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Recent Developments in Reconnection Theory: the Plasmoid Instability, Self-Generated Turbulence, and Implications for Laboratory and Space Plasmas[1]

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In recent years, new developments in reconnection theory have challenged classical nonlinear reconnection models. One of these developments is the so-called plasmoid instability of thin current sheets that grows at super-Alfvenic growth rates. Within the resistive MHD model, this instability alters qualitatively the predictions of the Sweet-Parker model, leading to a new nonlinear regime of fast reconnection in which the reconnection rate itself becomes independent of S. This regime has also been seen in Hall MHD as well as fully kinetic simulations, and thus appears to be a universal feature of thin current sheet dynamics, including applications to reconnection forced by the solar wind in the heliosphere and spontaneously unstable sawtooth oscillations in tokamaks. Plasmoids, which can grow by coalescence to large sizes, provide a powerful mechanism for coupling between global and kinetic scales as well as an efficient accelerator of particles to high energies. In two dimensions, the plasmoids are characterized by power-law distribution functions followed by exponential tails. In three dimensions, the instability produces self-generated and strongly anisotropic turbulence in which the reconnection rate for the mean-fields remain approximately at the two-dimensional value, but the energy spectra deviate significantly from anisotropic strong MHD turbulence phenomenology. A new phase diagram of fast reconnection has been proposed, guiding the design of future experiments in magnetically confined and high-energy-density plasmas, and have important implications for explorations of the reconnection layer in the recently launched Magnetospheric Multiscale (MMS) mission.

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