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Magnetic reconnection: From compact fusion to plasma propulsion

Fatima Ebrahimi [1]

[1] Princeton Plasma Physics Laboratory, and Department of Astrophysical Sciences, Princeton University NJ, 08544

ebrahimi@pppl.gov

Initial plasma-current formation via unconventional methods is a necessity in compact fusion concepts such as spherical tokamaks (STs), one of the leading fusion reactor designs with high magnetic field. A 3D current-sheet plasmoid instability, which is a common process both in space, fusion [1-3] and astrophysical [4] plasmas, has been shown to be instrumental during unconventional current start-up in STs. Multiple significant contributions have been made in understanding of the nonlinear dynamics [5-8] during helicity injection start-up, including a transition from Sweet-Parker [8] reconnection to a plasmoid instability that was for the first time simulated and predicted by global simulations with a guide field.[5] Fundamental theoretical and computational studies of fast magnetic reconnection in NSTX led to the experimental evidence of plasmoids [5]. Inspired by this research, state-of-the-art large-scale extended MHD simulations have for the first time been used to demonstrate that a particular configuration of externally applied static electric and magnetic fields can both create plasma and accelerate it by continuously and spontaneously producing plasmoids, detached plasma enclosed by magnetic fields.[9] This led to a new type of thruster, a magnetic reconnection plasma thruster, which relies on fast plasmoid-mediated magnetic reconnection [9]. Because of the Alfvénic outflow from the reconnection site, its thrust is proportional to the square of the magnetic field strength and does not ideally depend on the mass of the ion species of the plasma. Variable unidirectional exhaust velocities were directly demonstrated in the simulations (Figure 1). This plasma propulsion technology describes a practical device configuration that produces the required electric and magnetic fields (no guide field) to *induce a fast magnetic reconnection process in a thruster channel* for the first time [9]. New MHD simulation results for exhaust velocity and thrust scalings will also be presented. As another application of magnetic reconnection, I will conclude with new results on the rise and nonlinear relaxation of Peeling-Ballooning ELMs at the tokamak edge. Axisymmetric as well as small-scale poloidally extending current sheets, are formed as the pressure driven P-B ELM filaments nonlinearly evolve [3].

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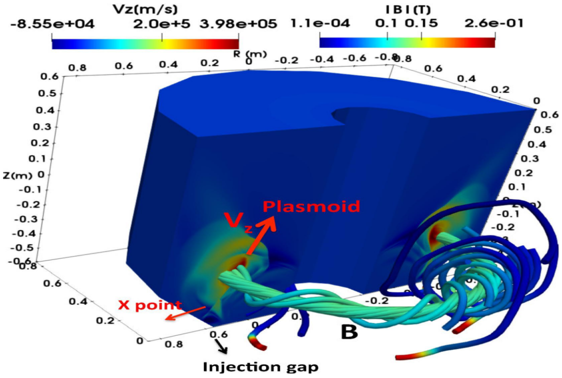

Figure 1: Continuous formation of momentum-carrying plasmoids with exhaust velocities of 400 km/s are obtained during three-dimensional global MHD simulations for the Alfvenic reconnecting plasmoid thruster concept [9].