzipped tar file in the "Other formats" link.

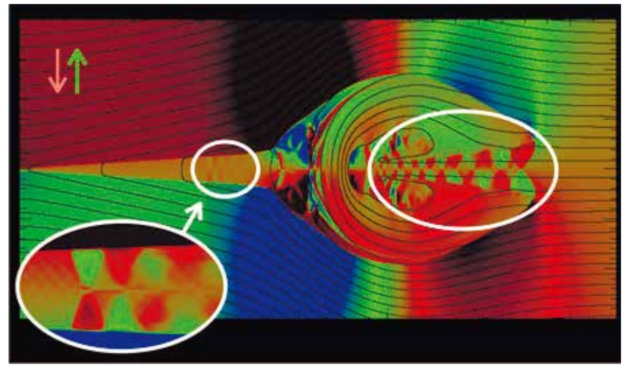

Figure 1: A snapshot of run 1 in Ref. [4]. Vertical MHD velocities are shown in color: the upward (downward) velocity in green (red). The black curves show the magnetic field lines.

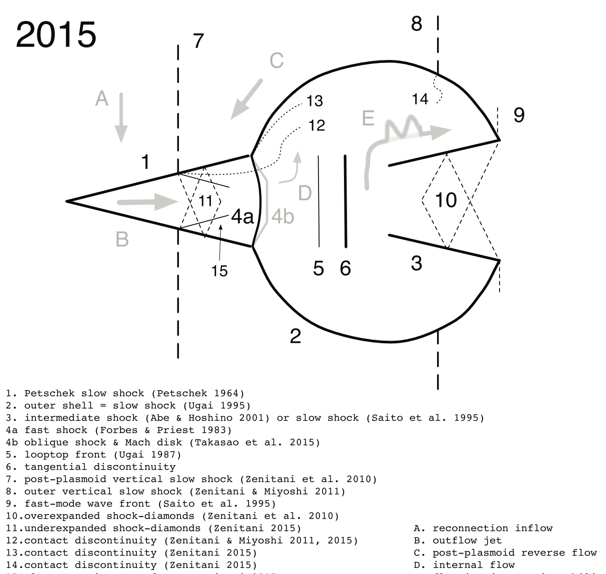

Figure 2: Schematic diagram of the plasmoid structure. Based on Fig. 7 in Ref. [2], it further contains recent updates in Ref. [4].

References

[1] Zenitani, S., et al.: 2010, *ApJ*, **716**, L214.
[2] Zenitani, S., Miyoshi, T.: 2011, *Phys. Plasmas*, **18**, 022105.
[3] Miyoshi, T., Kusano, K.: 2005, *J. Comput. Phys.*, **208**, 315.
[4] Zenitani, S.: 2015, *Phys. Plasmas*, **22**, 032114.