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Intrinsic MHD mixing in magnetically confined fusion plasma[1]

LINDA SUGIYAMA, MIT — Magnetically confined toroidal plasmas for fusion research have proven far more complex than originally envisioned. Recent results from magnetohydrodynamics (MHD), based partly on large scale numerical simulation, show that much of the complexity is intrinsic, even when turbulent fluctuations are neglected. Perturbative theories based on simplified models provide much of the understanding of MHD, but ignore major nonlinear and mixing effects. At the plasma edge, the magnetic boundary surface introduces a geometrical source of magnetic stochasticity. X-points on the surface help create an optimal plasma shape. Nonlinearly, the Hamiltonian nature of the field leads to "homoclinic" magnetic tangles near the X-points that produce plasma mixing and stochasticity, which can penetrate deep into the plasma. New work shows that compressible MHD also contributes to complexity, by effectively breaking small parameter orderings in slowly growing instabilities. In the $m = 1$, $n = 1$ internal kink of the central plasma, higher order terms determine the growth rate. Nonlinearly, a fast, explosive growth phase with strong stochasticity leads to a sawtooth crash similar to experiment. Other plasma instabilities, including reconnection in space plasmas, can have analogous behavior.

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