Equilibrium and near-equilibrium dynamics of plasma in magnetic confinement devices

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Abstract: Magnetic confinement of plasmas in toroidal devices offers a broad variety of challenging and interesting mathematical problems of great relevance to the nuclear fusion community. Although well understood in two dimensions, the fundamental question of obtaining an equilibrium of the underlying magnetohydrodynamics (MHD) model in a three-dimensional space remains an open problem. This poses considerable theoretical and computational challenges for fusion engineers and plasma physicists. Asymptotic analysis offers valuable tools and great physical insight in tackling some of these questions. After discussing the mathematical difficulties that arise from the basic system of partial differential equations governing three-dimensional MHD equilibrium, I will present a variety of asymptotic expansion methods to resolve these issues and obtain a self-consistent solution order by order. In particular, I shall demonstrate that the expansions can be carried to all orders and thereby provide direct evidence for the existence of large classes of three-dimensional MHD equilibria in a toroidal system. I will show that our analysis provides theoretical explanations for certain experimentally observed self-organized plasma states near certain magnetic surfaces where the magnetic field closes on itself after one toroidal turn. This work has been done in collaboration with Harold Weitzner (NYU), Joshua Burby (Los Alamos National Lab) and Adil Hassam (UMD College Park).