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Helical electric potential modulation via Zonal Flow coupling to Resonant Magnetic Perturbations

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Controlling Edge Localized Modes (ELMs) is very important for ITER, and a well-tested way to achieve this is by using external coils to generate Resonant Magnetic Perturbations (RMPs), demonstrated on several tokamaks [1-4]. The working hypothesis for the origin of ELM suppression is that RMPs increase transport in the pedestal, thus lowering the pressure-gradient below the ideal-MHD threshold. In this work, we show that - in presence of RMPS - Zonal Flows can drive a long-lived Vortex-Flow pattern. This finding clarifies the theory of RMP-induced Zonal Flow damping [5]. Note that evidence of such a Vortex-Flow pattern has been observed experimentally [6]. We obtain a dynamical system of coupled 1D equations for Zonal Flows and Vortex-Flow profiles, which we solve numerically (in our model, turbulence acts as a shear-dependent negative eddy-viscosity). As Zonal Flows are turbulence-driven, this shows that turbulence plays a major role in the plasma self-organization towards a 3D quasi-equilibrium. Contrary to Zonal Flows - which act as a benign reservoir of energy - the Vortex Flow pattern has a radial streamer-like flow associated to it and hence can drive convective transport. The associated enhancement in the particle transport - assuming the Vortex Flow has a density component - has a resonant character. This additional transport could act to limit the pressure-gradient, and is therefore a possible candidate to explain ELM suppression.

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