Direct Observation of TEM Turbulence and Nonlinear Upshift of TEM Critical Density Gradient

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Evidence of trapped electron mode (TEM) turbulence in density fluctuation spectra is presented. The evidence, based on measurements of the density fluctuation wavelength spectrum by Phase Contrast Imaging (PCI), comes from an Alcator C-Mod experiment in which gyrokinetic stability analysis finds that TEM turbulence dominates the spectrum. The measured wavelength spectrum is closely reproduced by nonlinear gyrokinetic simulations, using the GS2 code augmented by a new synthetic PCI diagnostic.[1] The measured spectrum is a linear combination of radial and poloidal modenumber spectra from the simulation. The nonlinear radial modenumber spectrum peaks at k_r=0, while the poloidal modenumber spectrum peaks at longer wavelengths than those of maximum linear growth, reminiscent of beam emission spectroscopy measurements on TFTR.[2] The TEM fluctuations are associated with the steep density gradient in an internal transport barrier. This provides spatial localization for the chordal PCI measurement, and allows us to utilize a radially local flux-tube simulation. The simulations also reproduce the relative increase in fluctuation level when TEMs are destabilized by on-axis heating. In addition, the simulated particle and energy fluxes agree with the results of transport analysis, within experimental measurement uncertainty.[3]

The nonlinear upshift of the TEM critical density gradient[3] is shown to increase strongly with collisionality,[1] consistent with the strong damping of TEMs by detrapping, and the relatively weak collisional damping of zonal flows. Further, we have included finite Larmor radius terms in the linearized GS2 Lorentz collision operator, which suppress TEM growth for $k_\theta\rho_i$>2. We have also implemented collisional energy scattering, and will explore its effects. Research supported by U.S. Dept. of Energy.

[1] D. R. Ernst *et al.,* Proc. 21st Int'l. Atomic Energy Agency Fusion Energy Conference, Chengdu, China, 16-21 October 2006, paper IAEA-CN-149/TH/1-3. <http://www-pub.iaea.org/MTCD/Meetings/FEC2006/th_1-3.pdf>
[2] R. Fonck, *et al.*, Phys. Rev. Lett. **70** (1993) 3736.
[3] D. R. Ernst et al., Phys. Plasmas **11**(5) 2637 (2004).