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Plasmoid Instability in High-Lundquist-Number Magnetic Reconnection

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Our understanding of magnetic reconnection in resistive magnetohydrodynamics has gone through a fundamental change in recent years. The conventional wisdom is that magnetic reconnection mediated by resistivity is slow in high Lundquist (S) plasmas, due to the $S^{-1/2}$ scaling of reconnection rate predicted by the classical Sweet-Parker theory. However, recent studies showed that when S exceeds a critical value $\sim 10^4$, the Sweet-Parker current sheet is unstable to a super-Alfvenic plasmoid instability, with a growth rate that increases with S [1]. Consequently, the reconnection layer changes to a chain of plasmoids connected by secondary current sheets that, in turn, may become unstable again. Eventually the reconnection layer will tend to a statistical steady state governed by complex dynamics of plasmoid formation and plasmoid loss due to advection and coalescence. The averaged reconnection rate in this regime is nearly independent of S [2,3], and the distribution function $f(\psi)$ of magnetic fluxes ψ in plasmoids follows a power-law $f \sim \psi^{-1}$. When Hall effects are included, the plasmoid instability may trigger onset of Hall reconnection even when the conventional criterion for onset is not satisfied. In addition to the usual single X-point topology of Hall reconnection, our large-scale resistive Hall MHD simulations reveal a novel intermediate regime, where formation of new plasmoids is observed after onset of Hall reconnection [4]. Qualitatively similar results have also been found when resistivity is replaced by hyper-resistivity. Our findings suggest that plasmoid formation may be a generic feature of magnetic reconnection in large systems, regardless of the mechanism of breaking the frozen-in condition. (In collaboration with A. Bhattacharjee and B. P. Sullivan).

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