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Nonlinear Upshift of Trapped Electron Mode Critical Density Gradient: Simulation and Experiment[1]

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A new nonlinear critical density gradient for pure trapped electron mode (TEM) turbulence increases strongly with collisionality, saturating at several times the linear threshold. The nonlinear TEM threshold appears to limit the density gradient in new experiments subjecting Alcator C-Mod internal transport barriers to modulated radio-frequency heating. Gyrokinetic simulations show the nonlinear upshift of the TEM critical density gradient is associated with long-lived zonal flow dominated states [1]. This introduces a strong temperature dependence that allows external RF heating to control TEM turbulent transport. During pulsed on-axis heating of ITB discharges, core electron temperature modulations of 50% were produced. Bursts of line-integrated density fluctuations, observed on phase contrast imaging, closely follow modulations of core electron temperature inside the ITB foot. Multiple edge fluctuation measurements show the edge response to modulated heating is out of phase with the core response. A new limit cycle stability diagram shows the density gradient appears to be clamped during on-axis heating by the nonlinear TEM critical density gradient, rather than by the much lower linear threshold. Fluctuation wavelength spectra will be quantitatively compared with nonlinear TRINITY/GS2 gyrokinetic transport simulations, using an improved synthetic diagnostic. In related work, we are implementing the first gyrokinetic exact linearized Fokker Planck collision operator [2]. Initial results show short wavelength TEMs are fully stabilized by finite-gyroradius collisional effects for realistic collisionalities. The nonlinear TEM threshold and its collisionality dependence may impact predictions of density peaking based on quasilinear theory, which excludes zonal flows.

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[1] D. R. Ernst et al., Proc. 21st IAEA Fusion Energy Conference, Chengdu, China, paper IAEA-CN-149/TH/1-3 (2006). http://www-pub.iaea.org/MTCD/Meetings/FEC200/th_1-3.pdf
[2] B. Li and D.R. Ernst, Phys. Rev. Lett. 106, 195002 (2011).

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