Multi-Scale Turbulent Interactions between Tearing Modes and Microturbulence in Magnetically Confined Plasmas

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Inhomogeneities in magnetically confined plasmas naturally give rise to different spatio-temporal scale instabilities that can interact with each other, leading to detrimental or beneficial consequences [1, 2]. Comprehensive studies of multi-scale interactions may capture key physics that guide efforts towards a sustained, enhanced confinement. Experiments in reversed-field pinches (RFPs) have shown that high activity of MHD-scale TMs results in strong turbulent transport, while TM suppression improves the plasma confinement, with higher electron temperature and plasma beta [1]. This highlights striking impacts of TM fluctuations on micro-scale turbulence. Here, multi-scale interactions of global TMs and microturbulence in an RFP and a tokamak plasma are separately examined, using the global gyrokinetic code Gene, whose background distribution is modified to a shifted Maxwellian, enabling current gradient drive for global TMs, coexisting with microturbulence [4]. Simulations with RFP equilibria show that large-scale core TMs couple and nonlinearly excite smaller-scale linearly stable TMs close to the edge, where trapped-electron-mode (TEM)-driven turbulence occurs. Edge TMs grow and erode zonal flows (ZFs) that are nonlinearly generated by TEMs. The ZF erosion brings a quiescent flux to a much higher level, consistent with observations in the RFP. Hence, controlling TMs in RFPs can allow one to retain TEM-driven ZFs, reducing turbulent flux [5]. In a TCV tokamak plasma, microturbulence is instead driven by ETGs, where saturation does not primarily depend on ZFs, so erosion of the ZFs by TMs does not significantly alter the transport. In contrast, nonlinear TMs modify the electron temperature gradient, leading to profile corrugation, lowering ETG drive and electrostatic electron heat flux. Preliminary analysis of back-reactions of ETGs on TMs also shows reduction on electromagnetic flux driven by TMs. This suggests that having TM and ETG-driven turbulence concurrently exist can enhance confinement, with lower fluxes.

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